The National Ribat University

Faculty of Graduate Studies & Scientific Research

MRI Evaluation of the Lumbar Lordosis Angle in Sudanese Population

A thesis Submitted in Partial Fulfillment Required for the MSc in Clinical Human Anatomy

By: Mohammed Zaidan M. Saeed

Supervisor: Prof. Kamal Eldin Elbadawi Babiker

1439-2018

الآية

قَالَ تَعَالَىٰ:

﴿ وَأَنزَلَ ٱللَّهُ عَلَيۡكَ ٱلۡكِتَٰبَ وَٱلۡحِكۡمَةَ وَعَلَّمَكَ مَا لَمۡ تَكُن تَعۡلَمُۚ وَكَانَ فَضۡلُ ٱللَّهِ عَلَيۡكَ عَظِيمٗا ١١٣ ﴾

سورةُ النِّساءْ الاية رقم (113)

Acknowledgement

- I would like to express my deep gratitude to **professor Kamal Eldin Elbadawi Babiker** for his supervision, views & comments & for his great encouragement & advice, which has contributed to the accomplishment of this work.
- The researcher wishes to express his cordial gratitude to Dr. Mohammed Elkhatim a radiologist at the Diagnostic Radiology Department, Sharg Alneel hospital (SNH), for his invaluable help and cooperation throughout the work.
- I express my great appreciation to all those who assisted me in one way or another to bring up this work in a nice way.
- I would like to take the opportunity to give special thanks to my colleagues for their grateful effort …

Dedication

- To my mother who gave me the hope to pursue my course in my life.
- This thesis is lovingly dedicated to our respective parents & teachers who have been our constant source of inspiration.
- They have given us the drive and discipline to tackle any task with enthusiasm and determination.
- Without their love and support, this project would not have been made possible.

مستخلص الدراسة

أُجريت هذهِ الدراسة لتقييِم الزاويَة القطنية في المرضى الذين تمَّ فحصهم عن طريق التصوير بالرنين المغناطيسي بإستخدام طريقة كوب. تم إجراء هذه الدراسة في مستشفى شرق النيل بولاية الخرطوم - السودان؛ وإستمرت في الفترة من الأول من يناير حتى يونيو 2017. إشتملت الدراسة على عينة من 80 مواطناً سودانياً ، تراوحت أعمارهم بين (20 - 80) سنة. من أصل 80 من أفراد عينة الدراسة، كان هنالك 40 من الذكور و 40 من الإناث خضعوا للدراسة. وقد تم قياس (الزاوية القطنية) من المقطع منتصف السهمي من العمود الفقري القطني باستخدام طريقة كوب، عن طريق رسم خط عمودي على الصفيحة الانتهائية العلوية من الفقرات القطنية الأولى و الصفيحة الإنتهائية من الفقرة العجزية الأولى؛ الزاوية التي شكَّلها تقاطع الخطَّين العموديين هي زاوية كوب. تم إجراء مقارنة زاوية كوب مع الجنس والعمر.

وخلُصت الدراسة إلى أن زاوية كوب لها علاقة مع العمر وليست لها علاقة مع الجنس، ولم يتم الكشف عن اختلاف في الشكلياء بين زاوية كوب في الأشخاص الطبيعيين والمرضى الذين يعانون من القرص المتدلي، ولم تختلف النتائج بين المرضى الذكور والإناث.

ووجد أنه من الأفضل إستخدام التصوير بالرنين المغناطيسي في الكشف عن التغيرات في شكلياء الفقرات التشريحية لأنه لا يحتوي على الإشعاع المؤين ولها ترسيم ممتاز يوضح معالم القرص التشريحية؛ الإعتماد على زاوية كوب في تشخيص تدلي القرص ليس له قيمة كبيرة.

Abstract

This study was done to evaluate the lumbar lordotic angle (LLA) in patients examined by magnetic resonance imaging (MRI) using Cobb's method. This study was conducted at Sharg El Neel Hospital - Khartoum State - Sudan and extended during the period between 1st of January up to June 2017. A total sample of 80 Sudanese subjects were included in the study, with ages ranging between (20 - 80) years. Out of 80 subjects underwent the study, 40 were males and 40 were females. Measurement of (LLA) was done from the mid-sagittal of T2 MRI lumbar spine using Cobb's method; by drawing a perpendicular line to a line drawn across the superior end-plate of first lumbar vertebra and the superior end-plate of first sacral vertebra; the angle formed by the intersection of the two perpendicular lines was the Cobb's angle or lumbar lordosis angle.

The Cobb's angle was then correlated with gender, age, to demonstrate if there was any degree of association. The study concluded that Cobb's angle has significant relation with age but there was no significant relation with gender, no significant difference was detected between Cobb's angle of the normal subjects and patients with prolapsed disc and the results did not differ among male and female patients. Using MRI in the detection of vertebral morphological changes and end-plates degeneration was recommended, since it involves no ionizing radiation and has an excellent demarcation of disc anatomy. The dependence upon the Cobb's angle in the diagnosis of disc prolapse was of no significant value.

List of abbreviations

ALL	Anterior longitudinal ligament
C	Cervical spinal level
CMLT	Conus medullaris level of termination
CI	Confidence interval
ICC	Interclass correlation coefficient
Fig	Figure
HOX	Homeobox
ICC	Interclass correlation coefficients
LB	Lumbar breadth
LH	Lumbar height
L	Lumbar spinal level
LLA	Lumbar lordosis angle
MD	Mean difference
MRI	Magnetic Resonance Imaging
mm	Millimeter
PLL	Posterior longitudinal ligament
P-value	Probability value
R	Range
S	Sacral spinal level
SD	Standard deviation
SPSS	Social package of statistical sciences
TSLT	Thecal sac level of termination
T	Thoracic spinal level
T_1-Wt	T_1- weighted
T_2-Wt	T_2- weighted
$()^0$	Degree
Yrs.	Years
*	Versus

List of figures

List of tables

List of contents

CHAPTER ONE

INTRODUCTION & OBJECTIVES

1. Introduction & Objectives

1.1 Background:

There is an increasing recognition of the functional and clinical importance for lumbar lordosis. It is the key postural component in maintaining sagittal balance. Affection of lumbar lordotic curve often results in sagittal spinal imbalance causing low back pain that represents one of the leading causes of disability. Therefore, there is a need for accurate reconstruction of the lordotic curvature. However, the current knowledge base for such reconstruction and spinal surgery is insufficient [(1)].

The normal range of lumbar lordosis is so wide (30 to 80∘) that it becomes difficult to determine its value for an individual. Unfortunately, the available data measuring the lumbar spine curvature using MRI are still limited, particularly in Sudan. Such data used in assessing the postural abnormalities. In addition, determining the size of the intervertebral disc and lumbar body vertebra is needed for the inter body fusion and artificial disc replacement. Studies on the cadaver are subject to distortion because of postmortem tissue changes. Meanwhile, the development of MRI has greatly enhanced understanding of the living human anatomy. The aim of the study was to illustrate the normal mid-sagittal lumbar lordosis in adult Sudanese, its morphology and values using magnetic resonance imaging (MRI), and to evaluate the role of lumbar spine segments “vertebrae and intervertebral discs parameters” in its formation as shown in table (1.1) . The established database could be useful as reference values for the evaluation of lumbar bodies and discs in symptomatic patients [(1)].

