Université de Montréal

Impact of Adolescent Idiopathic Scoliosis on Spinal Mobility

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Le but de cette étude est d'évaluer les caractéristiques associées à la mobilité de la colonne vertébrale chez les patients ayant une scoliose idiopathique. Selon les études antérieures, une augmentation de la flexibilité et de la mobilité de la colonne vertébrale serait reliée à une courbure scoliotique. Une meilleure compréhension de ce phénomène serait utile à l'évolution et au traitement de cette maladie. De plus, la caractérisation des mouvements normaux pourrait servir d'indicateur complémentaire au pronostique. Cette étude porte sur l'évaluation de la mobilité de la colonne vertébrale chez les patients scoliotiques. Les résultats ont été comparés à ceux de sujets témoins normaux afin d'établir s'il existe une relation entre la mobilité de la colonne vertébrale et certaines variables biodémographiques. Soixante-cinq adolescents ayant une scoliose idiopathique ont constitué le groupe patient alors que des sujets (13 garcons et 7 filles) d'âge comparable formaient le groupe témoin. Les patients avaient un âge moyen de 14 ans et n'avaient pas été opérés à la colonne vertébrale bien qu'une scoliose était présente. Tous les sujets ont été mesurés et évalués à la clinique de scoliose de l' hôpital Sainte-Justine. L'âge, la hauteur et le poids ont été mesurés. Les mesures de la mobilité ont été effectuées dans les trois plans à l'aide d'un inclinomètre. Un test-t de Student et une analyse de régression multiple ont été utilisés pour déterminer la présence de différences significatives entre les deux groupes et l'importance relative des variables biodémographiques sur la mobilité de la colonne vertébrale. Une valeur de $p < 0.001$ pour le test-t et de $p < 0.05$ pour les corrélations et les régressions multiples ont été arbitrairement choisies.

La mobilité de la colonne vertébrale du groupe patient était significativement différente de celle du groupe témoin. Elle était plus petite chez les patients dans les plans sagittal et transverse, un résultat qui n'appuie pas l'hypothèse d'une flexibilité excessive chez les patients scoliotiques. Très peu de corrélation a été trouvée entre les différentes variables biodémographiques et plus particulièrement avec l'angle de Cobb qui indique la sévérité des courbures. L'implication clinique de ce travail porte sur l'importance possible de maintenir une amplitude normale de mouvement dans les régions thoraco-lombaire chez les sujets scoliotiques.

SOMMAIRE

Le but de cette étude est d'évaluer les caractéristiques associées à la mobilité de la colonne vertébrale chez les patients ayant une scoliose idiopathique. Selon les études antérieures, une augmentation de la flexibilité et de la mobilité de la colonne vertébrale serait reliée à une courbure scoliotique. Une meilleure compréhension de ce phénomène serait utile à l'évolution et au traitement de cette maladie. De plus, la caractérisation des mouvements normaux pourrait servir d’indicateur complémentaire au pronostique. Cette étude porte sur l’évalation de la mobilité de la colonne vertébrale chez les patients scoliotiques. Les résultats ont été comparés à ceux de sujets témoins normaux afin d’établir s’il existe une relation entre la mobilité de la colonne vertébrale et certaines variables biodémographiques. Soixante-cinq adolescents ayant une scoliose idiopathique ont constitué le groupe patient alors que des sujets (13 garcons et 7 filles) d’age comparable formaient le groupe témoin. Les patients avaient un âge moyen de 14 ans et n avaient pas été opéres’ à la colonne vertébrale bien qu’ une scoliose était présente. Tous les sujets ont été mesurés et évalués à la clinique de scoliose de l’ hopital Sainte-Justine. L’age, la hauteur et le poids ont été mesurés. Les mesures de la mobilité ont été effectuées dans les trois plans à l’aide d’un inclinomètre. Un test-t de Student et une analyse de régression multiple ont été utilisées pour déterminer la présence de différences significatives entre les deux groupes et l’importance relative des variables biodémographiques sur la mobilité de la colonne vertébrale. Une valeur de $p < 0.001$ pour le test-t et de $p < 0.05$ pour les corrélations et les régressions multiples ont été arbitrairement choisies.

