A COMPARISON OF RELIABILITY IN MEASURING SPINAL CURVATURE

APICHAYA KIARTUBOLPAIBOON

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ABSTRACT

The purpose in this study is to assess intra-rater and inter-rater reliability of 3 methods for measuring spinal curvature in 30 anteroposterior radiograph 2D views (AP view) with spinal patients of Lerdsin hospital during the years 2004 to 2011. Three methods i.e. Cobb, Ferguson and Polynomial are compared with each value in terms of reliability. Ferguson is the traditional method and Cobb is probably the most popular, while polynomial is one of the first documented mathematical models for sagittal spinal curvature. Intraclass correlation coefficient (ICC) is used to calculate the inter-rater reliability (ICC model 2, 1) and intra-rater reliability (ICC model 3, 1). The statistical analysis shows that the intra-rater reliabilities of Ferguson, Cobb and Polynomial are 0.968, 0.950 and 0.910, respectively. Regarding similarity, their inter-rater reliabilities are 0.477, 0.659 and 0.407 respectively. The statistical analysis of the sample paired t-test was used to test the difference of the angles by measuring spinal curvature, showed that the difference between intra-rater and inter-rater Ferguson and Polynomial the mean was not statistically significant ($p>0.05$). In addition, we found significant differences between intra-rater and inter-rater in other methods where the mean is statistically significant ($p<0.05$). The results indicate that the most reliable measurement of spinal curvature is the Ferguson method. It can be used to assess the measurement with some special cautions. However, the most reliable measurement of spinal curvature is the Cobb method, when using between examiners.

KEY WORDS: COBB METHOD / FERGUSON METHOD / POLYNOMIAL METHOD / INTRA-RATER RELIABILITY / INTER-RATER RELIABILITY / ANTEROPOSTERIOR RADIOGRAPH 2D VIEW (AP-VIEW) / INTRACLASS CORRELATION COEFFICIENT (ICC)

43 pages

การเปรียบเทียบความน่าเชื่อถือในการวัดมุมความโค้งของกระดูกสันหลัง

A COMPARISON OF RELIABILITY IN MEASURING SPINAL CURVATURE

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คณะกรรมการที่ปรึกษาวิทยานิพนธ์:วรัญญู วงศ์เสรี,Ph.D.,อดิศร ลีลาสันติธรรม,Ph.D., บันลือ เอมะรุจิ ,Ph.D.

บทคัดย่อ

การศึกษาครั้งนี้มีวัตถุประสงค์เพื่อเปรียบเทียบค่าความน่าเชื่อถือของวิธีการวัดมุมความโค้งกระดูกสันหลังสามวิธี คือวิธีการวัดแบบเฟอร์กูสัน, คอบบ์และ พหุนาม ซึ่งวิธีการวัดแบบเฟอร์กูสันเป็นวิธีการวัดที่เก่าแก่ที่สุด ส่วนวิธีการวัดแบบคอบบ์เป็นวิธีการวัดที่มีความนิยมสูงสุดและวิธีการวัดแบบพหุนาม เป็นหนึ่งในแบบจำลองทางคณิตศาสตร์แรกที่ถูกเสนอในการวัดมุมความโค้งกระดูกสันหลัง โดยศึกษาวิธีการวัดมุมความโค้งกระดูกสันหลังจากภาพฉายรังสี 2 มิติ กระดูกสันหลังด้านหน้าในผู้ป่วยโรคกระดูกสันหลังโรงพยาบาลเลิดสิน จำนวน 30 ภาพ ทำการวัดโดยนักวิจัยที่ได้รับการอบรมการกำหนดจุดขอบกระดูกสันหลังจากแพทย์ผู้เชี่ยวชาญ จำนวน 3 คน โดยสถิติที่นำมาใช้ คือการเปรียบเทียบค่าความน่าเชื่อถือของตัวผู้ประเมินใช้แบบจำลอง ICC (3,1) และ ความน่าเชื่อถือในระหว่างผู้ประเมินใช้แบบจำลอง ICC (2,1) จากผลการศึกษาพบว่า ค่าความน่าเชื่อถือของตัวผู้ประเมินของวิธีการวัดแบบ เฟอร์กูสัน, คอบบ์และ พหุนาม เท่ากับ 0.924, 0.933 และ 0.515 ตามลำดับ ส่วนค่าความน่าเชื่อถือในระหว่างผู้ประเมินของวิธีการวัดแบบ เฟอร์กูสัน, คอบบ์ และ พหุนาม เท่ากับ 0.797, 0.805 และ 0.526 ตามลำดับ วิธีการวัดแบบเฟอร์กูสัน และ พหุนาม ของตัวผู้ประเมิน และ ระหว่างผู้ประเมินนั้นไม่แตกต่างกันอย่างมีนัยสำคัญ ($p>0.05$) และ พบว่าวิธีการวัดแบบคอบบ์แตกต่างจากวิธีการวัดแบบเฟอร์กูสัน และ พหุนาม ของตัวผู้ประเมิน และ ระหว่างผู้ประเมินอย่างมีนัยสำคัญ ($p<0.05$) ผลการศึกษานี้บ่งชี้ว่าวิธีการวัดมุมความโค้งของกระดูกสันหลังที่มีค่าความน่าเชื่อถือของตัวผู้ประเมิน และ ระหว่างผู้ประเมินมากที่สุดคือ วิธีการวัดมุมความโค้งกระดูกสันหลังแบบคอบบ์โดยมีความน่าเชื่อถือของตัวผู้ประเมินมากกว่าระหว่างผู้ประเมิน ควรใช้วิธีการวัดมุมความโค้งกระดูกสันหลังแบบคอบบ์ในการวัดของตัวผู้ประเมินจะให้ผลลัพธ์ที่มีความน่าเชื่อถือมากที่สุด

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CHAPTER I
INTRODUCTION

1.1 Background and Statement of Problems

Spine structure is strong, responsible for the protection of the spinal cord. It also served catch of the back muscles and connects to other important bones of the body. A general condition of spinal disease is crooked spine (Scoliosis) and age-related degeneration (Spondylosis). Scoliosis is a general condition of spinal disease and abnormal curvature of the spine. Spondylosis is an age-related degeneration. Scoliosis is a curvature deformity of spine in the left and the right. Further, it may be twisted or rotated out of the original spine line through some cases may be congenital disorders, or degeneration process, including crook spine (Kyphosis). The compression of cervical and high loaded tendons can cause back pain which is affected atrophy and destruction of tissues [1], [2]. The Spondylosis usually appears in increasing age to be significantly associated with degenerative of spine. Scoliosis and Spondylosis prevalence rise with both sexes of any age and differences in symptom. The main factor of spinal pain and Spondylosis are gender, age, and body mass index (BMI). Generally, it can be found in elderly and elevated BMI patients [3]. Because an increase or decrease in the curvature of spine that may result with force on the vertebral column depending on the curve that supports to the entire body weight. The spinal curvature can crowd or compress the spinal structures and become a lumber pain in which there is a sideways curvature of the spine [1]. According to an X-ray treatment, the radiographic is essential to quantify the spinal deformity for an angular measurement. The reliability result can lead the way to a suitable case for treatment. The aim of this study is to evaluate the reliability of measurements spinal curvature.

1.2 Objective of Study

The aim of this study are compared with each value in terms evaluate the reliability and difference of three methods Cobb, Ferguson and Polynomial for spinal curvature measurement techniques.

1.3 Scope of Work

In this study is examined by 3 graduate students who trained for spine landmarks and the anteroposterior radiographic 2D with spinal patients of Lerdsin hospital. The 30 photos are sampled as the complete sharpness of the edge lumbar vertebrae (L1 - L5) during on years 2004 - 2011.

1.4 Results

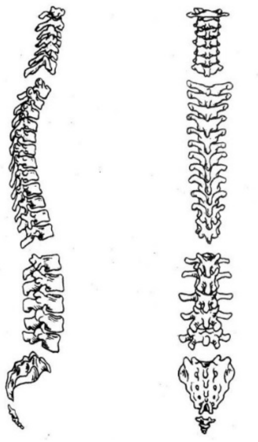
Measured between individuals (Inter Correlation) and measured in a person repeatedly (Intra Correlation) to measure and evaluate the curvature of the spine. Intraclass correlation coefficient (ICC) is used to calculate the inter-rater reliability (ICC model 2, 1) and intra-rater reliability (ICC model 3, 1). The statistical analysis shows that the intra-rater reliabilities of Ferguson, Cobb and Polynomial are 0.968, 0.950 and 0.910, respectively. In similarity, their inter-rater reliabilities are 0.477, 0.659 and 0.407 respectively. The statistical analysis of sample paired t-test to test the difference of the angles by measuring spinal curvature shown that the difference between intra-rater and inter-rater Ferguson and Polynomial the means is not statistically significant ($p>0.05$). And we found significant difference between intra-rater and inter-rater in other method the means is statistically significant ($p<0.05$).

CHAPTER II
LITERATURE REVIEW

The purpose in this study is to assess intra-rater and inter-rater reliability of 3 methods for measuring spinal curvature in anteroposterior radiograph 2D view (AP view) shown in figure 2.2. Three methods i.e. Cobb, Ferguson and Polynomial are compared with each value in terms of reliability. And compared 3 methods the difference is statistically significant. As expected, significant correlations were present between the relative corrections of methods for measuring spinal curvature. Must have knowledge and understand of the spine. e.g. anatomy of the spine, elements of the spine, vertebrae, diseases of the spine, Kyphosis, Spondylolisthesis and spinal deformity determination. And how to measuring curvature of the spine from x-ray radiation each method. The basic equations used in the calculation to adapt the procedure results in a way to measure the curvature of the spine. And statistical analysis to analyze the reliability and the difference of the results compared to the existing methods of how to measure the application including related research.

2.1 Anatomy of the Spine

The basic of spine is made of 33 individual bones stacked one on top of the other. Ligaments and muscles connect the bones together and keep them aligned. The spinal column provides the main support for body of human, allowing you to stand upright, bend, and twist. Protected deep inside the bones, the spinal cord connects body to the brain, allowing movement of arms and legs. Strong muscles and bones, flexible tendons and ligaments, and sensitive nerves contribute to a spine. Keeping spine healthy is vital if want to live an active life without back pain [4].



Lateral View AP View

Figure 2.1 Spinal in 2D images Lateral view and Anteroposterior view [5].