Table (1.1): shows the definitions of measured lumbar parameters:

Parameter	Abbreviation	Definition
Angle of lumbar lordosis	LLA	The angle between two straight lines passing along the upper border of the body of first lumbar vertebra (L1) and the upper sacral border.
Height of lumbar spine curvature	LH	The maximum distance between the upper anterior end of first lumbar vertebra (L1) to that of sacrum.
Breadth of lumbar spine curvature	LB	The maximum distance between the deepest point of lumbar curvature (at the back of upper part of L4 body) to the line representing the length of lumbar curvature.

1.2 Justification:

There are many gaps in the current knowledge regarding the LLA and its application. Additional studies are essential to fill in this gap and to identify factors that determine lordosis development. This study may help to understand the anatomy of the spine and not to rely only on cadaveric studies.

1.3 Objectives:

1.3.1 General objective:

MRI evaluation of the lumbar lordosis angle among Sudanese population.

1.3.2 Specific objectives:

1. To determine normal parameters of the lumbar lordosis angle (LLA).
2. To identify the normal variations of the lumbar lordosis angle (LLA) among normal Sudanese individuals.
3. To identify the determinants of the lumbar lordosis angle (LLA).
4. To augment the use of the lumbar lordosis angle (LLA) in the early detection of postural abnormalities.

CHAPTER TWO

LITERATURE REVIEW

2. Literature Review

2.1 Overview:

Lumbar lordosis is a key postural component that has interested both clinicians and researchers for many years. Despite its wide use in assessing postural abnormalities, there remain many unanswered questions regarding lumbar lordosis measurements [1].

Anatomical planes used in clinical practice and spinal anatomy teaching are largely derived from cadaveric studies. Numerous variations exist in the position of the conus medullaris with a peak incidence at the lower third of L1 but can range between the middle third of T12 and the upper third of L3. Similar disparities were also described concerning the TSLT, which has been described in standard textbooks and cadaveric studies at S2. However, it may extend caudally beyond the S2 level. On the other hand, variations of the LLA also exist and were defined as ranging from 30∘ to 75∘ in normal individuals. The question we ask in this paper is whether these variations are related. This work tries to find the relationship between the age, gender, and LLA based on magnetic resonance imaging in normal living individuals [1].

2.2 Anatomy of the spine:

The spine is made of 33 individual bony vertebrae stacked one on top of the other. This spinal column provides the main support for your body, allowing you to stand upright, bend, and twist, while protecting the spinal cord from injury. Strong bones and muscles, flexible tendons and ligaments, and sensitive nerves contribute to a healthy spine. Yet, any of these structures affected by strain, injury, or disease can cause pain [1] as shown in fig (2.1).

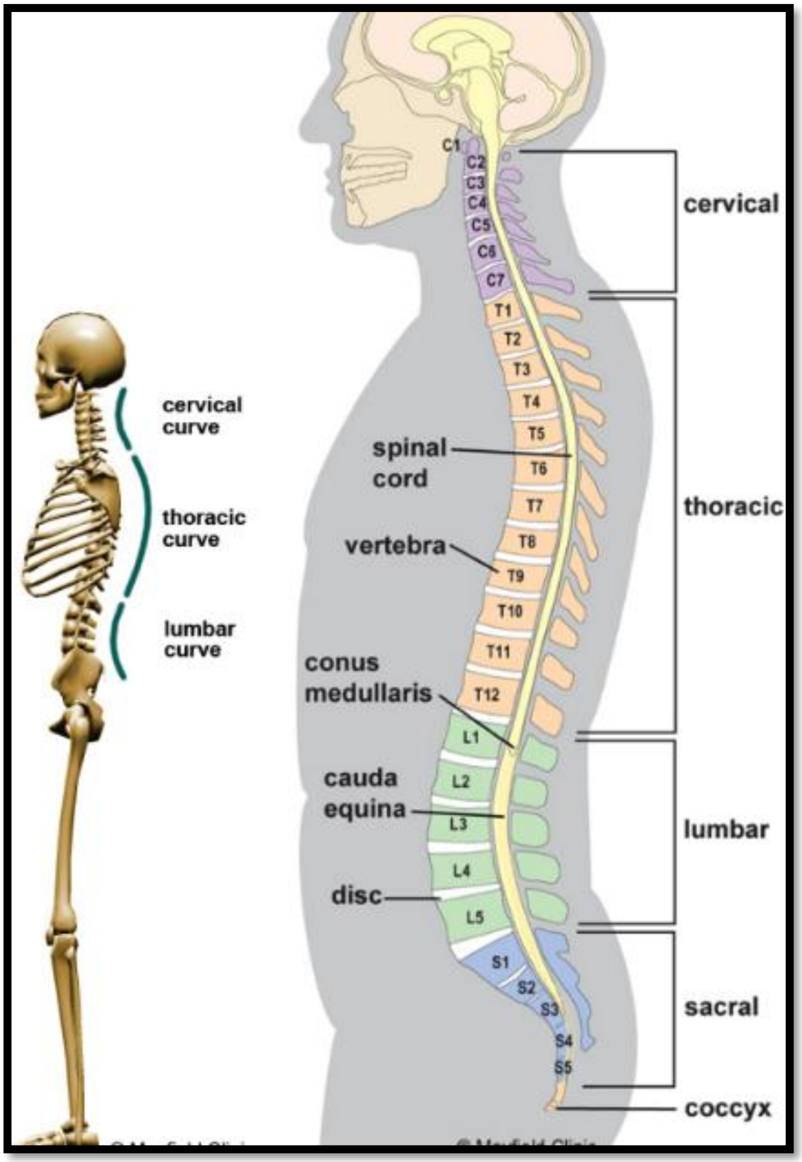

Fig (2.1): (left) the spine has three natural curves that form an S - shape; strong muscles keep our spine in alignment, (right) the five regions of the spinal column. [1]

2.3 Spinal curves:

When viewed from the side, an adult spine has a natural S - shaped curve. The neck (cervical) and low back (lumbar) regions have a slight concave curve, and the thoracic and sacral regions have a gentle convex curve Fig (2.1). The curves work like a coiled spring to absorb shock, maintain balance, and allow range of motion throughout the spinal column. The muscles and correct posture maintain the natural spinal curves. Good posture involves training your body to stand, walk, sit, and lie so that the least amount of strain is placed on the spine during movement or weight - bearing activities. Excess body weight, weak muscles, and other forces can pull at the spine's alignment: An abnormal curve of the lumbar spine is lordosis, also called sway back; an abnormal curve of the thoracic spine is hypnosis, also called hunchback; an abnormal curve from side - to - side is called scoliosis; vertebrae are the 33 individual bones that interlock with each other to form the spinal column [(1)].

2.4 Vertebrae:

Vertebrae are the 33 individual bones that interlock with each other to form the spinal column. The vertebrae are numbered and divided into regions: cervical, thoracic, lumbar, sacrum, and coccyx as shown in Fig (2.2). Only the top 24 bones are moveable; the vertebrae of the sacrum and coccyx are fused. The vertebrae in each region have unique features that help them perform their main functions. Cervical (neck) - the main function of the cervical spine is to support the weight of the head (about 10 pounds). The seven cervical vertebrae are numbered C1 to C7. The neck has the greatest range of motion because of two specialized vertebrae that connect to the skull. The first vertebra (C1) is the ring-shaped atlas that connects directly to the skull. This joint allows for the nodding or "yes" motion of the head. The second vertebra (C2) is the peg-shaped axis, which has a projection called the odontoid, that the atlas pivots around. This joint allows for the side-to-side or "no" motion of the head [(2)].