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ABSTRACT

The primary purpose of this study was to evaluate the characteristics of spinal mobility in adolescent idiopathic scoliosis. Earlier studies have indicated that an increase in flexibility and spinal mobility may be of importance in producing deviation of spine. Knowledge of the effect of adolescent idiopathic scoliosis on spinal mobility could be useful in the evaluation and treatment of the disease. Furthermore, characterization of the abnormal motion may be of prognostic value. This study focused on the assessment of spinal mobility in adolescent idiopathic scoliosis as compared to that of normal subjects and tried to establish a relationship between the likely spinal mobility differences and some biodemographic variables.

Sixty five girls with progressive adolescent idiopathic scoliosis formed the patient group while 20 age-matched controls (13 boys and 7 girls) with normal spine comprised the able-bodied group. The scoliotic patients were girls with a mean age of 14 years, and all had combined thoracic and lumbar nonoperated curves. All subjects were measured and evaluated in the scoliosis clinic of Sainte-Justine Hospital. Age, height, and weight were

determined. Measurements of the mobility were done in three planes with an inclinometer.

Student t-test technique and multivariate regression analysis were used to determine the significant differences between the two groups and the relative importance of the biodemographic variables on spinal mobility with a p value of 0.001 for t-test and 0.05 for correlation and mutivariate regression.

Spinal mobility of the patient group was found to be significantly different from those of normals. Spinal mobility was more restricted among scoliotic patients in the sagittal and transverse planes, a finding which does not support the hypothesis of excessive flexibility of the spine in idiopathic scoliosis. Very little correlation could be detected between biodemographic variables, and specially the Cobb angle which measured severity of curves even though the spinal mobility was reduced in scoliotic patients. The clinical implication of this work may be that preservation of a normal range of motion in the thoracolumbar spine should be one of the aims of treatment.

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CHAPTER ONE

INTRODUCTION

1.1 Definition

The word "scoliosis" is derived from the ancient Greek world, Skoliosis, meaning a curve. In medicine, it is used to designate a lateral curvature of the spine (Cassella and Hall, 1991). Throughout the eighteenth and nineteenth centuries, scoliosis was believed to be caused by abnormal postural positioning of the body. It is now defined as a lateral spinal curvature in excess of 10 degrees. The pathological description is clear: scoliosis is seen as deformed vertebrae when the vertebral body shifts towards the convexity of the curve and the spinous processes deviate to the concave side. If the deformity involves the thoracic spine, the result is a diminution in the entire volume of the thoracic cage leading ultimately to respiratory impairment in very severe deformities. The spinal deformity will produce a progressive distortion of the spinal canal itself which may be responsible for spinal cord compression, particularly in congenital curvatures (Downie, 1990).

1.2 Structural Versus Nonstructural Scoliosis

Scoliosis is either structural or nonstructural. A structural curve usually has a rotary component (Scoliosis Research Society Terminology Committee, 1976). Clinically, a structural curve will not correct when the trunk is flexed forward and will not fully correct in a supine, bending radiograph. Conversely, a nonstructural curve has no rotary component and will usually straighten when the trunk is flexed forward. When viewed on radiographs, a nonstructural curve will often correct or overcorrect. Some causes of nonstructural scoliosis are leg-length discrepancies, postural problems, muscle spasm, and spinal tumours. Nonstructural curves associated with muscle spasm and spinal tumours may even be exaggerated when the patient bends forward. This, however, causes pain, which is not a characteristic of other curves (Cassella and Hall, 1991).

Ninety percent of scolioses are so-called "idiopathic"; treatment thus remains empirical and speculative. The term "idiopathic" means of unknown etiology and the pathology develop mainly during the growing years. There are, however, two general observations: (1) Usually the younger the patient at the onset of the curvature, the worse the prognosis; and (2) curves which are rapidly deteriorating and/or are painful usually need surgical treatment (Downie, 1990).

Various curve patterns are seen in the idiopathic adolescent with scoliosis:

a) Main thoracic with the apex around T8 or T9 and the end vertebrae around T6 and T11. This pattern was found in 22 per cent of patients.

b) Thoracolumbar with the apex at T12 or L1 and the end vertebrae around T6 or T7 and L2 or L3. This pattern was found in 16 per cent.

c) Main lumbar with the apex around L2 or L3, the end vertebrae around T11 or T12 and L4 or L5. This pattern was found in 24 per cent of patients.

d) Combined thoracic and lumbar in which the upper curve (thoracic) has its apex around T6 or T7. The lower curve (lumbar) has its apex at L2. This pattern was found in 37 per cent of patients (Weinstein, 1994).