2.1.1 Vertebrae

The vertebrae are the 33 individual bones that interlock with each other to form the spinal column. The vertebrae are numbered and divided into regions is cervical, thoracic, lumbar, sacrum, and coccyx (Figure 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 [6].

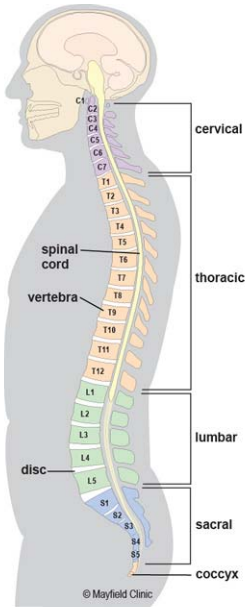


Figure 2.2 The five regions of the spinal column [6].

2.1.1.1 Cervical vertebrae

The cervical spine has 7 pieces, called C1-C7 in the neck. Served the spine associated with the movement of the neck and head. The first cervical vertebra (C1) is called the atlas. The Atlas is ring-shaped and it supports the skull. C2 is called the Axis. It is circular in shape with a blunt peg-like structure that projects upward into the ring of the Atlas. Together, the Atlas and Axis enable the head to rotate and turn. The other cervical vertebrae (C3 through C7) are shaped like boxes with small spinous processes (finger-like projections) that extend from the back of the vertebrae [4].

2.1.1.2 Thoracic vertebrae

Thoracic Spine with 12 pieces of the T1-T12 in the chest and there is a special point for the skeletal ribs of the chest cavity. In addition to longer spinous processes, rib attachments add to the thoracic spine’s strength. These structures make the thoracic spine more stable than the cervical or lumbar regions. In addition, the rib cage and ligament systems limit the thoracic spine’s range of motion and protect many vital organs [4].

2.1.1.3 Lumber vertebrae

Lumbar spine with 5 pieces called L1-L12 in the waist and sized to support the weight of the upper body. The island is part of the muscles of the abdominal wall at the back as well. Each structural element of a lumbar vertebra is bigger, wider and broader than similar components in the cervical and thoracic regions. The lumbar spine has more range of motion than the thoracic spine, but less than the cervical spine. The lumbar facet joints allow for significant flexion and extension movement but limit rotation [5].

2.1.1.4 Sacral vertebrae and coccygeal vertebrae

Spine small of or buttocks and coccyx bone pieces together as one piece, which is attached to the pelvis (pelvic bone) will be opening (sacral foramina) for the passage of nerves. To the pelvic area and legs and coccyx (Coccygealvertebrae), a triangular bone at the bottom of the spine [4].

2.1.2 Elements of the Spine

The elements of the spine are designed to protect the spinal cord, support the body and facilitate movement [5].

2.1.2.1 Intervertebral Disc

Between the spinal vertebrae are discs, which function as shock absorbers and joints. They are designed to absorb the stresses carried by the spine while allowing the vertebral bodies to move with respect to each other. Each disc consists of a strong outer ring of fibers called the annulus fibrosis, and a soft center called the nucleus pulposus as seen in Figure 2.3. The outer layer (annulus) helps keep the disc's inner core (nucleus) intact. The annulus is made up of very strong fibers that connect each vertebra together. The nucleus of the disc has a very high water content, which helps maintain its flexibility and shock-absorbing properties. Intervertebral discs (purple) are made of a gel-filled center called the nucleus and a tough fibrous outer ring called the annulus. The annulus pulls the vertebral bodies together against the resistance of the gel-filled nucleus [4].

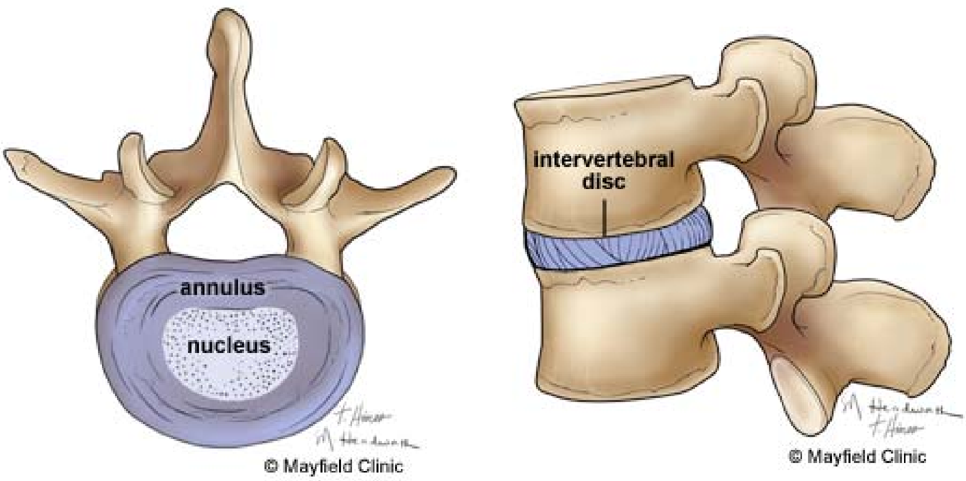


Figure 2.3 Intervertebral discs (purple) [6].

2.1.2.2 Facet Joint

The facet joints connect the bony arches of each of the vertebral bodies. There are two facet joints between each pair of vertebrae, one on each side. Facet joints connect each vertebra with those directly above and below it, and are designed to allow the vertebral bodies to rotate with respect to each other [4].

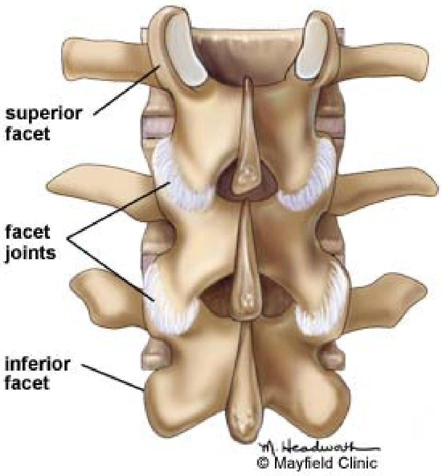


Figure 2.4 The superior, facet joints and inferior facets [6].

2.1.2.3 Neural Foramen

The neural foramen is the opening through which the nerve roots exit the spine and travel to the rest of the body. There are two neural foramen located between each pair of vertebrae, one on each side. The foramen creates a protective passageway for the nerves that carry signals between the spinal cord and the rest of the body [4].

2.1.2.4 Spinal Cord and Nerves

The spinal cord extends from the base of the brain to the area between the bottom of the first lumbar vertebra and the top of the second lumbar vertebra. The spinal cord ends by diverging into individual nerves that travel out to the lower body and the legs. Because of its appearance, this group of nerves is called the cauda equina - the Latin name for “horse’s tail.” The nerve groups travel through the spinal canal for a short distance before they exit the neural foramen. The spinal cord is covered by a protective membrane called the dura mater, which forms a watertight sac around the spinal cord and nerves. Inside this sac is spinal fluid, which surrounds the spinal cord. The nerves in each area of the spinal cord are connected to specific parts of the body. Those in the cervical spine, for example, extend to the upper chest and arms; those in the lumbar spine the hips, buttocks and legs. The nerves also carry electrical signals back to the brain, creating sensations. Damage to the nerves, nerve roots or spinal cord may result in symptoms such as pain, tingling, numbness and weakness, both in and around the damaged area and in the extremities [4].

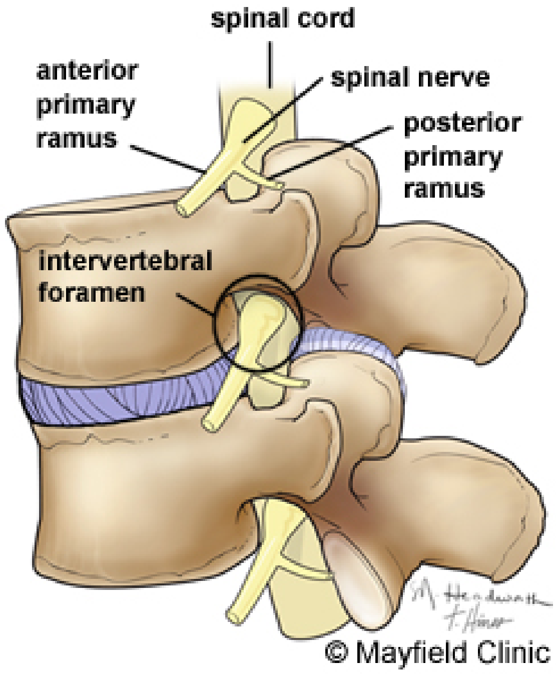


Figure 2.5 Spinal nerves [6].

2.1.2.5 Spinal muscles

The Spinal muscles and Nervous has low effect to cause for diseases of the spine, but is an important of spine. The muscular system of the spine is complex, with muscles has an important roles. The primary function of the muscles is to support and stabilize the spine. Specific muscles are associated with movement of parts of the anatomy. Thus the muscles that closely surround the bones of the spine are important for maintaining posture and helping the spine to carry the loads created during activity.

2.2 Diseases of the spine

The spine is the central axis of the fuselage structure. And also related to the muscular and nervous. Disorder or disease to the spinal cord are important in significantly medical. This disorder can be congenital or can be caused by disorders of the muscles and bones. Or accidental Examples of disorders of the spine, causing curvature of the spine.

2.2.1 Kyphosis

Kyphosis refers to the normal convex curvature of the spine as it occurs in the thoracic and sacral regions. Inward concave curving of the cervical and lumbar regions of the spine is called lordosis. The term kyphosis can also be used to describe excessive kyphosis or overcurvature when it is also known as hyperkyphosis. Kyphosis can be called roundback or Kelso's hunchback. It can result from degenerative diseases such as arthritis; developmental problems, most commonly Scheuermann's disease; osteoporosis with compression fractures of the vertebrae, or trauma. A normal thoracic spine extends from the 1^{st} to the 12^{th} vertebra and should have a slight kyphosis ranging from 20° to 45°. When the "roundness" of the upper spine increases past 45° it is called "hyperkyphosis". Scheuermann's kyphosis is the most classic form of hyperkyphosis and is the result of wedged vertebrae that develop during adolescence. The cause is not currently known and the condition appears to be multifactorial and is seen more frequently in males than females [7].