Thoracic (mid back) – the main function of the thoracic spine is to hold the rib cage and protect the heart and lungs. The twelve thoracic vertebrae are numbered T1 to T12. The range of motion in the thoracic spine is limited. Lumbar (low back) – the main function of the lumbar spine is to bear the weight of the body. The five lumbar vertebrae are numbered L1 to L5. These vertebrae are much larger in size to absorb the stress of lifting and carrying heavy objects. Sacrum – the main function of the sacrum is to connect the spine to the hip bones (iliac). There are five sacral vertebrae, which are fused together. Together with the iliac bones, they form a ring called the pelvic girdle. Coccyx – the four fused bones of the coccyx or tailbone provide attachment for ligaments and muscles of the pelvic floor. While vertebrae have unique regional features, every vertebra has three functional parts: a drum - shaped body designed to bear weight and withstand compression; an arch - shaped bone that creates a hollow tube for the spinal cord and nerve s Star - shaped processes designed as outriggers for muscle attachment [2].

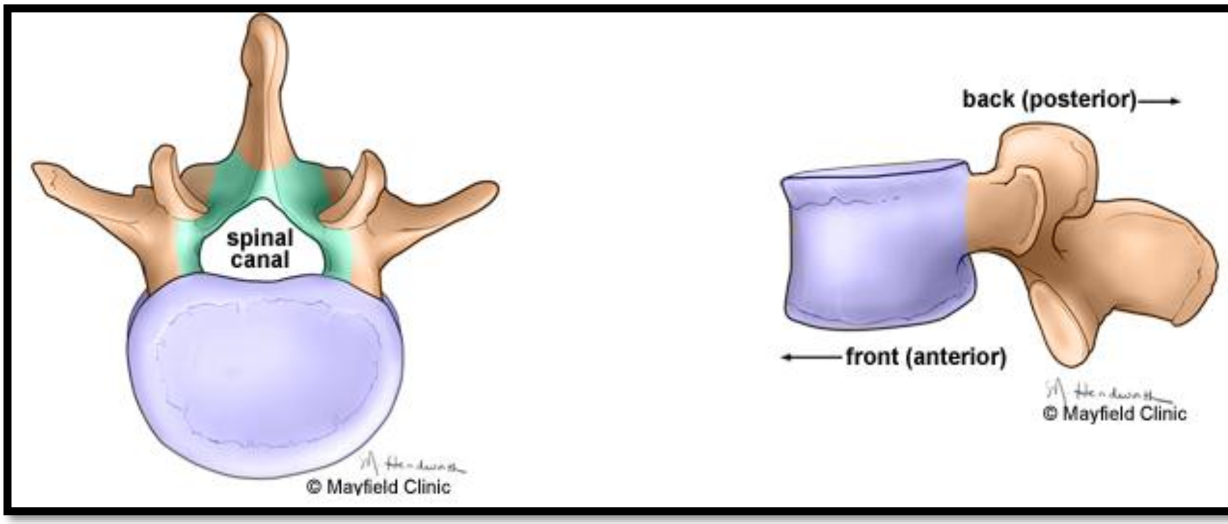

Fig (2.2): While vertebrae have unique regional features, every vertebra has three main parts: body (purple), vertebral arch (green), and processes for muscle attachment (tan) [2].

2.5 Intervertebral disc:

Each vertebra in the spine is separated and cushioned by an intervertebral disc, keeping the bones from rubbing together. Discs are designed like a radial car tire. The outer ring, called the annulus fibrosus, has criss - crossing fibrous bands, much like a tire tread. These bands attach between the bodies of each vertebra. Inside the disc is a gel - filled center called the nucleus polposus, much like a tire tube as shown in fig (2.3). Discs function like coiled springs. The criss - crossing fibers of the annulus pull the vertebral bodies together against the elastic resistance of the gel - filled nucleus. The nucleus acts like a ball - bearing when you move, allowing the vertebral bodies to roll over the incompressible gel. The gel - filled nucleus polposus is composed mostly of fluid. This fluid absorbed during the night when lying down and is pushed out during the day when moving upright. With age, the discs increasingly lose the ability to reabsorb fluid and become brittle and flatter; this is why we get shorter as we grow older. In addition, diseases, such as osteoarthritis and osteoporosis, cause bone spurs (osteophytes) to grow. Injury and strain can cause discs to bulge or herniate, a condition in which the nucleus is pushed out through the annulus fibrosus to compress the nerve roots causing back pain [3].

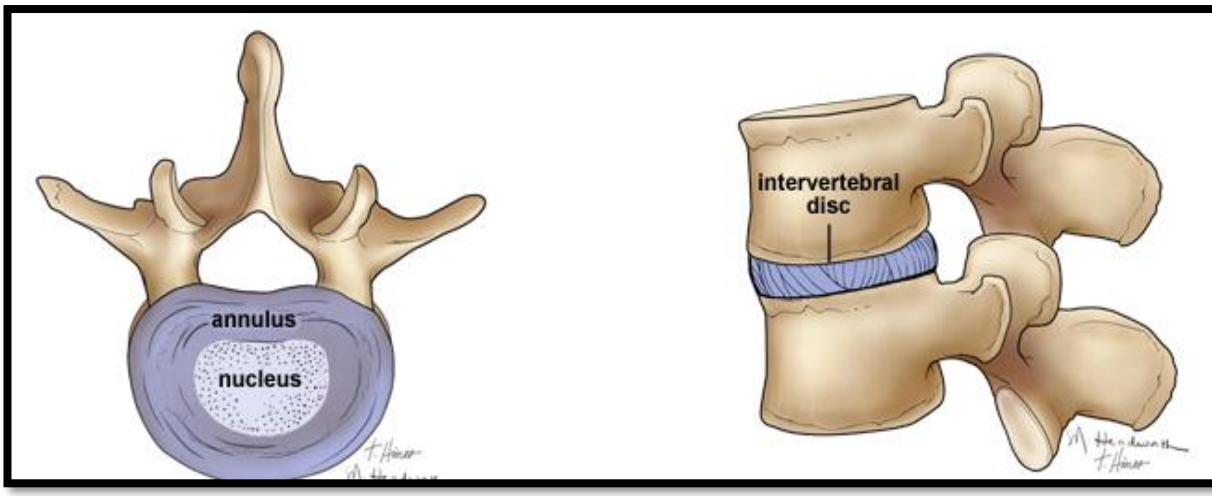

Fig (2.3): Intervertebral discs (purple) are made of a gel-filled center called the nucleus polposus and a tough fibrous outer ring called the annulus fibrosus. The annulus pulls the vertebral bodies together against the resistance of the gel-filled nucleus polposus [3].

2.6 Vertebral arch & spinal canal:

On the back of each vertebra are bony projections that form the vertebral arch. The arch is made of two supporting pedicles and two laminae as shown in fig (2.4). The hollow spinal canal contains the spinal cord, fat, ligaments, and blood vessels. Under each pedicle, a pair of spinal nerves exits the spinal cord and passes through the intervertebral foramen to branch out to your body. Surgeons often remove the lamina of the vertebral arch (laminectomy) to access and decompress the spinal cord and nerves to treat spinal stenosis, tumors, or herniated discs.