Popular texts on the subject of adolescent idiopathic scoliosis generally report incidence being anywhere from 1.4 to 4.1 per thousand people with the girl to boy ratio being approximately 9:1 (Danbert, 1989). Rogala et al (1978) reported the incidence of idiopathic scoliosis to be 4.5 percent. The girl to boy ratio was 1.25:1.0 over-all, but the ratio varied directly with the severity of the curve, that is, 1:1 for curves of 6 to 10 degree, and 5.4:1 for curves of more than 20 degrees. However, exact figures vary considerably, depending upon the use of different diagnostic definitions as to the degree of scoliosis and which category each degree of curvature properly fits (Kane, 1977).

1.3 Treatment and outcome

The strategy for treating idiopathic scoliosis depends principally upon the severity of the deformity and its potential for progression. No data exist as to which curves will tend to progress (Lonstein, 1984; Weinstein, 1986). It is clear, however, that mild curves are very common and rarely progressive. Once a curve has increased beyond 30 degrees in a child with considerable skeletal growth remaining, progression is almost inevitable.

1.3.1 Nonoperative treatments

A. Brace treatment

In the skeletally immature child, the use of orthoses is the most widely accepted method of nonoperative treatment for progressive curves greater than 25 degrees. The use of braces to stop the progression of structural curves dates back to the time of Hippocrates (Moe et al, 1978). From the 4th century until the early part of the 20th century, spinal deformities were treated with forcible horizontal traction and leg distraction in suspension, corsets, casts, and a variety of braces (Moe et al, 1978 and Bradford et al, 1987). The objective is to use the brace to prevent progression of the curvature while waiting for the patient to reach skeletal maturity. The most common types of braces, however, that established the role of orthoses in effective curve control involve the Milwaukee brace. This brace was first designed by Blount and Schmidt in 1946 (Blount and Moe, 1973). This brace is used to control high thoracic curves.

The Lyon brace was developed in France by Dr. Pierre Stagnara. This type of brace is used for treating thoracic, thoracolumbar, and double major curve pattern. The Boston brace system was designed by Hall and Miller (Hall et al, 1976; Watts et al, 1977). It is used in the treatment of low thoracolumbar and lumbar curves in the adolescent patients. It has been shown that the treatment usually produces satisfactory results, although further investigation with longer follow-up is necessary (Cassella and

Hall, 1991).

B. Electrical Stimulation

Electrical surface stimulation has been used for the conservative management of scoliosis (Farady, 1983). It consists of stimulating the paraspinal musculature on the convex side of the major curves. The technique requires nightly application of intermittent electrical stimulation by use of surface electrodes. The indications for electrical surface stimulation are essentially the same as those for orthotic treatment: skeletal immaturity, a structural curve(s) of 25 to 40 degrees, and documenting progression of the curve(s) (Sullivan, 1986). Although early studies using electrical surface stimulation appeared promising, the results of this treatment in recent years, have been disappointing (Axelgaard, 1983 and Sullivan, 1986). The authors concluded that this method could not be considered an alternative to bracing.

C. Traction and Exercises

In the 5th century, Hippocrates attempted to correct scoliotic spines using traction. More recently, Cotrel traction has been used to apply correction forces preoperatively and to exploit the viscoelastic of the spine (Nachemson and Nordwall, 1977). Nachemson (1977) compared the end result of spine fusions performed after preoperative Cotrel traction with a two-stage Harrington rod without preoperative traction and found no significant difference.

The role of exercise in the nonoperative management of adolescent idiopathic scoliosis is controversial (Lonstein, 1988). There have been attempts to correct structural curves with vigorous exercises alone, stressing active derotation of the spine (Klapp, 1966). The objective of the exercise is primarily to maintain spinal mobility and muscle strength, rather than to reduce the curvature per se. Today, most experts agree that exercise alone will not affect the progression of a structural scoliosis. There is agreement, however, that a selective exercise program in conjunction with bracing treatment is beneficial (Blount, 1967; Miyasaki, 1980).