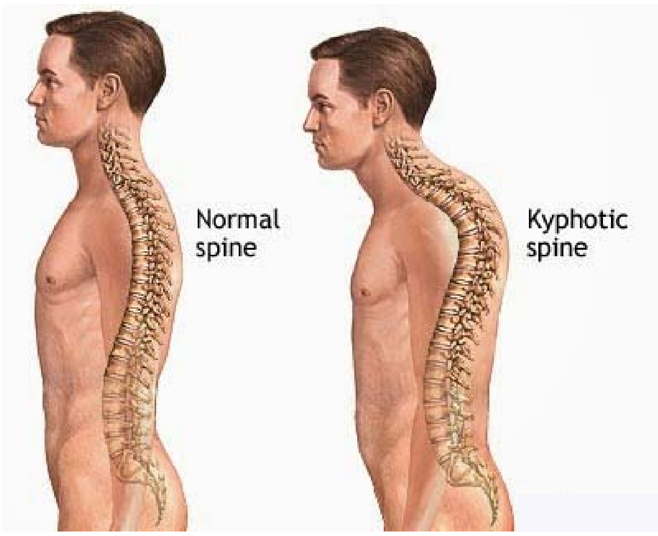


Figure 2.6 Spine images normal spine and kyphosis spine [8].

In the sense of a deformity, it is the pathological curving of the spine, where parts of the spinal column lose some or all of their lordotic profile. This causes a bowing of the back, seen as a slouching posture.

While most cases of kyphosis are mild and only require routine monitoring, serious cases can be debilitating. High degrees of kyphosis can cause severe pain and discomfort, breathing and digestion difficulties, cardiovascular irregularities, neurological compromise and, in the more severe cases, significantly shortened life spans. These types of high-end curves typically do not respond well to conservative treatment and almost always warrant spinal fusion surgery, which can successfully restore the body's natural degree of curvature. The Cobb angle is the preferred method of measuring kyphosis [7].

2.2.2 Spine fractures

The most common fractures of the spine occur in the thoracic (midback) and lumbar spine (lower back) or at the connection of the two (thoracolumbar junction). These fractures are typically caused by high-velocity accidents, such as a car crash or fall from height. Because of the energy required to cause these spinal fractures, patients often have additional injuries that require treatment. The spinal cord may be injured, depending on the severity of the spinal fracture. Fractures of spine are usually caused by high-energy trauma, such as: car crash, fall from height, sports accident, violent act, etc. [9].

There are different types of spinal fractures. Doctors classify fractures of the thoracic and lumbar spine based upon pattern of injury and whether there is a spinal cord injury. Classifying the fracture patterns can help to determine the proper treatment. The three major types of spine fracture patterns are flexion, extension, and rotation.

Flexion Fracture Pattern. Compression fracture. While the front (anterior) of the vertebra breaks and loses height, the back (posterior) part of it does not. This type of fracture is usually stable and rarely associated with neurologic problems.

Extension Fracture Pattern. Flexion/distraction (Chance) fracture. The vertebra is literally pulled apart (distraction). This can happen in accidents such as a head-on car crash, in which the upper body is thrown forward while the pelvis is stabilized by a lap seat belt.

Rotation Fracture Pattern. Transverse process fracture. This fracture is uncommon and results from rotation or extreme sideways (lateral) bending, and usually does not affect stability.

2.2.3 Spondylolisthesis

The word spondylolisthesis is a forward slip of one vertebra (one of the 33 bones of the spinal column) relative to another. Spondylolisthesis usually occurs towards the base of your spine in the lumbar area [10].

Figure 2.7 Spine images of spondylolisthesis [11].

Types of Spondylolisthesis different types of spondylolisthesis may be caused in a various ways. Some examples are:

- Developmental Spondylolisthesis: This type of spondylolisthesis may exist at birth, or may develop during childhood, but generally is not noticed until later in childhood or even in adult life.

- Acquired Spondylolisthesis: Acquired spondylolisthesis can be caused in one of two ways with all of the daily stresses that are put on a spine, such as carrying heavy items and physical sports. And single or repeated force being applied to the spine, such as the impact of falling off a ladder and landing on your feet.

Spondylolisthesis can be described according to its degree of severity. One commonly used description grades spondylolisthesis, with grade 1 being least advanced, and grade 5 being most advanced. The spondylolisthesis is graded by measuring how much of a vertebral body has slipped forward over the body beneath it, Grade 1 : 25% of vertebral body has slipped forward, Grade 2 : 50%, Grade 3 : 75%, Grade 4 : 100%, Grade 5 Vertebral body completely fallen off [10].

2.2.4 Spondylosis

Spondylosis (spinal osteoarthritis) is a degenerative disorder that may cause loss of normal spinal structure and function. Although aging is the primary cause, the location and rate of degeneration is individual. The degenerative process of spondylosis may affect the cervical (neck), thoracic (mid-back), or lumbar (low back) regions of the spine. Spondylosis often affects the following spinal elements [11].

Intervertebral Discs As people age, certain biochemical changes occur affecting tissue found throughout the body. In the spine, the structure of the intervertebral discs (annulus fibrosus, lamellae, nucleus pulposus) may be compromised. The annulus fibrosus is composed of 60 or more concentric bands of collagen fiber termed lamellae. The nucleus pulposus is a gel-like substance inside the intervertebral disc encased by the annulus fibrosus. Collagen fibers form the nucleus along with water and proteoglycans. The degenerative effects of aging can weaken the annulus fibrosus' structure, causing the 'tire tread' to wear or tear. The water content of the nucleus decreases with age affecting its ability to rebound following compression (shock absorbing quality). The structural alterations from degeneration may decrease disc height and increase the risk for disc herniation.

Facet Joints. The facet joints are also termed zygapophyseal joints. Each vertebral body has four facet joints that work like hinges. These are the articulating (moving) joints of the spine that enable extension, flexion, and rotation. Like other joints, the bony articulating surfaces are coated with cartilage. Cartilage is a special type of connective tissue that provides a self-lubricating and low-friction gliding surface. Facet joint degeneration causes loss of cartilage and formation of osteophytes (bone spurs). These changes may cause hypertrophy or osteoarthritis, also known as degenerative joint disease.

Bones and Ligaments Osteophytes (bone spurs) may form adjacent to the end plates, which may compromise blood supply to the vertebra. Further, the end plates may stiffen due to sclerosis; a thickening or hardening of the bone under the end plates. Ligaments are bands of fibrous tissue connecting spinal structures (vertebrae) and protect against the extremes of motion (hyperextension). However, degenerative changes may cause ligaments to lose some of their strength. The ligamentum flavum (a primary spinal ligament) may thicken and buckle posteriorly (behind) toward the dura mater (a spinal cord membrane) [11].

2.3 Spinal deformity determination.

The most commonly use 2 methods for spinal deformity determination. The invasive technique is a radiographic analysis such as Cobb's method, which has high accuracy of popular measurement. The other one is non-invasive techniques, which measured using Flexicurve [12], [13]. The invasive technique is a radiographic analysis such as Cobb's method. The radiographic measurement is performed in AP-View and lateral view shown in Figure2.8. There is primarily focused on the measurement of Scoliosis. The other one is non-invasive techniques, which measured using Flexicurve. There is primarily focused on the measurement of Kyphosis shown in Figure 2.9.