Seven processes arise from the vertebral arch: the spinous process, two transverse processes, two superior facets, and two inferior facets [3].

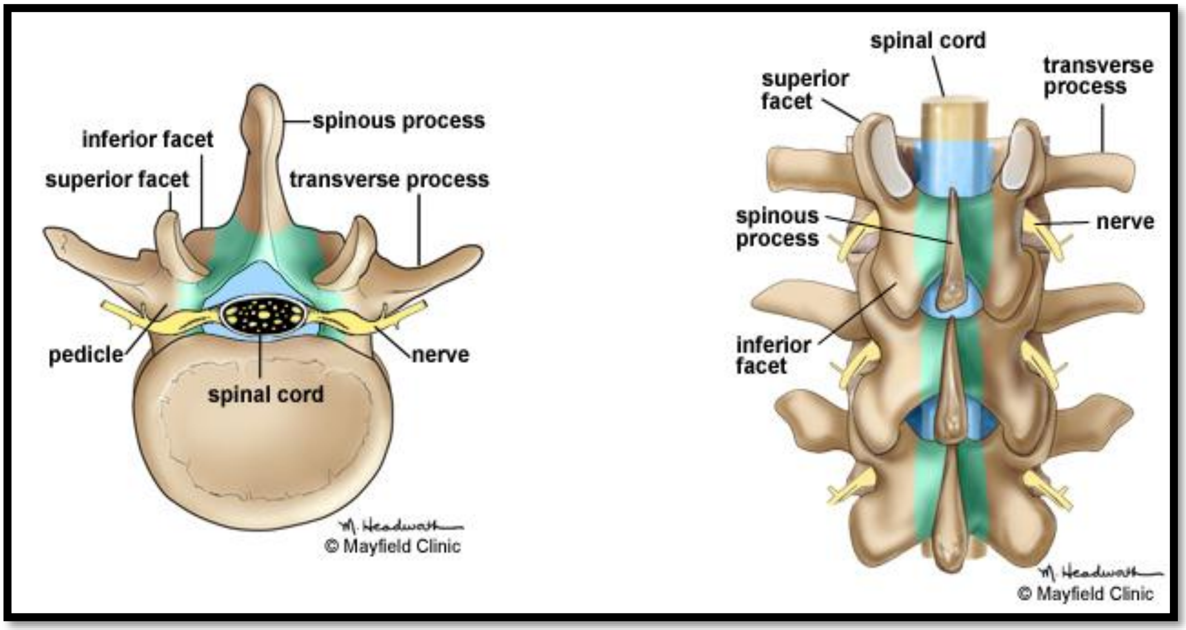

Fig (2.4): The vertebral arch (green) forms the spinal canal (blue) through which the spinal cord runs. Seven bony processes arise from the vertebral arch to form the facet joints and processes for muscle attachment [3].

2.7 Facet joints:

The facet joints of the spine allow back motion. Each vertebra has four facet joints, one pair that connects to the vertebra above (superior facets) and one pair that connects to the vertebra below (inferior facets) [3] fig (2.5).

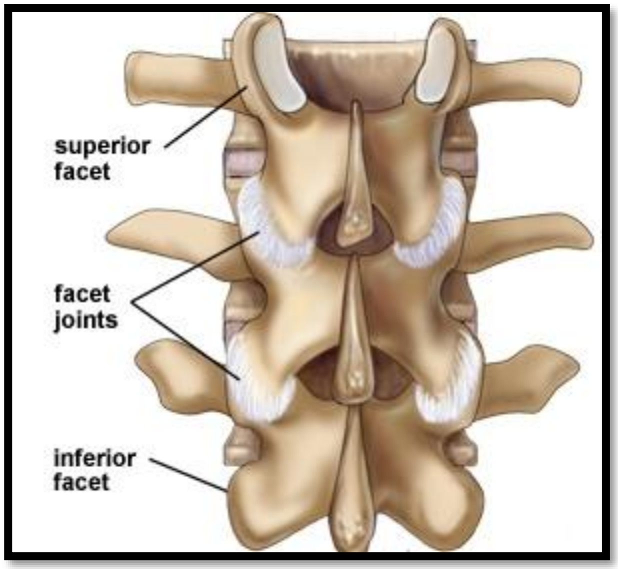

Fig (2.5): The superior and inferior facets connect each vertebra together. There are four facet joints associated with each vertebra [3].

2.8 Ligaments:

The ligaments are strong fibrous bands that hold the vertebrae together, stabilize the spine, and protect the discs. The three major ligaments of the spine are the ligamentum flavum, anterior longitudinal ligament (ALL), and posterior longitudinal ligament (PLL) as shown in fig (2.6)**.** The ALL and PLL are continuous bands that run from the top to the bottom of the spinal column along the vertebral bodies. They prevent excessive movement of the vertebral bones. The ligamentum flavum attaches between the lamina of each vertebra [3].

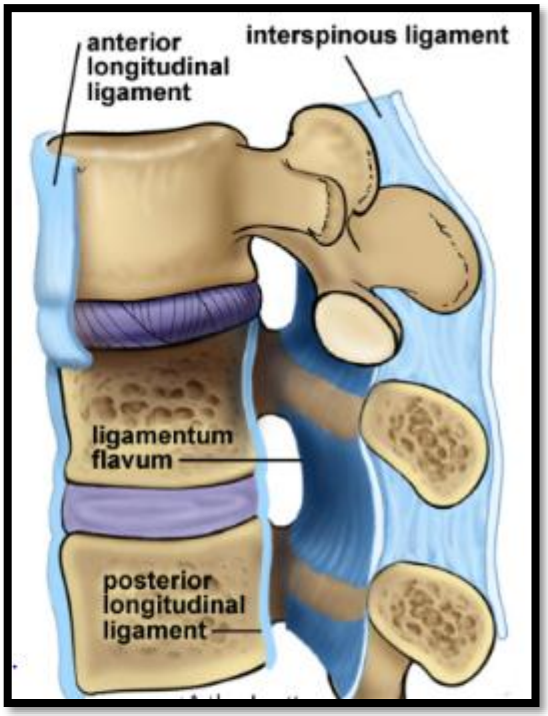

Fig (2.6): The ligamentum flavum along with the anterior and posterior longitudinal ligaments enable flexion and extension of the spine while keeping the vertebrae in alignment [3].

2.9 Anatomy of lumbar lordosis:

Lumbar lordosis is the inward (ventral) curvature of the lumbar spine formed by the wedging of lumbar vertebral bodies and the intervertebral disks. Dorsal wedging of the vertebral bodies and disks (anterior part longer than posterior) increases the lordosis angle, whereas more ventral wedging of these structures (anterior part shorter than posterior) reduces the lordosis angle. Lumbar lordosis is similarly influenced by the shape of the vertebral bodies and the shape of the intervertebral discs, because each account for nearly 50% of the variability seen in lordotic angles of adults. Each of the five lumbar segments (vertebral body and the adjacent disc) contributes to the lordosis. The last lumbar segment (L5) contributes almost 40% to overall lordosis. The first segment (L1) contributes only 5%. The lordosis angle also correlates with the orientation of the inferior articular processes— greater lordosis correlates with more dorsally (horizontally) inclined inferior articular (facet) processes in relation to the vertebral bodies [4].