1.3.2 Surgical Management

When nonoperative management fails in a child with idiopathic scoliosis, operative management must be considered, depending on the age of the child. Patients with curves that exceed 40 degrees when the patients are still growing and those with curves more than 50 degrees after the end of the growth are candidates for surgical correction (Weinstein, 1983). The aims of surgical management of adolescent idiopathic scoliosis is: (a) straighten the spine as much as possible consistent with safety; (b) balance the trunk on the pelvis; and (c) stabilize the spine by arthrodesis, which will maintain the correction. For many years, the standard instrumentation has been the Harrington set, consisting of both distraction and compression rods (Harrington, 1962). Harrington instrumentation helps to correct the rib hump and obtain more stability so that less external immobilization will be required. The Cotrel-Dubousset instrumentation is another device that was introduced in United States in 1984. It is designed to derotate the spine to obtain correction of the rib hump and to establish a normal sagittal contour with the proper amount of thoracic kyphosis and lumbar lordosis (Cotrel, 1985). Many new types of instrumentation, such as the Texas Scottish-Rite Hospital system, have been developed based on the Cotrel-Dubousset principles. Long term follow-up of patients who have had spinal fusion as adolescents has shown that it is more important to pay attention to the sagittal contour or rib hump (Kostuik, 1988). Many patients whose lumbar lordosis has been obliterated by the use of a straight Harrington rod have developed a problem known as the flat back syndrome. These patients have great difficulty standing erect because of collapse of the disks below the level of fusion. Other complications, such as neurologic problems up to and including paraplegia, are fortunately rare (Hall et al, 1978).

1.4 Statement of Problem

During the past several decades, investigations on many aspects of scoliosis have been reported in numerous publications. These include studies on alterations of connective tissue metabolism, operative disturbance of bone and spinal ligaments, denervation procedures, dietary factors, enzymatic factors, tendon and ligament elasticity, joint elasticity, the intervertebral disc, electromyography of paravertebral muscles, vestibular function, vertebral rotation, and inheritance factors (Weinstein, 1994). Of all these studies, none have shown any consistent abnormalities bearing on the etiology of idiopathic scoliosis, with the exception of the genetic aspects. The etiopathogenic events occurring in the development of a progressive idiopathic scoliosis are still obscure, and very few studies evaluating spinal mobility in idiopathic scoliosis have been conducted.

This study focuses on the pathomechanics of idiopathic scoliosis and more specifically on the characterisation of spinal mobility in adolescent idiopathic scoliosis. Mobility is defined as range of motion, which is the difference between the neutral position and the physiologic extent of movement. Some authors have postulated that alteration in the flexibility and the spinal mobility may be of importance in producing deviation of spine.

Secondly, measurements of spinal mobility have traditionally been important for clinical and disability evaluation. Obtaining good measures is not a simple task because motion occurs at several motion segments and around different axes of rotation which vary at different levels. Therefore, it is clinically relevant to determine the range of motion of a patient's spine (Dillard et al, 1991).

Thirdly, maintenance of a normal back mobility in adolescent with idiopathic scoliosis may be a major functional goal of physical therapy management. This study seeks to determine a method of spinal mobility measurement for clinical assessment of the scoliotic patients for both the physical therapist and physician and to define the characteristics of spinal motion in adolescent idiopathic scoliosis in order to shed some light on the severity of the disease, the potential for progression, and ultimately the decision for conservative or surgical treatment.

1.5 Objectives:

The main objective of the study is to analyse the relationship between the spinal mobility changes and some biodemographic variables.

In the light of the above discussion, the following questions emerge as the other objectives of the present study:

1. Are there any differences between the scoliotic patients and abled-bodied subjects in terms of spinal range of motion? If there is, What is the nature of the limitation of motion? These limitations can be located at thoracic, lumbar, or thoracolumbar levels and about different cardinal planes (sagittal, horizontal, and frontal).
2. Are there any known biodemographic variables associated with spinal mobility changes?

CHAPTER TWO

REVIEW OF LITERATURE

This chapter presents a brief description of the spinal column and provides a background for the study and discussion of spinal mobility in the following sections: 1) spinal column; 2) posture; 3) biomechanics and spinal mobility; 4) spinal deformity in adolescent idiopathic scoliosis; 5) spinal mobility in adolescent idiopathic scoliosis; and 6) review of measurement techniques.

2.1. Spinal column

The vertebrae and ribs have multiple functions that frequently must be carried out simultaneously namely a) protecting organs, spinal cord and viscera; b) providing vital functions of breathing; c) supporting head, arms, and trunk against gravity; d) transmitting forces between upper and lower extremities; and e) providing stability and mobility for hand function, locomotion, and other activities (Lehmkuhl and Smith, 1984).