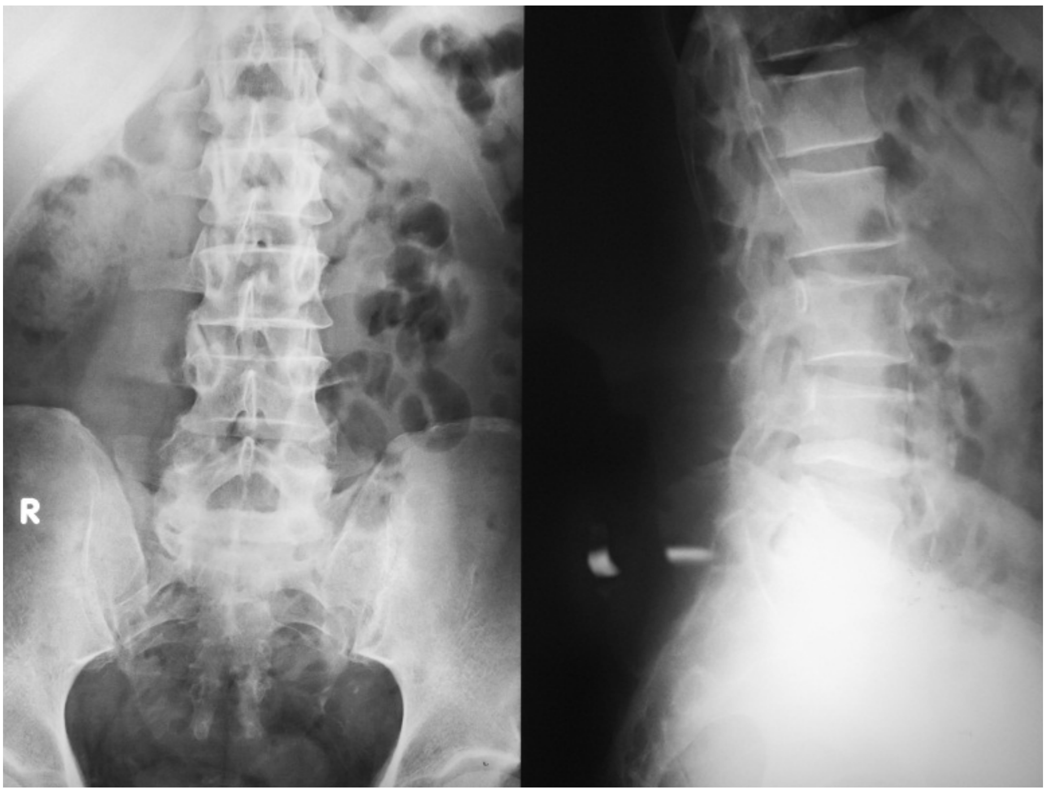


Figure 2.8 Invasive techniques: Radiographic analysis

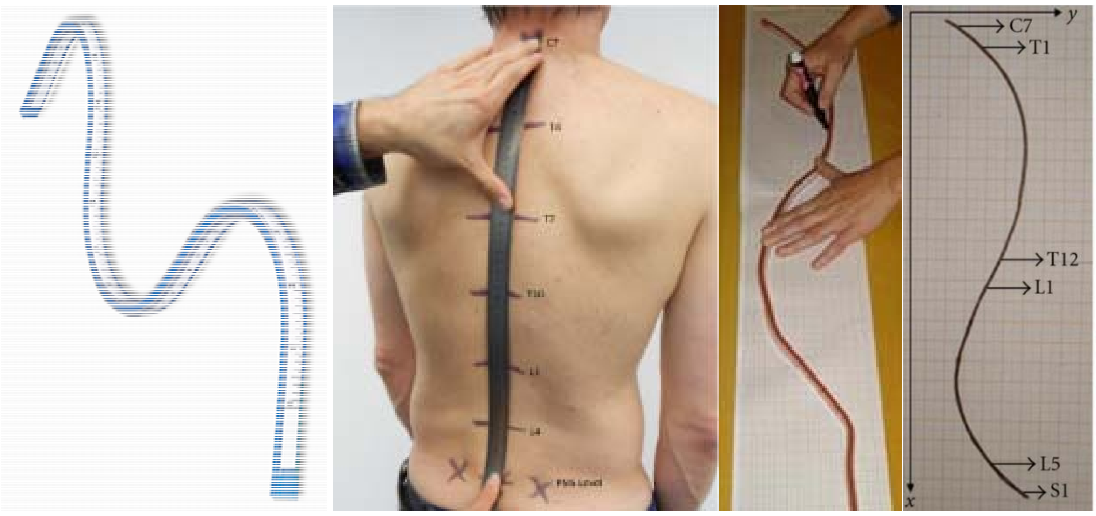


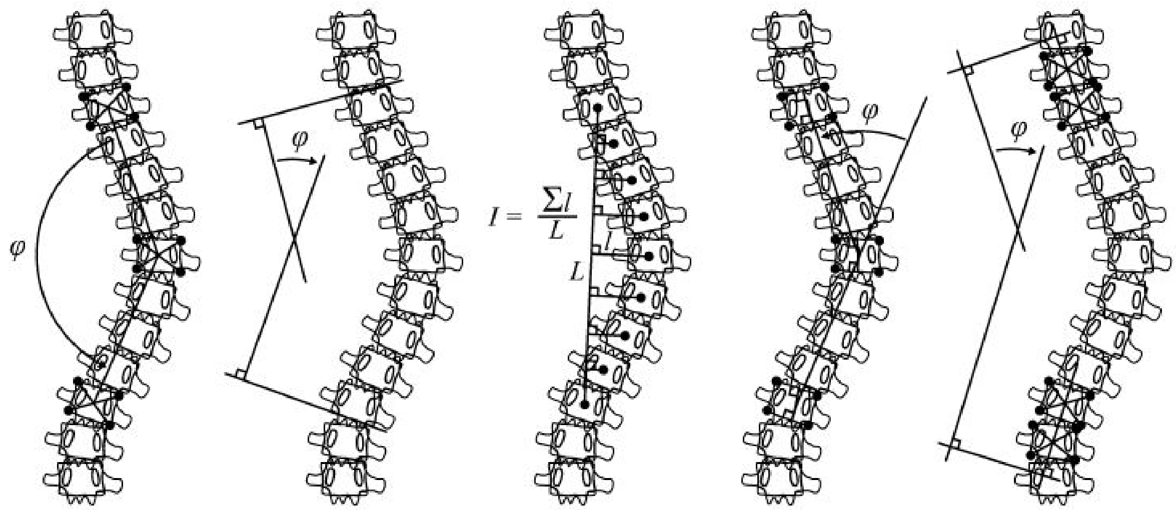
Figure 2.9 Non-invasive techniques: Flexicurve [14], [15].

2.4 Evaluation of spinal curvature in 2D images.

The evaluation of spinal curvature in the anposterior view is the measurement of scoliosis. Anteroposterior view cross-sections show a scoliosis deformity. The methods for evaluation of spinal curvature were developed first for anteroposterior view radiographic images.

Ferguson and Cobb is the earliest methods. The both methods are variability and unreliability is relatively high. The Cobb angle reflects changes in the end vertebrae inclination rather than changes within the spinal curvature. Scoliosis Research Society (SRS) as the standard method for quantification of scoliotic deformities was adopted in 1966, resulting in being nowadays the Cobb method still the most common method for the evaluation of spinal curvature [3].

Ferguson [16]. The method evaluates the deformity by the angle between the two straight lines that connect the centers of the end vertebrae with the center of the apical vertebra (Figure 2.10a). Cobb [17]. The method evaluates the deformity by the angle between the two straight lines that are tangent to the superior and inferior endplate of the superior and inferior end vertebra, respectively (Figure 2.10b). Greenspan index [18]. The method evaluates the deformity by allows to measure the deformity at small spinal curvatures. Vertebrae are connected to form the spinal line, orthogonally to which lines are drawn from the center of each vertebra in the spine curve The sum of the lengths of these additional lines divided by the length of the spinal line represents the index of the deformity (Figure 2.10c). Diab et al [19]. The method consisted of identifying the four vertebral corners of the apical and end vertebrae. The centers of vertebral bodies were found at the intersection of lines orthogonal to the superior and inferior endplates. The centers of both end vertebrae were then connected with the center of the apical vertebra, forming two intersecting lines that defined the angle of the deformity (Figure 2.10d). Centroids method [20]. The method evaluates the deformity by connecting the opposite corners of two vertebral bodies at both ends of the measured spine curve. The curvature angle was then defined as the angle between the straight lines through the two top and through the two bottom vertebral centroids. The measurements in radiographic showed that the centroid angle revealed smaller curvatures (Figure 2.10e).



a. b. c. d. e.

Figure 2.10 Evaluation of coronal spinal curvature in 2D images (AP-View) [21].

2.5 Landmark point

In determining the value of the angle in the lateral view and anteroposterior view of the spine are set at the edge of the spine, which can be defined in a variety of formats, such as 4 points, 6 point, 9 points, 36 points and the other (Shown in figure 2.11 and figure 2.12) [22]. Measuring the curvature of the spine by define point for reduce the error and increased accuracy, because the point is the basic of the measurement the angle for the values of the formula to use in the next. Which point up to the discretion of the judge, technical expertise or experience of the individual (Specialists, Doctors) that there must be a point at any location, or to use any formula to calculate the angle of the spine.

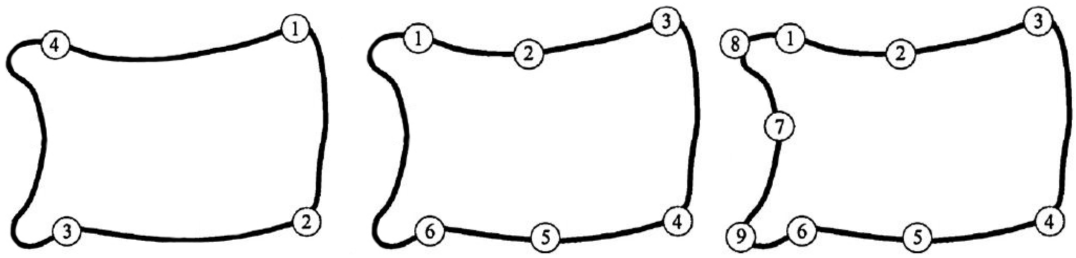


Figure 2.11 Landmark points of a vertebra. 4points, 6points, 9points [22].

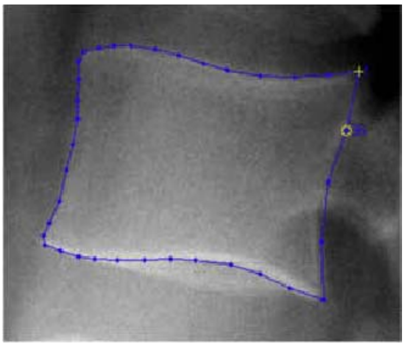


Figure 2.12 Landmark points of a vertebra 36 points [22].

Landmark points of a vertebra 4 points (Figure 2.13) shows the rim contours lateral radiographic view. Posterior are two dorsal corners (Point 3 and 4). Points 2 and 5 define the medial line. Point 7 defines the median height point. Points 8 and 9 define the extreme protrusions of anterior osteophytes, which may or may not be present. Landmark points of a vertebra 6 points shows the endplate rim contours, which can be identified in a lateral radiographic view. There are two dorsal corners (3 and 4). Points 2 and 5 define the medial line. Landmark points of a vertebra 9 points shows the endplate rim contours, which can be identified in a lateral radiographic view. There are two dorsal corners (3 and 4). Points 2 and 5 define the medial line. Point 7 defines the median height point. Points 8 and 9 define the extreme protrusions of anterior osteophytes, which may or may not be present [3].

2.6 Statistical analysis

No matter what, any comparison must start from the formulation of a statistical hypothesis and end with statistical testing to answer the hypothesis of that research, which includes various methods depending on the factors of the data such as the type of data, the continuity of the data, the number of data pieces, etc.

2.6.1 Intra- class and inter-class correlation coefficient

In statistics, the intra-class correlation coefficient (ICC) is a descriptive statistic that can be used when quantitative measurements are made on units that are organized into groups. It describes how strongly units in the same group resemble each other. While it is viewed as a type of correlation, unlike most other correlation measures it operates on data structured as groups, rather than data structured as paired observations [23].

The intra-class correlation is commonly used to quantify the degree to which individuals with a fixed degree of relatedness resemble each other in terms of a quantitative trait. Another prominent application is the assessment of consistency or reproducibility of quantitative measurements made by different observers measuring the same quantity.

2.6.1.1 Relationship to Pearson's correlation coefficient

In terms of its algebraic form, Fisher's original ICC is the ICC that most resembles the Pearson correlation coefficient. One key difference between the two statistics is that in the ICC, the data are centered and scaled using a pooled mean and standard deviation, whereas in the Pearson correlation, each variable is centered and scaled by its own mean and standard deviation. This pooled scaling for the ICC makes sense because all measurements are of the same quantity. For example, in a paired data set where each "pair" is a single measurement made for each of two units rather than two different measurements for a single unit, the ICC is a more natural measure of association than Pearson's correlation [23].

2.6.1.2 Use in assessing conformity among observers

The ICC is used to assess the consistency, or conformity, of measurements made by multiple observers measuring the same quantity [24]. An important aspect of this problem is that there is both inter-observer and intra-observer variability. Inter-observer variability refers to systematic differences among the observers.

2.6.1.3 The type of Intra-class correlation (ICC)

The types of ICC are divided into two types as follows [24].

- Single measure reliability

Individual ratings constitute the unit of analysis. That is, single measure reliability gives the reliability for a single judge's rating.

- Average measure reliability. The mean of all ratings is the unit of analysis. That is, average measure reliability gives the reliability of the mean of the ratings of all raters. Use this if the research design involves averaging multiple ratings for each item across all raters.