2.10 Development of the lumbar lordosis:

The physical capacity of the human spine to develop lumbar lordosis is due to evolutionary changes in the spine and pelvis; however, the degree of lumbar lordosis develops through infancy, toddler, and childhood. Human infants show little or no lumbar lordosis in utero, and the degree of lumbar lordosis coincides with the stages of bipedal activity in modern humans. Other researchers have demonstrated that the degree of lumbar lordosis continues to increase through childhood. Lumbar lordosis alone is not sufficient to support the range of motions the human body undergoes on a daily basis; the spine must also be flexible. Lumbar lordosis can be developed (to a lesser extent) in primates trained to walk bipedally from infancy however, the lumbar curve in these primates is fixed and does not have the flexibility of the human spine. The striking segmented pattern of the spine is established during embryogenesis when somites are rhythmically added to the posterior of the embryo. Somite formation begins around the third week when the embryo begins gastrulation and continues until around 52 somites are formed [13].

The somites are spheres, formed from the paraxial mesoderm that lies at the sides of the neural tube and they contain the precursors of spinal bone, the vertebrae, ribs and some of the skull bones, as well as muscle, ligaments and skin. A clock and wave front model acting in cells of the paraxial mesoderm control somitogenesis and the subsequent distribution of somites.

However, as the somite matures, its various regions become committed to forming only certain cell types. The ventral medial cells of the somite (those cells located farthest from the back but closest to the neural tube) undergo mitosis, lose their round epithelial characteristics, and become mesenchymal cells again. The portion of the somite that gives rise to these cells is called the sclerotome, and these mesenchymal cells ultimately become the cartilage cells (chondrocytes) of the vertebrae and part (if not all) of each rib. Soon after their formation, sclerotomes, which give rise to some of the bone of the skull, the vertebrae and ribs migrate, leaving the remainder of the somite now termed a dermamyotome behind [13]. This then splits to give the myotomes which will form the muscles and dermatomes which will form the skin of the back [13]. Sclerotomes become subdivided into an anterior and a posterior compartment. This subdivision plays a key role in the definitive patterning of vertebrae that form when the posterior part of one somite fuses to the anterior part of the consecutive somite during a process termed resegmentation. Disruption of the somitogenesis process in humans results in diseases such as congenital scoliosis [13].

In humans, the first four somites are incorporated in the base of the occipital bone of the skull and the next 33 somites will form the vertebrae, ribs, muscles, ligaments and skin. The remaining posterior somites degenerate. During the fourth week of embryogenesis, the sclerotomes shift their position to surround the spinal cord and the notochord. This column of tissue has a segmented appearance, with alternating areas of dense and less dense areas. As the sclerotome develops, it condenses further eventually developing into the vertebral body. HOX genes regulate development of the appropriate shapes of the vertebral bodies [13]. The less dense tissue that separates the sclerotome segments develop into the intervertebral discs. The notochord (which is a flexible rod made out of a material similar to cartilage) disappears in the sclerotome (vertebral body) segments, but persists in the region of the intervertebral discs as the nucleus pulposus. The nucleus pulposus and the fibers of the anulus fibrosus make up the intervertebral disc. The primary curves (thoracic and sacral curvatures) form during fetal development. The secondary curves develop after birth. The cervical curvature forms as a result of lifting the head and the lumbar curvature forms as a result of walking [13].

2.11 Ontogenetic development of the lumbar lordosis:

Although many authors believe that the spine of the human fetus shows only one kyphotic curvature from cranial to caudal, studies have shown that the fetal spine has lordotic curvature at the lumbosacral junction. Choufani et al, in an (MRI) study of 45 fetuses aged 23 to 40 weeks' gestation demonstrated that all fetuses had lordotic lumbar curvature with a mean radius of 18.7 mm. This lordosis was uncorrelated with gestational age, which means that it was not related to growth and, according to the authors, might have been genetically determined. Few researchers have examined the lordosis angle in early childhood, with Reichmann and Lewin, being a notable exception. They found that lordosis angles increased during the first 3 years of life, claiming that at the age of 3, the child's spine reaches an adult-like lordosis angle. Other researchers, however, found that the lordosis angle continues to increase during later childhood and puberty even until the age of 20. For example, Cil et al. [demonstrated an increase of the lordosis angle from 44.3 at 3 to 6 years to 54.6 at 13 to 15 years. It can be concluded that lumbar lordosis begins to develop in fetuses. The major increase of the lordosis angle occurs during the first 3 years of life and continues increasing at least until puberty. There are many gaps in the current knowledge regarding the ontogenetic development of lumbar lordosis. Additional studies are essential to fill in this gap and to identify the factors that determine lordosis development. Ascertaining the normal values of lordosis in children is essential for early detection and treatment of postural abnormalities [(4)].

2.12 Evaluation of lumbar lordosis:

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 end-plate of L1, and the lower line at the superior end-plate of the sacrum. 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 [(5)].

2.13 Mechanical & physiological Advantage of Lumbar Lordosis

To understand the potential underlying causes of degeneration of the intervertebral discs; it is important to know the functional benefits of lumbar lordosis. Lumbar lordosis is critical for balancing the human body in upright posture. However, lumbar lordosis is not a uniquely human trait. In infants, the lumbar spine has only slight lordosis or may have no lordosis at all. The lordotic curve develops with developmental stages of bipedalism. Infants and toddlers who walk early demonstrate increased lordotic curves while those who walk late or not at all have only slight lordosis [(14)].

Lumbar lordosis is necessary for efficient upright walking, lumbar flattening is equally necessary for other activities.

The degree of lordosis in the lumbar spine is the main factor that influences the conversion of the extensor power developed by the intrinsic back muscles to axial torsion necessary to rotate the pelvis in walking [(14)].

2.14 Clinical considerations of lumbar lordosis:

Given the importance of lumbar lordosis in the evolution of the human spine and its role in our transition to bipedalism, it is not surprising that loss of sagittal balance contributes to a significant pain and disability. Sagittal malalignment also results in increased energy expenditure and induces a variety of compensatory measures including knee flexion, pelvic retroversion, and thoracic hypokyphosis. Studies have shown that surgical correction of sagittal malalignment leads to improvements in a variety of health-related quality of life measurements. In patients with lumbar degenerative kyphosis, surgical restoration of lumbar lordosis results in spontaneous resolution of pelvic retroversion and thoracic hypokyphosis [14].

The role of musculature in supporting lumbar lordosis is clearly established through observations of human-specific evolutionary changes in spinal musculature, the mechanical role of spinal muscles, and the correlations between muscle volume and postural changes. However, clinical research has not yet established a cause or effect relationship between spinal muscles and postural changes. Establishing a timeline for degenerative postural changes and musculature may provide insights into the effectiveness and timing of muscle development rehabilitation strategies. Effective conservative treatments also depend on identifying patients at risk for postural degeneration before they become symptomatic. Recent research to establish definitions of normal lumbar curvature and optimize lordosis measurement methods provides an important foundation to establish early diagnosis and track postural degeneration. The relationship between vertebral structure and posture defined for studying human evolution may provide a means for early identification of small deviations from an individual's optimal posture. These structure-postural relations may also be able to predict the degree of spontaneous correction possible in the thoracic spine following the restoration of lumbar lordosis [14].