2.1.1. Anatomy

The normal spine is composed of 33 vertebrae, separated by intervertebral disks superincumbent on each other, that form the vertebral column (Figure 2.1). The entire column, supported upon the sacrum in vertical alignment, forms four physiological curves in the sagittal plane (Figure 2.2). These four curves are termed cervical and lumbar lordosis with an anterior convexity and dorsal and sacral kyphosis with a posterior convexity (Cailliet, 1981).

The thoracic kyphosis is due to the lesser vertical height of the anterior thoracic vertebral borders, as opposed to the posterior borders. This is also true for the sacral curve. Curvatures at the cervical and lumbar regions are largely due to the wedge-shaped intervertebral discs (Figure 2.3). Consequently, when distracting forces are applied to the entire spine, there is a greater flattening of the cervical and lumbar lordosis as compared with thoracic kyphosis (Panjabi, 1978).

The vertebral column is a succession of articulated, superimposed segments, each of which is a functional unit (each anatomic component of the vertebral column that contributes to the mobility and stability of a motion segment). The function of the vertebral column is to support a two-legged animal, in the upright

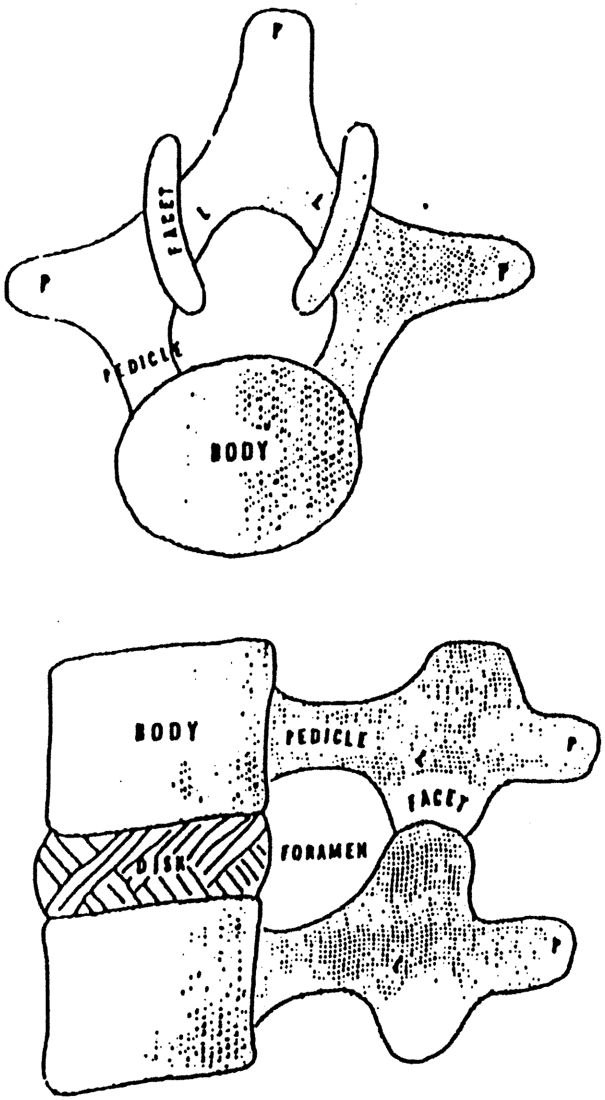


Figure 2.1. The upper figure is a view of the vertebra from above, which consists of the posterior facets, the pedicles, the processes(P), and the lamina(L). The bottom figure shows a lateral view of the vertebral unit and intervertebral disk.
Adapted from: Cailliet, 1981.

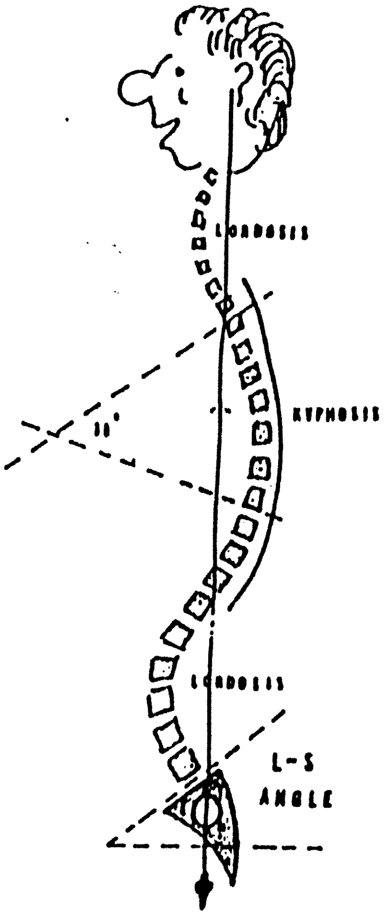


Figure 2.2. The figure demonstrates the four physiologic curves.
Adapted from: Cailliet, 1981.