2.6.1.4 The models of Intra-class correlation (ICC)

The models of ICC are divided into three types as follows [24].

- One-way random effects model

Raters are conceived as being a random selection of possible raters, who rate all subjects of interest. This assumption is used in the example output above.

- Two-way random effects model

Raters are conceived as being a random selection from among all possible raters, and subjects are conceived as being a random factor too. Raters rate all subjects chosen at random from a pool of subjects and it is known how each judge rated each subject. The ICC is interpreted as the proportion of subject plus rater variance that is associated with differences among the scores of the subjects. The ICC is interpreted as being generalizable to all possible raters.

- Two-way mixed model

All raters of interest rate all subjects, which are a random sample. This is a mixed model because the judges are seen as a fixed effect and the subjects are a random effect. The ICC coefficients will be identical to the two-way random effects model, but the ICC is interpreted as not being generalizable beyond the given raters.

Table 2.1 Different types of ICC

Shrout and Fleiss convention (ICC type)	Name in SPSS
ICC(1,k)	One-way random average measures
ICC(1,1)	One-way random single measures
ICC(3,k)	Two-way mixed average measures (Consistency/Absolute agreement)
ICC(3,1)	Two-way mixed single measures (Consistency/Absolute agreement)
ICC(2,k)	Two-way random average measures (Consistency/Absolute agreement)
ICC(2,1)	Two-way random single measures (Consistency/Absolute agreement)

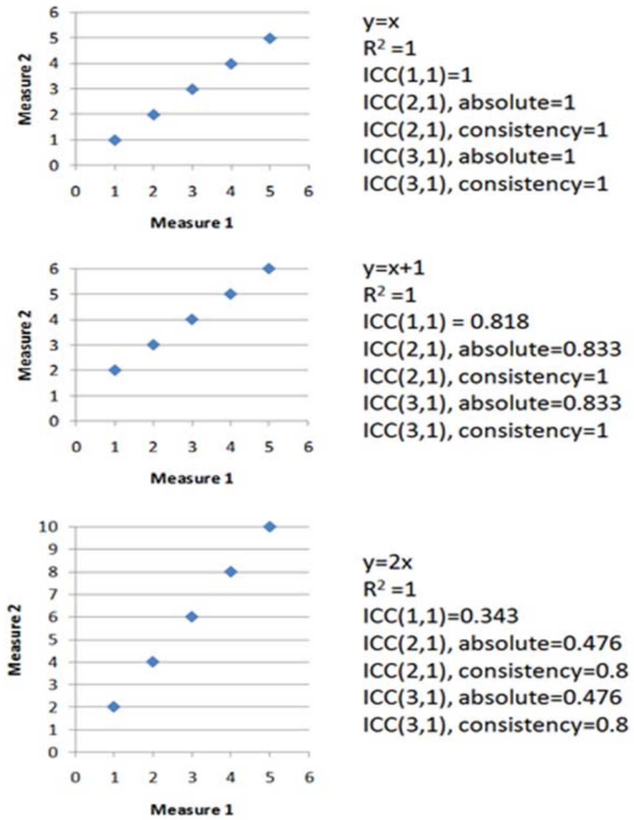


Figure 2.13 Results from different ICCs applied to 3 pairs of measurements [25].

2.6.2 Comparison of Means

Comparison of the means use the t-test is a statistical method of both groups of data, which includes:

2.6.2.1 One sample t-test

The one-sample t test compares two average values: the first generated from sample compared with a second known from another study or in the population. For example, if you assessed self-esteem among Latino elementary school children using the Rosenberg Self-Esteem Inventory, you could compare that average with another self-esteem average based on the Rosenberg, for example, one found in a published article about mainstream elementary school children.

2.6.2.2 Independent t-test

The independent t-test, also called the two sample t-test or student's t-test, is an inferential statistical test that determines whether there is a statistically significant difference between the means in two unrelated groups. For example, an independent samples t test would be used to assess the difference in income (measured in raw dollars) by gender (defined as male and female). The key to why it is called "independent" is because the two subcategories in the categorical variable (male and female) are operationally defined to be mutually exclusive and exhaustive: a participant according to this definition must either be male or female (thus mutually exclusive) and no other subcategory for gender is allowable (thus exhaustive).

2.6.2.3 Paired-samples t-test

The paired-samples t-test (also called the dependent t-test or paired t-test) compares the means of two related groups to detect whether there are any statistically significant differences between these means. For example, a dependent samples t-test would be used to evaluate the improvement in depression levels, measured on a continuous scale, of a group involved in therapy at pre-test (before intervention) and at post-test (after intervention). From measure the curvature of the spine that has been studied. Found the calculated values of the high statistical discrepancy. Propose method to measure the reliability of the results is maximal. Intra-class correlation coefficient (ICC) was used for statistical evaluation. And method to measure the difference is statistically significant of the results. Paired samples t test was used for statistical evaluation.

CHAPTER III
MATERIALS AND METHOD

3.1 The research experimental design

In this study is to assess intra-rater and inter-rater reliability of 3 methods for measuring spinal curvature in anteroposterior radiograph 2D view (AP view). Three methods i.e. Cobb, Ferguson and Polynomial are compared with each value in terms of reliability. And compared 3 methods the difference is statistically significant.

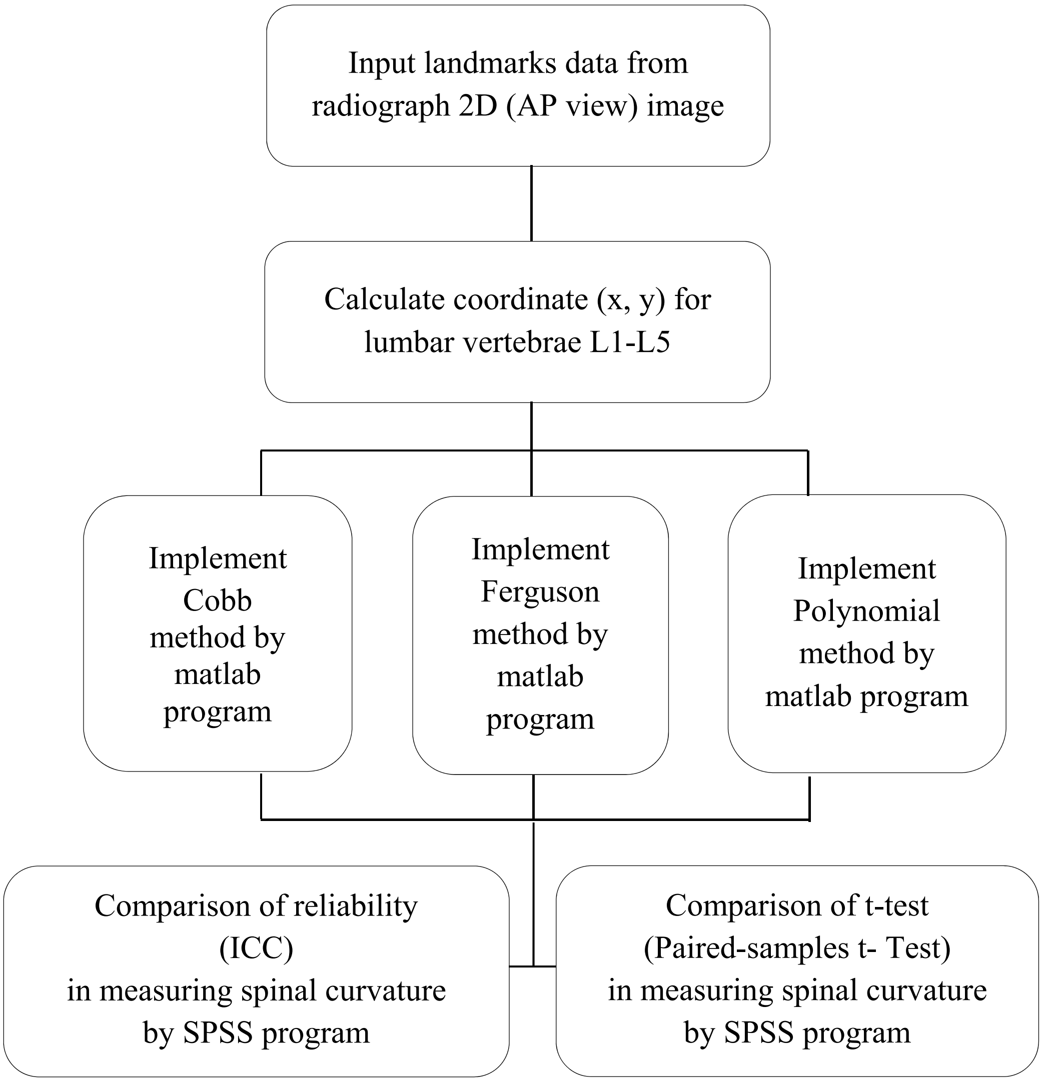


Figure 3.1 A comparison of reliability process for measurement spinal curvature.

In this research, four distances transform-based, a comparison of reliability in measuring spinal curvature process as shown in Figure 3.1. The first step of the process is input landmarks point in radiograph 2D (AP view) images. The second step of the process is calculating coordinate (x, y) of lumbar vertebrae (L1 - L5) from first step data. The third step of process is performing implement to Cobb, Ferguson, Polynomial methods, which three methods is measurements spinal curvature. The final step is to comparison of reliability in measuring spinal curvature using intra class correlation coefficient (ICC).

3.2 Radiograph 2D

Evaluation of anteroposterior radiograph 2D (AP-View) analysis exams which is difficult to define. For example, the photo of lumber vertebrae is unclear of the edge (L1 - L5) because it possible causes of errors in the measurement curvature of the spine from landmark point as shown in Figure 6. The clearly image of lumber vertebrae (L1 - L5) may reduce in significant error in curve evaluation as shown in Figure 3.2.