Lumbar flattening often results from degenerative changes in the spine. Osteoporotic wedge fractures in the vertebrae and degenerative disc disease' both correlated with reduced lordosis in the lumbar spine. Muscle weakness also correlated with a loss of lordosis. Older patients show a reduction in lumbar lordosis because of these degenerative changes. However, the degree of lumbar lordosis in normal individuals is highly variable (41°–70°) and broadly overlaps with measures of degenerative hypolordosis (−40° to 67°) [14].

2. 15 Previous studies:

A study done by Been E, Kalichman L, Tel Aviv University, Tel Aviv, Israel, in January 2014 ; concluded that the lumbar lordosis angle is positively and significantly associated with spondylolysis and isthmic spondylolisthesis. However, no association has been found with other spinal degenerative features. Inconclusive evidence exists for association between lordosis and low back pain [(2)]. On the other hand they concluded that the optimal lordotic range remains unknown and may be related to a variety of individual factors such as weight, activity, muscular strength, and flexibility of the spine and lower extremities [(2)].

Another study done by Caroline Edward Ayad et al, in Sudan, named evaluation of lumber lordotic angle in patients with inter vertebral disc prolapse using Cobb's method, published in the global journal of medical research, 20th February. 2014. Their study concluded that Cobb's angle and disc prolapse levels have no significant relation with job, height, weight, age, BMI, no significant difference was detected between Cobb's angle of the normal subjects and patients with prolapsed disc, and the results did not differ among male and female patients [(4)].

In article done by Abdelmonem Hegazy anatomy departtment, faculty of medicine, Zagazig university, Egypt; he reported that; the lumbar lordosis angle (LLA) was larger in females than in males. Its mean values increased by age. The lumbar height (LH) was longer in males than in females. At the same time, the lumbar breadth (LB) was higher in females than in males. Lumbar index ($LI = LB/LH \times 100$) showed a significant gender differences [(5)]. He stated that the MRI might clearly reveal the anatomy of the lumbar lordosis. Use of LI in association with LLA could be useful in evaluation of lumbar lordosis. [(5)].

In additional study done by Harrison D E, et al, in California in (2001); their study concluded that all four radiographic methods had high reliability and low mean absolute differences of observer's measurements. The centroid, Cobb's, and Harrison posterior tangent methods provide global and segmental angles. However, the centroid segmental method requires three segments and is less useful for a stability analysis [(7)].

CHAPTER THREE

MATERIALS & METHODS

3. Materials & Methods:

3.1 Study design:

A retrospective descriptive cross-sectional hospital based study was conducted using lumbar magnetic resonance imaging (MRI) from the Radiology Department at the Sharg Elneel Hospital data available from 1^{st} of January up to June 2017.

3.2 Study area:

The study was conducted at the Sharg Elneel Hospital Radiology Department, at the Sharg El neel Area-Khartoum state, Sudan.

3.3 Study duration:

The study last for six months from 1^{st} of January up to June 2017, after approval by our institutional research and ethic committee.

3.4 Study populations:

Eighty cases were collected by the proposed sampling technique from the individuals who went to the Radiology Department of the Sharg Elneel Hospital during the period of the study.

3.4.1 Inclusion criteria:

All cases referred to the Diagnostic Radiology Department at SNH with age groups more than 18 years & without any congenital or degenerative deformities.

3.4.2 Exclusion criteria:

Patients having spinal anomalies such as fractures or deformities were excluded from the study as well as patients with previous spinal surgeries, intra- or extradural tumors, spinal degenerative changes, or obvious anatomical abnormalities. Individuals with lumbosacral transitional segment anomalies were also excluded. All patients aged less than 18 years were also eliminated since considered that spinal maturity is not completed of this age group.

3.5 Study variables:

The variables such as; age, sex, LLA parameters were recorded.

Fig (3.1): T2-weighted MRI for a female-aged 51 years with LLA (54^0) measured between L1 and S1.

3.6 Sampling:

3.6.1 Sampling type:

Simple random sampling method, hospital based was used**.**

3.6.2 Sampling size:

Eighty cases were collected by the proposed sampling technique.

3.7 Technique of LLA measurement:

Measurement of (LLA) was done from the mid-sagittal slice of T2 MRI lumbar spine using Cobb's method; by drawing a perpendicular line to a line drawn across the superior end-plate of first lumbar vertebra and the superior end-plate of first sacral vertebra; the angle formed by the intersection of the two perpendicular lines is the Cobb's angle or lumbar lordotic angle as shown in figure (3.1).

3.8 Data collection tools:

3.8.1 Data analysis:

Data were analyzed using SPSS version 21, Microsoft word, excel & the obtained data were scrutinized, tabulated, and statistically analyzed, using maximum and minimum values, range (R), mean (M), difference between means of two groups (MD), standard deviation (SD), and 95% confidence intervals (CI) of mean. The existence of significant differences between the means for the gender and the age groups were analyzed by using Chi-square test. A P value <0.05 will be considered to be statistically significant.

3.8.2 Data management:

The data were analyzed and managed by using the following parameters; Pearson's linear correlation coefficients. Probability values ($P \leq 0.05$) were considered statistically significant. Means, standard deviations, mean absolute differences, interclass and interclass correlation coefficients (ICC), and confidence intervals were calculated.

3.9 Ethical consideration

After approval by the institutional research and ethic committee, the purpose of the study was well explained to the subjects under the study & the cases were selected with the proposed method.

CHAPTER FOUR

RESULTS

4. Results

The following tables and figures presented the data obtained from 40 males and 40 females came to MRI department for lumbar spine examination as they all were complaining of lower back pain, the Cobb's angle was measured to study the relations regarding the Cobb's angle variations.

The age distribution of the study population was predominantly between (41-60) years as shown in table (4.1) & fig (4.1).

Table (4.1): Age distribution of the study population (N=80):

Age(yrs.)	Frequency	Percent
(20 - 40)	26	32.5
(41- 60)	41	51.3
(61- 80)	13	16.3
Total	80	100.0

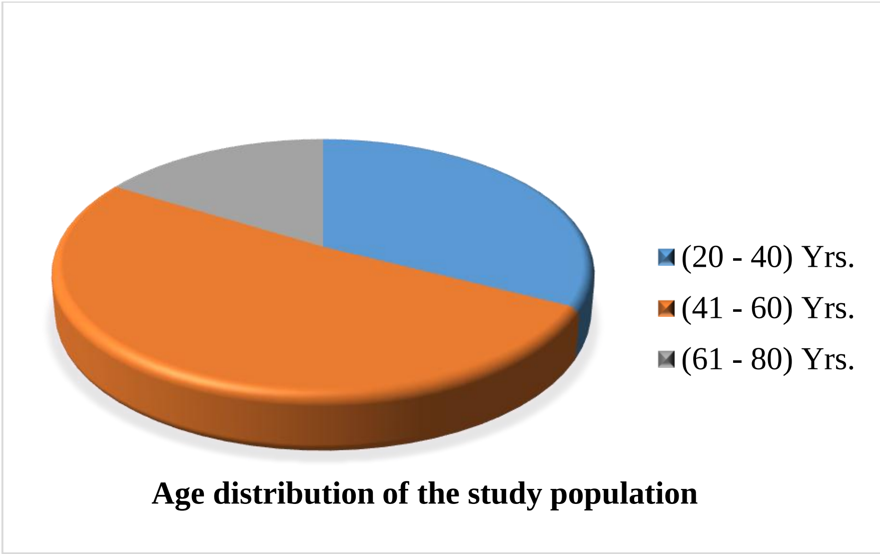

Fig (4.1): Percentages of the age distribution of the study population (N=80).