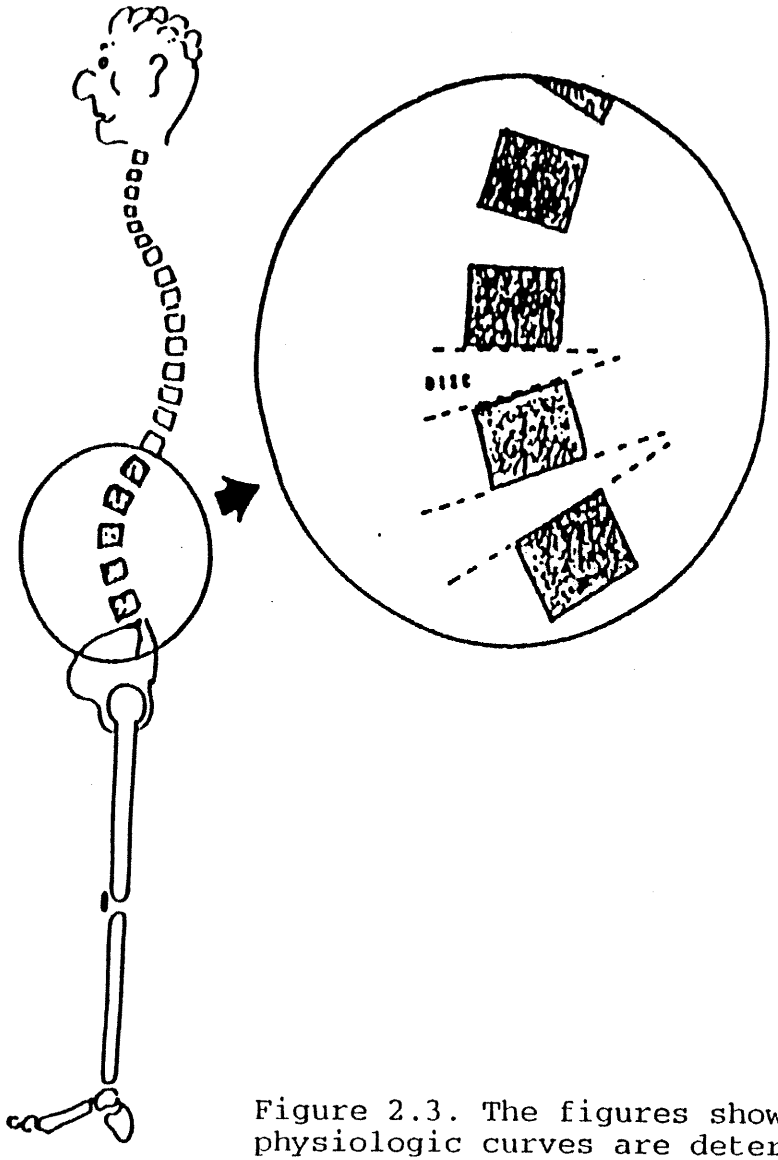


Figure 2.3. The figures shows that the physiologic curves are determined by the shape of the intervertebral disks. Adapted from: Cailliet, 1981.