Figure 3.2 Anteroposterior radiograph 2D (AP view) are unclearly image

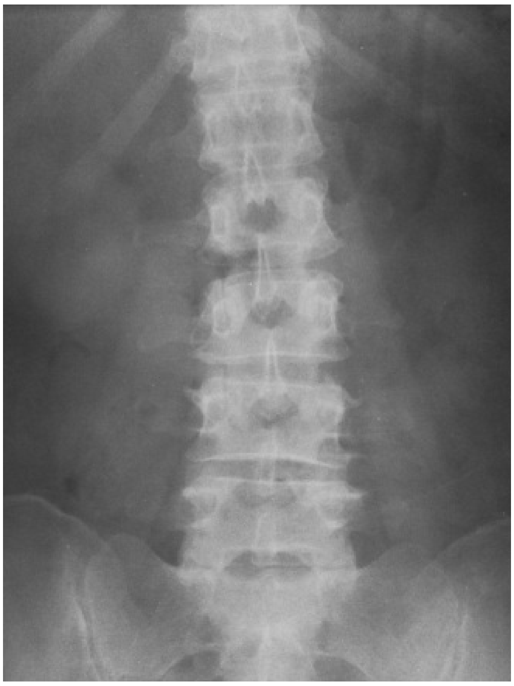


Figure 3.3 Example of anteroposterior radiograph 2D (AP view) are clearly image.

Figure 3.4 Sample of radiographic AP view.

In this study is examined by 3 graduate students who trained for spine landmarks and the anteroposterior radiographic 2D with spinal patients of Lerdsin hospital. The 30 photos are sampled as the complete sharpness of the edge lumbar vertebrae (L1 - L5) during on year 2004 - 2011.

3.3 Method

3.3.1 Landmark point

Landmark points of a vertebra. Shows the rim contours, anteroposterior radiographic view. Posterior are two dorsal corners (Point 1 and 2). Anterior are two forepart corners (Point 3 and 4) as shown in Figure 3.5. Determination color this is defined by the red, yellow, green and blue as shown in Figure 3.6.

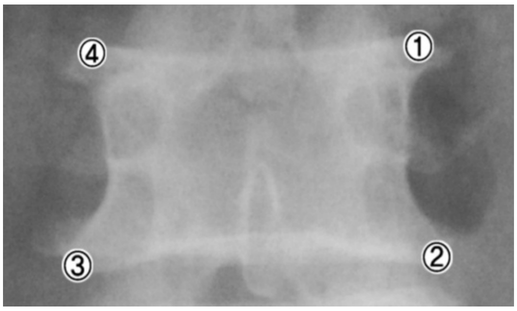


Figure 3.5 Landmark point of a vertebra

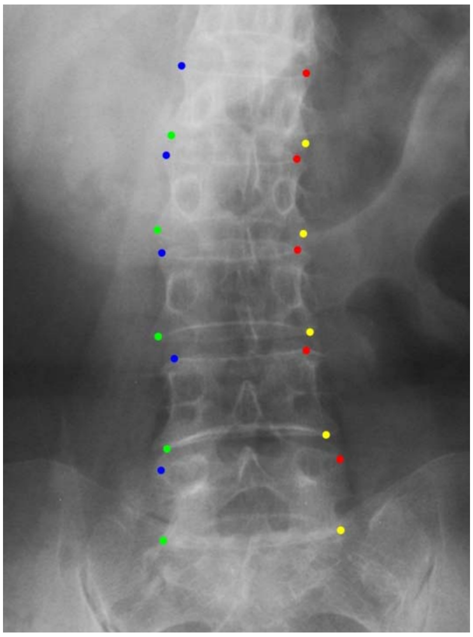


Figure 3.6 Example defined to measure the curvature of the spine.

Advantages are image processing program on Matlab can determine the position (x, y) to the position of each point. Flaws are not save time and make a mark hard and slow.

Prescriptive

- Posterior 1 = RGB RED
- Posterior 2 = RGB YELLOW
- Anterior 1 = RGB GREEN
- Anterior 2 = RGB BLUE

3.3.2 Calculate the curvature of the spine with other methods

Ferguson method

The method evaluates the deformity by the angle between the two straight lines that connect the centers of the end vertebrae with the center of the apical vertebra. This method identified in geometrically using 12 points. An angle to be defined properly at the intersection of line a and line b as shown in Figure 3.7.

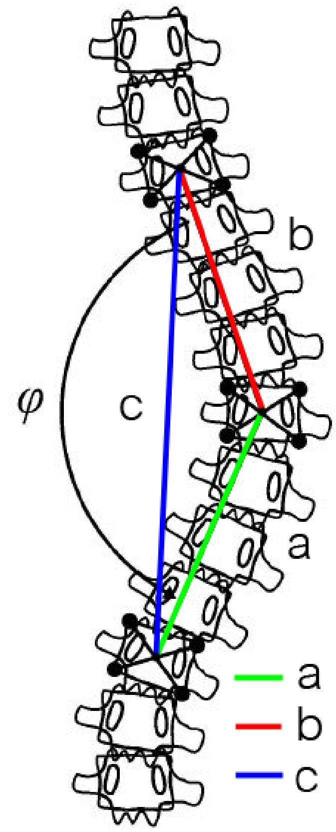


Figure 3.7 Ferguson method

Find the angle (φ)

$$\varphi = \cos^{-1}\left(\frac{a^2+b^2-c^2}{2ab}\right)$$

Cobb method

The method evaluates the deformity by the angle between the two straight lines that are tangent to the superior and inferior endplate of the superior and inferior end vertebra, respectively. This method identified an angle drawing lines by 4 points as shown in Figure 3.8.

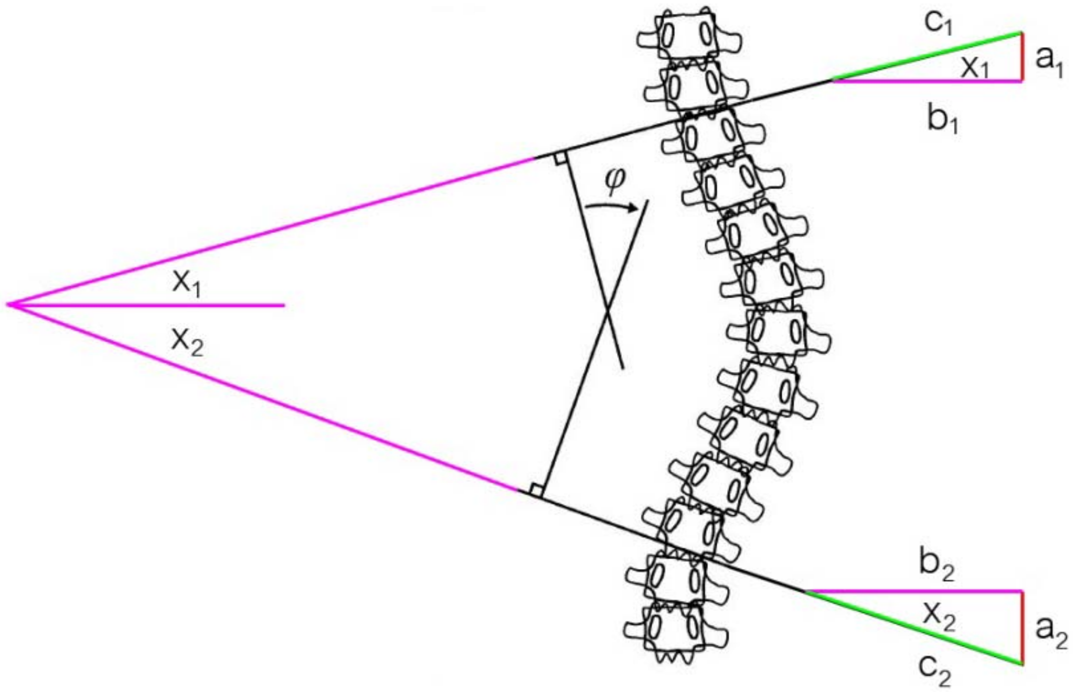


Figure 3.8 Cobb method

Find the angle (φ)

$$\varphi = (\sin^{-1}(\frac{a_1}{c_1})) + (\sin^{-1}(\frac{a_2}{c_2}))$$

3.3.3 Regression

Polynomial Method: The method evaluates the deformity by divided the edge of the lumbar vertebrae (L1 - L5) and 4 point for every single spine bones. Thus, the coordinates of spines possible create a polynomial equation with regression analysis. In this category, the second order of polynomial equation is determined an angular of the upper to the lower of spine bones. This method should identify 20 points as shown in Fig. 3.10 – 3.12.

A linear regression line has an equation of the form Y = a + bX, where X is the explanatory variable and Y is the dependent variable. The slope of the line is b, and a is the intercept (the value of y when x = 0). Multiple regression analysis is a technique to analyze the relationship of several variables (dependent variable) consisting of one variable, which is a quantitative variable or interval scale (interval/ratio scale) and ratio scale variables / parameters, many independent variables, which variable or group quantitative / qualitative. [10]

Multiple regression analysis has an equation of the form

$$Y = b_0 + b_1x_1 + b_2x_2 + \ldots + b_kx_k$$

Polynomial regression is the methodology used to construct the polynomial function for the data is distributed generally not in the form of a linear graph of the image [12].

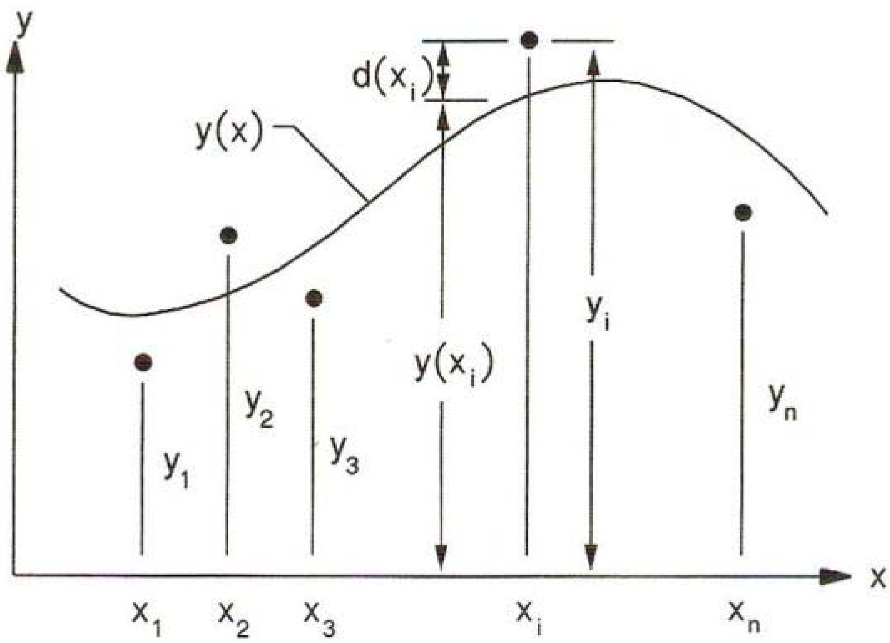


Figure 3.9 Polynomial regression

Polynomial regression has an equation of the form

$$Y = b_0 + b_1x + b_2x^2 + \ldots + b_nx^n$$

$b_0, b_1, b_2, \ldots, b_n$ is a constant determined from the condition that the polynomial equations generated this makes the average error is minimal.