The gender distribution of the study population was same between males & females as indicated in table (4.2) & fig (4.2).

Table (4.2): The gender distribution of the study population (N=80)

Gender	Frequency	Percent
Male	40	50.0
Female	40	50.0
Total	80	100.0

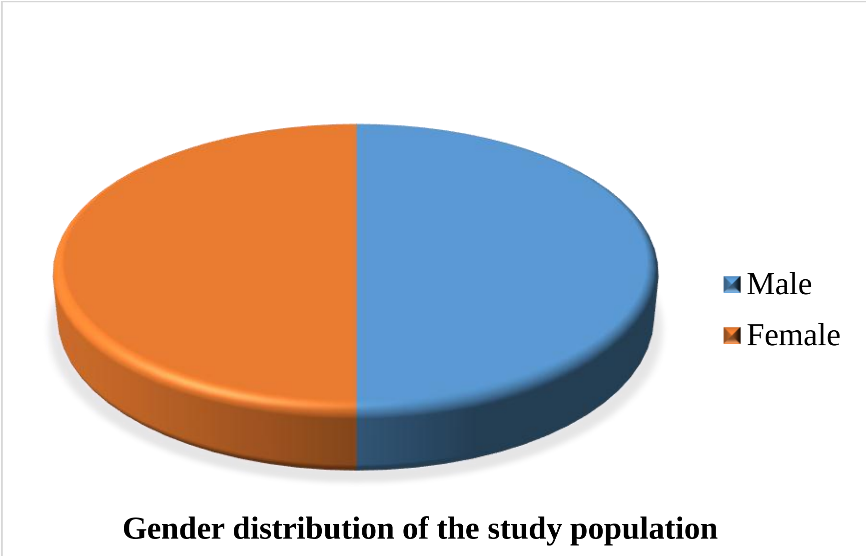

Fig (4.2): Percentages of the gender distribution of the study population (N=80)

The main magnetic resonance imaging modality used in this study was T2 weighted MRI with excellent demonstration of the anatomical land marks of the lumbar region as shown in table (4.3)

Table (4.3): MRI modality used for the measurements of the LLA: (N=80)

MRI modality	Frequency	Percent
T2	80	100.0

In the majority, 53 subjects (66.3 %) of the population their lumbar lordosis angle was found to range between (20-45^0), in four (5 %) subjects less than 20^0 but in the most of them 23 individuals (28.8%) were more than 45^0 as shown in table (4.4) & fig (4.3).

Table (4.4): The LLA among the study population (N=80)

LLA (^{0})	Frequency	Percent
20 - 45	53	66.3
less than 20	4	5.0
more than 45	23	28.8
Total	80	100.0

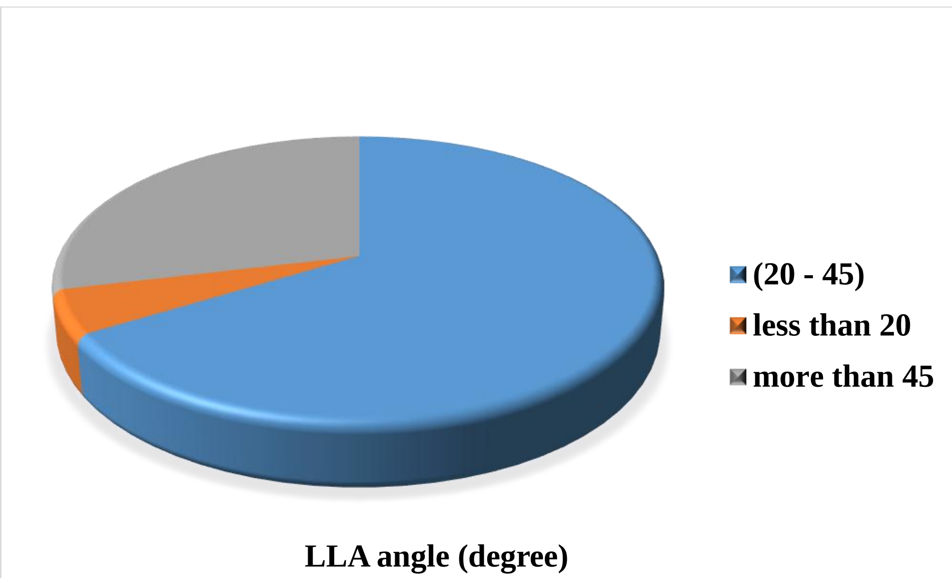

Fig (4.3): Shows the percentages of the LLA (^{0}) among the study population (N=80)

The lumbar lordosis angle & the gender cross tabulation showed that there was no significant association between them as indicated with the P-value of more than 0.05 as shown in table(4.5), (4.6) respectively.

Table (4.5): LLA * Gender Cross tabulation.

LLA (^{0})	Gender		Total
	Male	Female	
20 - 45	30	23	53
less than 20	3	1	4
more than 45	7	16	23
Total	40	40	80

Table (4.6): Chi-Square Test (LLA & Gender).

Test	P-value
Pearson Chi-Square	0.066
Total	80

The lumbar lordosis angle & age cross tabulation showed that there was a significant association between them as indicated with the P-value of less than 0.05 (i.e. correlation is significant at the 0.05 level) as shown in table (4.7), (4.8) respectively.

Table (4.7): LLA * Age Cross tabulation.

LLA (^{0})	Age (yrs.)			Total
	(20 - 40)	(41- 60)	(61- 80)	
20 - 45	21	25	7	53
less than 20	4	0	0	4
more than 45	1	16	6	23
Total	26	41	13	80

Table (4.8): Chi-Square Test (LLA & Age).

Chi-Square Test	Value	P-value
Pearson Chi-Square	18.093	0.001
Total	80	

The mean distribution of the LLA & age was found to be 1.6, while the mean distribution of the male & female gender were found to be (1.4, 1.8) respectively.

Table (4.9): The mean of the LLA, male & female variables.

Variable	Mean	Number of cases
LLA	1.6	80
Age	1.6	80
Male	1.4	40
Female	1.8	40

The interclass correlation coefficient using absolute agreement definition showed excellent correlation & reliability at the level of 0.8 as shown in table (4.10).

Table (4.10): The interclass correlation coefficient (ICC) & confidence interval (CI):

Variables	ICC	CI (95%)
Age	0.85	0.58
Gender	0.9	0.85
LLA	0.97	0.92

CHAPTER FIVE

DISCUSSION

5. Discussion

MRI of 80 subjects (40 males and 40 females) with, their ages ranged between (20-80) years old. The males and the females mean age and Cobb's angle were examined. The mean Cobb's angle was measured from the superior end-plate of L1 to the superior end-plate of S1, and the mean Cobb's angle was found to be 1.6**.** For the female patients the mean Cobb's angle was 1.8, while the mean Cobb's angle for male patients was 1.4. It was higher in female than male but the difference was not significant, similar findings were found by Ayad CE et al [4].

The study concluded that Cobb's angle had no significant relation with, gender but there was a significant association with age, reverse results were found by Ayad CE (4)' who had mentioned that the gender can be predictor of the lumbar lordosis angle in addition, different findings were found by Khodadad et al, who found that the gender has a significant effect on the lumbar total & segmental lordosis(11). However, the Cobb's angle was correlated significantly with the patient age (P-value= 0.001) as mentioned by Hegazy AA (5).