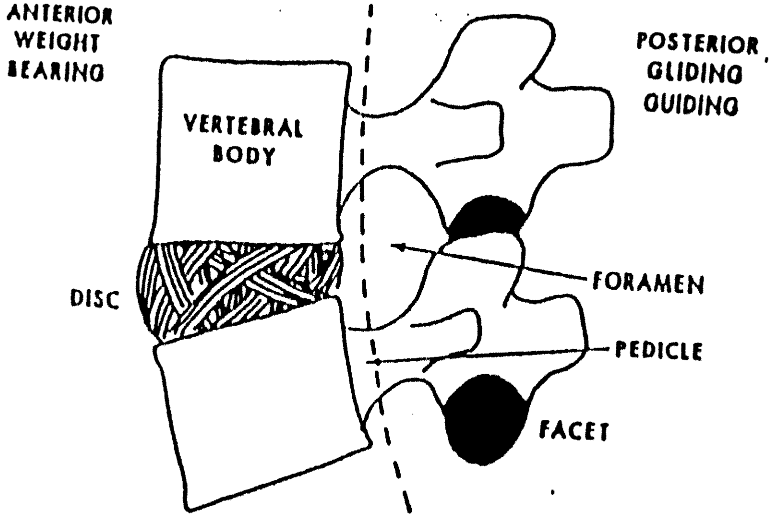


Figure 2.4. The functional unit of the spine in cross section. Adapted from: Cailliet, 1981.

position, mechanically balanced to conform to the effect of gravity, permitting locomotion and assisting in purposeful movements.

The functional unit is composed of two segments: the anterior segment contains two adjacent vertebral bodies, separated by an intervertebral disc, and a posterior neural segment. The posterior portion of the unit is composed of two vertebral arches, two transverse processes, a central posterior spinous process, and paired articulations, inferior and superior, known as facets (Figure 2.4 and 2.5). The anterior segment is essentially a supporting, weight-bearing, shock-absorbing, flexible structure. The posterior segment is a non-weight-bearing structure that contains and protects the neural structures of the central nervous system as well as paired joints that function to direct the movement of the unit.

A rib articulates with the thoracic vertebrae at two points: the head of the rib articulates with the vertebral body, and the tubercle of the rib articulates with the transverse process (Figure 2.6).

The intervertebral disks represent approximately one quarter of the length of the vertebral column and function as hydraulic

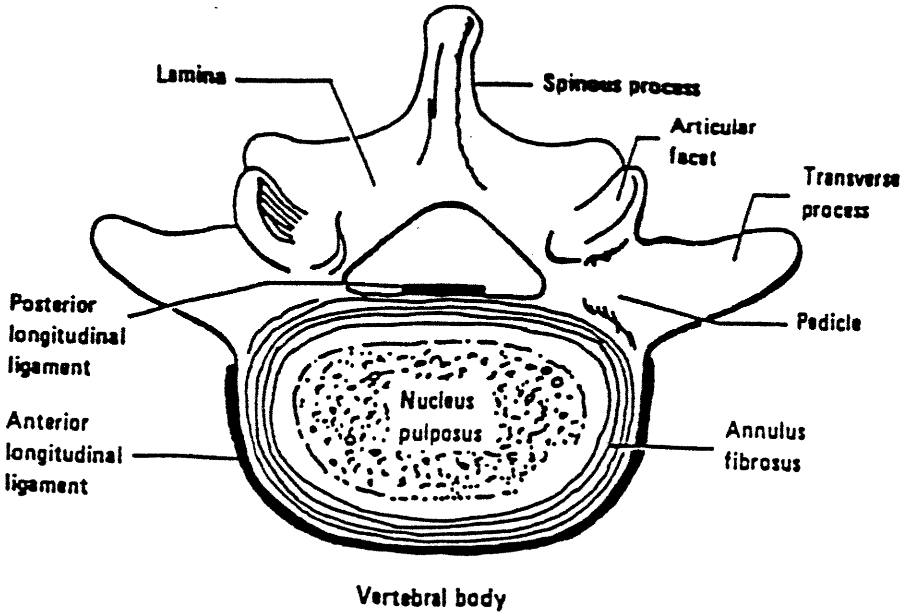


Figure 2.5. The anterior and posterior segments of the functional unit. Adapted from: Cailliet, 1981.

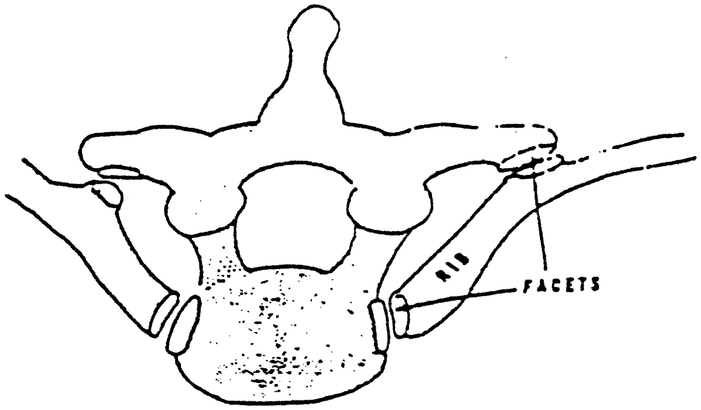


Figure 2.6. Articulations of the rib to the thoracic vertebrae. Adapted from: Cailliet, 1981.

shock absorbers permitting compression and distortion. In their torsion facility they allow flexion, extension, rotation, or combination of these movements. The disks are essentially made of mucopolysaccharide gelatinous tissue consisting of a central mass, the nucleus pulposus, contained within an elastic container, the annulus fibrosus.