$$E = \sum [y_i - (b_0 + b_1x + b_2x^2 + \cdots + b_nx^n)]^2$$

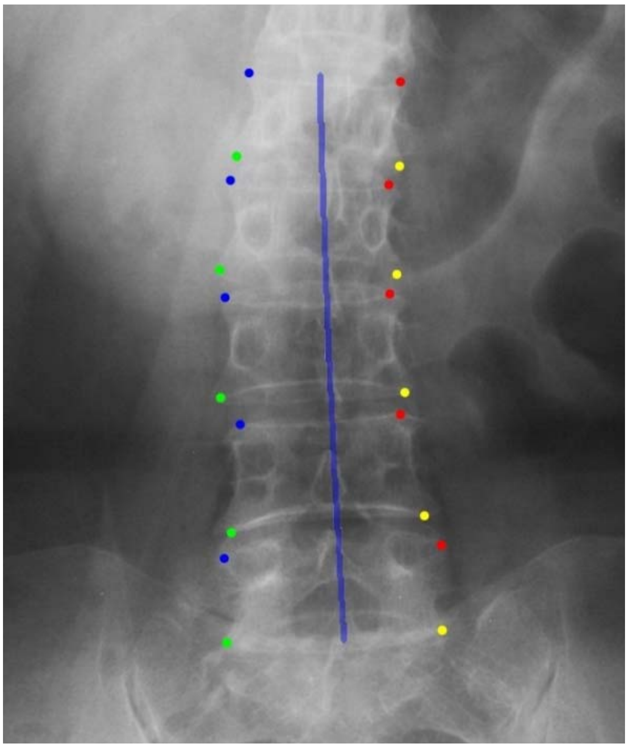


Figure 3.10 Polynomial Method AP-View

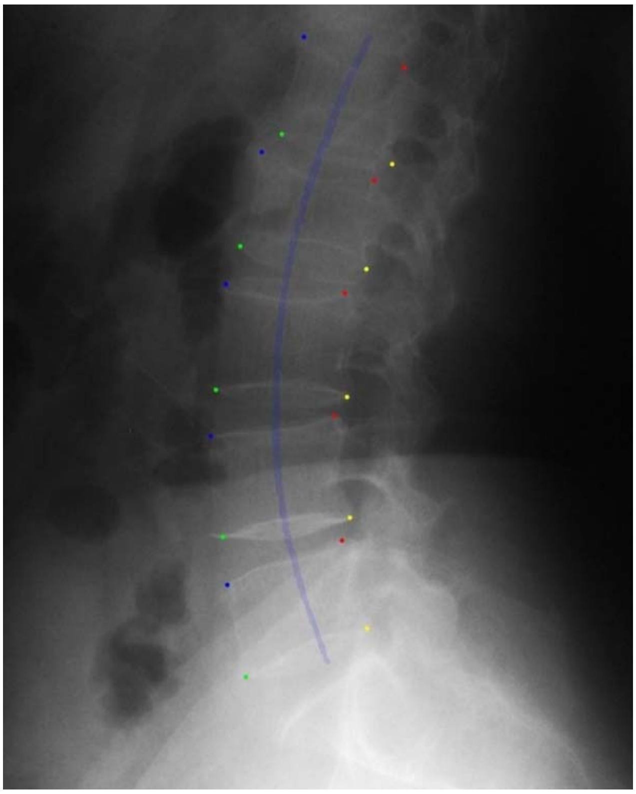


Figure 3.11 Polynomial Method Lateral View

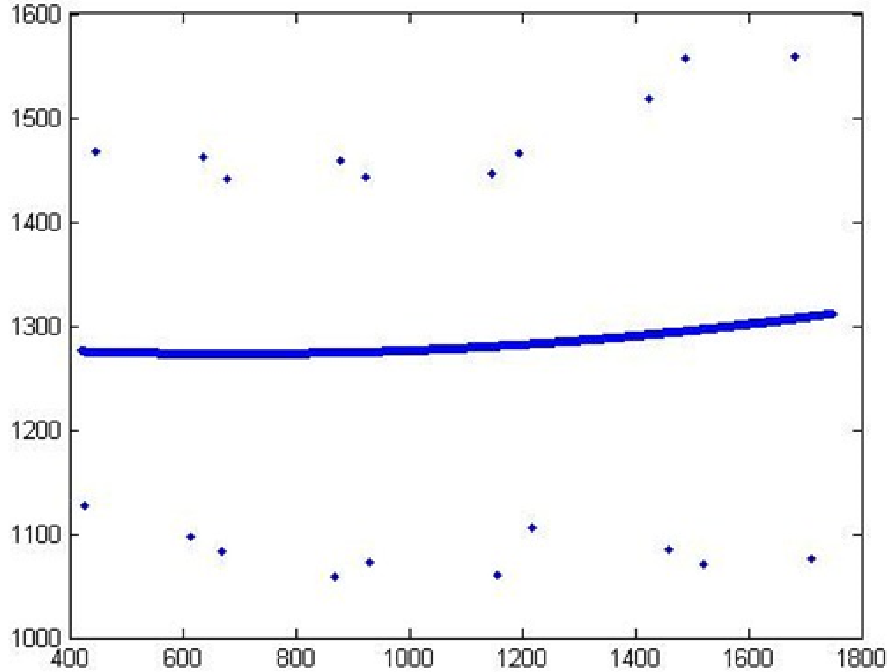


Figure 3.12 Polynomial Method AP-View by Matlab Program

3.3.4 Assessment

Intra- or inter-class correlation coefficient (ICC) was the value used as an indicator to measure the efficiencies of the accurately measure a curve by measuring the differences between intra- or inter-observer variability of the measurements for each methods include Ferguson method, polynomial method and Cobb method. In this research, use type of the Intra- or inter-class correlation coefficient (ICC) was single measure reliability and use the model were two-way random single measures and two-way mixed single measures. In values will display the curve of spinal at the measuring when compared to the assess intra and inter examiner reliability as measured by observer. The lesser the value, the more efficient the data processing was. It can be calculated according to the following equation [24].

Two-way random single measures or ICC (2, 1). It can be calculated according to the following equation:

$$ICC\ (2,1) = \frac{BMS - EMS}{BMS + (k-1)EMS + k(JMS - EMS)/n}$$

Two-way mixed single measures or ICC (3, 1). It can be calculated according to the following equation:

$$ICC\,(3,1) = \frac{BMS - EMS}{BMS + (k-1)EMS}$$

Where k was the number of raters rating each subjects, BMS was a between subjects mean square, EMS was a mean square expectations, JMS was the measures a value between raters, n is the number of subjects.

3.4 Tool

3.4.1 Program Adobe Photoshop CS5

Imaging applications used to mark the edge of the spine. Defined by the red, yellow, green and blue

3.4.2 Program Image J

Photo analysis program can be calculated coordinate of the spine. And can be measured in the landmark point. This can be found in the area such as square millimeters in the pixel values of the image.

3.4.3 Program MATLAB 7.10.0 (R2010a)

MATLAB Matrix Laboratory is software for the calculation and programming one that can cover. Which the research used the program MATLAB for development of the algorithm. Calculate angle of measuring spinal curvature. There are Cobb, Ferguson and Polynomial methods.

3.4.4 Program IBM SPSS Statistics 20

IBM SPSS Statistics is an integrated family of products that addresses the entire analytical process, from planning to data collection to analysis, reporting and deployment. You can find the specialized capabilities you need to increase revenue, outperform competitors, conduct research and make better decisions.

Which the research used the program IBM SPSS for calculates statistic. Intra-class correlation coefficient (ICC) was used for statistical evaluation. And method to measure the difference is statistically significant of the results. Paired samples t test was used for statistical evaluation.

CHAPTER IV
EXPERIMENTAL RESULT

4.1 Result of paired-samples t-test between each methods

The comparisons of statistically significant difference in measurements spinal curvature from anteroposterior radiograph 2D view (AP-View) are studied on 30 images of spinal patients Lerdsin hospital by 3 intra-observers. The calculations were 3 methods for measuring spinal curvature. Three methods are Cobb, Ferguson, and Polynomial method. As expected, significant correlations were present between the angles of 3 methods. This study shows a highly significant correlation between the intra-rater and inter-rater. Paired samples t-test was used for statistical evaluation. The level of significance was set at $p<0.05$

Table 4.1 Shows Paired Samples t-test between Methods of Intra-Rater

No.	Method	Round of measurements	Paired Differences			
			Mean	Std. Deviation	t value	p value
Pair 1	Ferguson	1-2	.05400	.72588	.407	.687
Pair 2	Ferguson	2-3	-.07633	.79261	-.527	.602
Pair 3	Ferguson	1-3	-.02233	.67986	-.180	.858
Pair 4	Cobb	1-2	.074333	1.350248	.302	.765
Pair 5	Cobb	2-3	-.165000	1.383453	-.653	.519
Pair 6	Cobb	1-3	-.09067	.96127	-.517	.609
Pair 7	Polynomial	1-2	.12667	1.30884	.530	.600
Pair 8	Polynomial	2-3	-.24467	1.24464	-1.077	.290
Pair 9	Polynomial	1-3	-.11800	1.29053	-.501	.620

In the statistical analysis of sample paired t-test to test the difference statistically significant of the angles by measuring spinal curvature, there are Ferguson, Cobb and polynomial methods. The comparison of assess intra examiner as measured by observer. The result of intra-rater is accurately measure a curve using 3 times per 1 image for observer. Significant correlation was present round of measurement results between round 1 and 2, round 2 and 3, round 1 and 3. The present study also shows comparison results of measuring spinal curvature by observer. The difference between the means is not statistically significant ($p>0.05$) as shown in Table 4.1.