It is known that the MRI is a valuable tool to demonstrate the vertebral body end-plate borders, which have value in applying the Cobb's method. Harrison DE et al (7) reported similar P-value to the current study for postural lordosis, agreement between these two findings might relate to similar subject positioning as both studies measured spinal curvatures in neutral standing. In a more recent study, Moussallem CD et al measured lumbar angles in combination with lumbar range of movement on 12 healthy men with no history of back pain, they concluded that the mean lumbar lordosis angle was 46^0 ranging from (20 – 80) in normal individuals (8).

The inter class correlation (ICC) results for lumbar lordosis were 0.95, suggesting that the method of measurement employed by Lin RM et al, showed adequate clinical reliability (10). However, even though their score is similar to that achieved in the present study, it should not be considered as a definitive clinical representation of reliability. These authors did not calculate the confidence interval, which help to indicate the magnitude of disagreement between measurements, or indicate which ICC model was used for analysis.

The results of the present study also lend support to the findings of Lefatkar KH et al (11), who measured the effects of weight, gender and number of pregnancies on lumbar total and segmental lordosis and low back pain demonstrated an ICC (3,3) of 0.92. Similarities in the ICC scores are thought to be due to the reason that the investigators in the current study recorded lumbar lordosis from the spinous processes of L1/S1.

CHAPTER SIX

CONCLUSIONS & RECOMMENDATIONS

6. Conclusion & Recommendations

6.1 Conclusion:

- ✓ Lumbar lordosis is an important postural feature of spinal balance.
- ✓ The use of Cobb's method to measure Lumbar lordosis angle between the superior end-plate of the first lumbar vertebra to the superior end-plate of the first sacral vertebra.
- ✓ The lumbar lordosis angle was positively and significantly associated with age, but no association has been found with gender.
- ✓ The normal range of the lumbar lordosis angle was found to be ranged between $(20 - 45)^0$.
- ✓ There were variations of the LLA from an individual to another.

6.2 Recommendations:

- Additional studies are needed to confirm the presence or absence of the associations between lordosis angle with age, gender, ethnicity, occupation, and leisure physical activity.
- Measurement of lumbar lordosis (Cobb's method) should be performed between the superior end-plate of the first lumbar vertebra and the superior end-plate of the sacrum.
- The study recommends using MRI in detecting and monitoring vertebral morphological changes and end-plates degeneration.
- More studies were needed in this area with bigger sample to determine the normal range of lumbar lordosis angle in normal Sudanese individuals.
- The use of MRI as a method for quantifying modifications in postural geometry would be valuable to clinicians who assess patients presenting with conditions with abnormal Lumbar lordosis.

CHAPTER SEVEN

REFERENCES

7. References

1) Anatomy of the human spine: Anon, [online] Available at: https://www.mayfieldclinic.com/PE-AnatSpine.htm [Accessed 9 Sep. 2017].
2) Been E, Kalichman L. Lumbar lordosis. The Spine Journal. 2014 Jan 1; 14 (1): 87-97.
3) Been E, Pessah H, Been L, Tawil A, Peleg S. New method for predicting the lumbar lordosis angle in skeletal material. The Anatomical Record. 2007 Dec 1; 290 (12): 1568-73.
4) Ayad CE, Wahby DM, Abdall EA, Kajoak SA. Evaluation of Lumbar Lordotic Angle in Patients with Inter Vertebral Disc Prolapse using Cobb's Method. Global Journal of Medical Research. 2014 Feb 20: 55 - 67.
5) Hegazy AA, Hegazy RA. Midsagittal anatomy of lumbar lordosis in adult Egyptians: MRI study. Anatomy research international. 2014 Aug 18; 104 - 118.
6) Hwang SH, Park SW, Kim YH. Measurement Comparison about Lumbar Lordosis: Radiography and 3D Motion Capture. In World Congress on Medical Physics and Biomedical Engineering, Springer Berlin Heidelberg. Munich, Germany 2010 September 7-12, 2009, (pp. 1669-1671).
7) Harrison DE, Harrison DD, Cailliet R, Janik TJ, Holland B. Radiographic analysis of lumbar lordosis: centroid, Cobb's, TRALL and Harrison posterior tangent methods. Spine. 2001 Jun 1; 26 (11): 235-42.
8) Moussallem CD, El Masri H, El-Yahchouchi C, Abou Fakher F, Ibrahim A. Relationship of the lumbar lordosis angle to the level of termination of the Conus Medullaris and thecal sac. Anatomy research international. 2014. Vol 2014; 36 – 50.
9) Van Blommestein AS, MaCrae S, Lewis JS, Morrissey MC. Reliability of measuring thoracic kyphosis angle, lumbar lordosis angle and straight leg raise with an inclinometer. Open Spine Journal. 2012. Dec 1; 290 (7): 130 - 45.
10) Lin RM, Jou I M, Yu CY. Lumbar lordosis: normal adults. Journal of the Formosan Medical Association= Taiwan yi zhi. 1992 Mar; 91(3): 329-33.
11) Letafatkar Khodadad, Hadadnezhad M, Arashpour H, Heris MB. Effects of weight, gender and number of pregnancies on lumbar total and segmental lordosis and low back pain. Journal of Research in Rehabilitation Sciences. 2010 Feb 6; 4 (2):23 – 34.

12) Damasceno LH, Catarin SR, Campos AD, Defino HL. Lumbar lordosis: a study of angle values and of vertebral bodies and intervertebral discs role. Acta Ortopédica Brasileira. 2006: 14 (4):193-8.

13) Carlson BM. Human Embryology and Developmental Biology E-Book: With Student consult online Access. Elsevier Health Sciences; 2012 Dec 24.503- 523

14) Sparrey CJ, Bailey JF, Safaee M, Clark AJ, Lafage V, Schwab F, Smith JS, Ames CP. Etiology of lumbar lordosis and its pathophysiology: a review of the evolution of lumbar lordosis, and the mechanics and biology of lumbar degeneration. Neurosurgical focus. 2014 May; (5):36.

APPENDIX:

The National Ribat University

Faculty of Graduate Studies & Scientific Research

MSc of Clinical Human Anatomy

MRI Evaluation of Lumbar Lordosis Angle in Sudanese Population

Data collection sheet:

Index No: ☐☐☐

1. Socio-demographic data:

1.1. Age: (groups)

a) (30 – 45) years ☐
b) (46 – 60) years ☐
c) (61 – 75) years ☐
d) More than 75 years ☐

1.2. Gender:

a) Male ☐
b) Female ☐

2. MRI measurements:

2.1. MRI modality: ☐

a) T1.MRI
b) T2.MRI ☐

3. Lumbar lordosis parameters:

3.1. Lumbar lordosis angle {LLA (Cobb's angle)}

3.2. Lumbar breadth{LB (mm)}

3.3. Lumbar height {LH (mm)}

3.4. Lumbar lordosis index (LLI = LB/LH*100):

	Age	Gender	MRI- Modality	LLA	LB	LH	LLI
1)							
2)							
3)							
4)							
5)							
6)							
7)							
8)							
9)							
10)							
11)							
12)							
13)							
14)							
15)							
16)							
17)							
18)							
19)							
20)							
21)							
22)							
23)							
24)							
25)							
26)							
27)							
28)							
29)							
30)							