Table 4.2 Shows Paired Samples t-test between Methods of Inter-Rater

No.	Method	Observer of measurements	Paired Differences			
			Mean	Std. Deviation	t value	p value
Pair 1	Ferguson	1-2	-.47533	2.70146	-.964	.343
Pair 2	Ferguson	2-3	.28333	2.92317	.531	.600
Pair 3	Ferguson	1-3	-.19200	2.82097	-.373	.712
Pair 4	Cobb	1-2	-1.47867	3.49472	-2.317	.028
Pair 5	Cobb	2-3	1.17800	4.05557	1.591	.122
Pair 6	Cobb	1-3	-.30067	2.55095	-.646	.524
Pair 7	Polynomial	1-2	-1.37200	3.70185	-2.030	.052
Pair 8	Polynomial	2-3	.88233	2.60011	1.859	.073
Pair 9	Polynomial	1-3	-.48967	2.97420	-.902	.375

In the statistical analysis of sample paired t-test to test the difference statistically significant of the angles by measuring spinal curvature, there are Ferguson, Cobb and polynomial methods. The comparison of assess intra examiner as measured by observers. The result of inter-rater is accurately measure a curve using 1 times per 1 image for each individual. Significant correlation was present round of measurement results between observer 1 and 2, observer 2 and 3, observer 1 and 3.

The present study also shows comparison results of measuring spinal curvature by observers. The difference between observer 1 and observer 2 in Cobb method the means is statistically significant ($p<0.05$). Cobb method has the mean of observer 2 more than observer 1 at 1.479. Despite the heterogeneity of final follows up, but we found no significant difference between other rounds in other method. So the difference between the means is not statistically significant ($p>0.05$) as shown in Table 4.2.

Table 4.3 Shows Paired Samples t-test between Methods of Inter-Rater & Intra-Rater

No.	Method	Paired Differences			
		Mean	Std. Deviation	t value	p value
Pair 1	Intra Ferguson-Cobb	-2.64067	3.14098	-7.976	.000
Pair 2	Intra Cobb-Polynomial	2.94067	4.11175	6.785	.000
Pair 3	Intra Ferguson-Polynomial	.30000	2.28400	1.246	.216
Pair 4	Inter Ferguson-Cobb	-2.98789	3.82074	-7.419	.000
Pair 5	Inter Cobb-Polynomial	2.90489	4.72922	5.827	.000
Pair 6	Inter Ferguson-Polynomial	-.08300	2.99617	-.263	.793

In the statistical analysis of sample paired t-test to test the difference statistically significant of the angles by measuring spinal curvature, there are Ferguson, Cobb and polynomial methods. The comparison of assess intra examiner as measured by observer and observers. The result is intra-rater and inter-rater. The difference between intra-rater Ferguson & Polynomial the means is not statistically significant ($p>0.05$). And the difference between inter-rater Ferguson & Polynomial the means is not statistically significant ($p>0.05$), which intra-rater has the mean of Ferguson more than Polynomial method at 0.300 and inter-rater has the mean of Polynomial more than Ferguson method at 0.830. But we found significant difference between intra-rater and inter-rater in other method the means is statistically significant ($p<0.05$) as shown in Table 4.3.

4.2 Result of comparison reliability between each method

The comparisons of reliability in measurements spinal curvature from anteroposterior radiograph 2D view (AP-View) are studied on 30 images of spinal patients Lerdsin hospital by 3 intra-observers. The result of intra-rater two-way mixed single model with absolute agreement type ICC (3, 1) is accurately measure a curve using 3 times per 1 image for observer. And inter-rater model two-way random single measures in absolute agreement type ICC (2, 1) is accurately measure a curve using 1 times per 1 image for each individual.

The comparison of assess intra examiner reliability as measured by observer ICC (3, 1) vs observers ICC (2, 1) in absolute agreement type as shown in Table 4.4. And consistency type as shown in Table 4.5.

Ferguson method were considered of highest reliability when ICC (3, 1) = 0.969. On the other hand, the polynomial method were lowest reliability with ICC (3, 1) = 0.912. Turning to Cobb method, there was significantly reliability up to 0.644 in ICC (2, 1), whereas the polynomial method had less measure accurately ICC (2, 1) = 0.392 as shown in Table 4.4.

Table 4.4 Shows Comparison the Intra-Rater ICC (3, 1) & Inter-Rater ICC (2, 1) Reliability in Absolute Agreement Type of Measuring Spinal Curvature

Method	Absolute agreement		
	Ferguson	Cobb	Polynomial
ICC (3, 1) Intra	0.969	0.952	0.912
ICC (2, 1) Inter	0.481	0.644	0.392

Ferguson method were considered of highest reliability when ICC (3, 1) = 0.968. On the other hand, the polynomial method were lowest reliability with ICC (3, 1) = 0.910. Turning to Cobb method, there was significantly reliability up to 0.659 in ICC (2, 1), whereas the polynomial method had less measure accurately ICC (2, 1) = 0.407 as shown in Table 4.5.

Table 4.5 Shows comparison the Intra-Rater ICC (3, 1) & Inter-Rater ICC (2, 1) reliability in consistency type of measuring spinal curvature

Method	Consistency		
	Ferguson	Cobb	Polynomial
ICC (3, 1) Intra	0.968	0.950	0.910
ICC (2, 1) Inter	0.477	0.659	0.407

In both conclusions, the reliability of spinal curvature is measured by Ferguson method that is considered higher reliability more than Cobb and Polynomial method. The angle identified by the Cobb method show acceptable performance as observers more than Ferguson method and Polynomial method.

Table 4.6 Shows Intra Descriptive Statistics

Method	N	Minimum	Maximum	Mean	Std. Deviation
Ferguson	90	.04	13.04	3.4184	2.85545
Cobb	90	.29	20.72	6.0591	3.91464
Polynomial	90	.05	14.56	3.1184	2.99534

Intra-rater descriptive statistics are shown mean as measured by Ferguson, Cobb, and Polynomial method. Cobb method has the mean higher than Ferguson & Polynomial method at 6.059, while Ferguson has mean similar to Polynomial method as shown in Table 4.6.

Inter-rater descriptive statistics are shown mean as measured by Ferguson, Cobb, and Polynomial method. Cobb method has the mean higher than Ferguson & Polynomial method at 6.647, while Ferguson has mean similar to Polynomial method as shown in Table 4.7.

Table 4.7 Shows Inter Descriptive Statistics

Method	N	Minimum	Maximum	Mean	Std. Deviation
Ferguson	90	.04	12.77	3.6589	2.72018
Cobb	90	.00	19.12	6.6468	4.14944
Polynomial	90	.09	13.84	3.7419	2.89478

In both conclusions, the mean of intra-rater and inter-rater is measured by Cobb method that is considered higher mean more than Ferguson and Polynomial method. Ferguson have mean similar to Polynomial method.

CHAPTER V
CONCLUSIONS

This study is to assess intra-rater and inter-rater reliability of 3 methods for measuring spinal curvature in anteroposterior radiograph 2D view (AP view) with spinal patients of Lerdsin hospital. The 30 photos are sampled as the complete sharpness of the edge lumbar vertebrae (L1 - L5) during on years 2004 - 2011. Three methods i.e. Cobb, Ferguson and Polynomial are compared with each value in terms of reliability and statistical analysis to analyze the reliability of the results compared to the existing methods of how to measure the application including related research.

This investigation illustrates the accuracy and consistency values have no significant difference value between Cobb and Ferguson method, with a level of substantially more than the polynomial method. The polynomial methods are globalization, which has 20 points for landmarks point of the lumbar vertebrae edge (L1-L5). Conversely, Cobb method and Ferguson are localization, which are measured on partial landmarks point of the lumbar vertebrae. There is processing of coordinate data points from the landmarks point of especially. Measuring spinal curvature of Ferguson method is processing on the lumbar spine top (L1) on the middle (L3) and bottom (L5). And measuring spinal curvature of Cobb method is processing on the lumbar spine top (L1) and bottom (L5) so the measuring spinal curvature is global makes angle of curvature less than local. But the advantage global can be used the classification of the spinal curvature from coefficients of the equation. And to improve polynomial methods to better measure may be adjusted to a local or spline may give results more similar of Cobb method. In the statistical analysis of sample paired t-test to test the difference statistically significant of the angles by measuring spinal curvature, there are Ferguson, Cobb and polynomial methods. The comparison of assess intra examiner as measured by observer and observers. The result is intra-rater and inter-rater. The difference between intra-rater Ferguson & Polynomial the means is not statistically significant ($p>0.05$). And the difference between inter-rater Ferguson & Polynomial the means is not statistically significant ($p>0.05$). We found significant difference between intra-rater and inter-rater in other method the means is statistically significant ($p<0.05$). The difference statistically significant between intra-rater and inter-rater in Cobb and Ferguson methods the means is statistically significant.

It can be concluded that the research found the best method that is suitable for measuring spinal curvature was Ferguson method for intra class correlation and Cobb method suitable for intra class correlation.

5.1 Discussion

According to this research, several factors influence Ferguson and Cobb methods. Apparently, Ferguson is more reliable than Cobb when estimated by intra-rater reliability. In contrast, Cobb method dedicates that this method is more suitable for inter-rater reliability. Unfortunately, 12 co-ordinate points of spinal curvatures were required by Ferguson’s formula to determine the angle found that the cumulative errors probably due to the set number of reference points in locating. So determination by Cobb’s formula is preferable because only 4 co-ordinate points were used. Moreover, the Cobb method is more reliable than the two methods (Ferguson and Polynomial). Subsequently, the Polynomial method requires 20 co-ordinate points can lead to more cumulative error measurement than the others. Although the co-ordinate points decreased from 20 to 12, it does not improve the credible. Then, the Polynomial method might be changed into the Spline form for enhancing the reliability.

Obviously, the main factors as the result accuracy are resolution of the pictures and skill of assessors. The scoliosis analysis pictures were provided by Lerdsin Hospital that has low resolution as can be seen that the deformities of spinal curvatures are unclear than the normal form. Since, it would be difficulty to get accuracy estimated and high discrepancy for determining the angle of spinal curvatures, which requires the precise co-ordinate points. Besides to set the coordinate point depends on human consideration. In addition, human error in selection coordinates points is the one possibilities mistake for measuring exactly the angle of curvatures. Regarding to the resulting verified by the scoliosis specialist from Lerdsin Hospital, this highly appreciated for cooperating. More importantly, the measurements of co-ordinate points on the low-quality resolution images have attributed the intolerance in intra-rater reliability and inter-rater reliability. Especially, the inter-rater reliable who has beyond the individual skill, and physical abilities can cause dizzy and vertigo. Consequently, the decision to treat scoliosis is under the doctor consideration. Finally, with increasing the number of sample images found that there are no significantly divergent under the condition of low resolution in the spine at position L1-L5.

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