The annulus fibers connect around the entire periphery of the vertebral end-plates and intertwine at approximately a 30 degree angle. By this arrangement, flexion, extension, and rotation motion is permitted and simultaneously restricted. The nucleus pulposus, totally contained within the inner fibbers of the annulus fibrosus and between the opposing vertebral end-plates, is placed under pressure (Figure 2.5). The intradiscal pressure of the annulus is approximately one atmosphere and is partially responsible for the elongation of the vertebral column, its length, its flexibility, and maintenance of the ligamentous tension that supports the column (Downie, 1990).

2.1.2. Ligamentous-Muscular Support

The ligaments have many functions: they allow adequate physiologic motion and fix postural attitudes between vertebrae;

they protect the spinal cord by restricting the motions within well defined limits; they share with the muscles the role of providing stability to the spine, and finally, they protect the spinal cord in traumatic situations (Panjabi. 1978). These ligaments consist of: a) the anterior longitudinal ligament which arises from the anterior surface of all vertebrae, down to and including a part of the sacrum, b) the posterior longitudinal ligament which runs over the posterior surface of all the vertebral bodies down to the coccyx, c) the intertransverse ligaments which connect the transverse processes, d) the capsular ligaments which are attached just beyond the margins of the adjacent articular processes, e) the ligamenta flava extending from the antero-inferior border of the laminae above to the postero-superior border of the laminae below, f) the interspinous ligaments which connect adjacent vertebrae, g) the supraspinous ligament which originates in the ligamentum nuchae and continues down to the sacrum (Panjabi, 1978).

The muscles that surround the vertebral column and that are located close to it provide a flexible support for the upright column, and they act to stabilize its parts in relation to each other and in balancing the trunk as a whole in relation to the pelvis (Lehmkuhl and Smith, 1984). These muscles consist of:

1. Anteriorly: psoas major, longus colli, longus capitis, rectus capitis anterior, scalene, sternocleidomastoid, anterior abdominal muscles, intercostals.
2. Posteriorly: erector spinae in lumbar, thoracic, and cervical region.
3. Laterally: psoas major, quadratus lumborum, scalene, sternocleidomastoid, erector spinae, lateral abdominal muscles, intercostals.

The anterior and lateral trunk muscles are concerned with movements of trunk flexion, lateral bending, and rotation. The posterior trunk muscles, or simply back muscles, are concerned with extension, lateral flexion, and rotation of the trunk, and in general, with the balance of the vertebral column (Lehmkuhl and Smith, 1984).

2.2. Posture

Correct posture consists of an alignment of the body with maximal physiological and biomechanical efficiency, which minimizes stresses and strains imparted to the supporting system by the effects of gravity. In correct posture, the gravity line passes through the axes of all joints with the body segments aligned vertically. The gravity line is represented by a vertical line drawn through the body's centre of gravity, located at the second sacral vertebra. It is the reference point from which gravitational effects on individual body segments are assessed. The closer a person's postural alignment lies to the centre of all joint axes, the less gravitational stress is placed on the soft tissue components of the supporting system. Not only is it ideal to have gravitational forces passing through the centre of the joint axes, it is also advantageous for the muscles, ligaments, and other soft tissue structures about the joints to be balanced. The strength and length of muscles involved in joint motion must be balanced. The balance is based on force couple (two forces that in combination produce rotation) among muscles involved in the three cardinal planes of motion. When a force couple is out of balance, the segment moves about its axis of rotation. The head, trunk, shoulders, and pelvic girdle are the most important segments to have in muscular and mechanical balance.

The erect stance is balanced upon an angled sacrum that forms the lumbosacral angle with the horizontal plane. The head must be well balanced above the sacrum so that a plumb line visibly passes through the ear, through the shoulder joint, through the greater

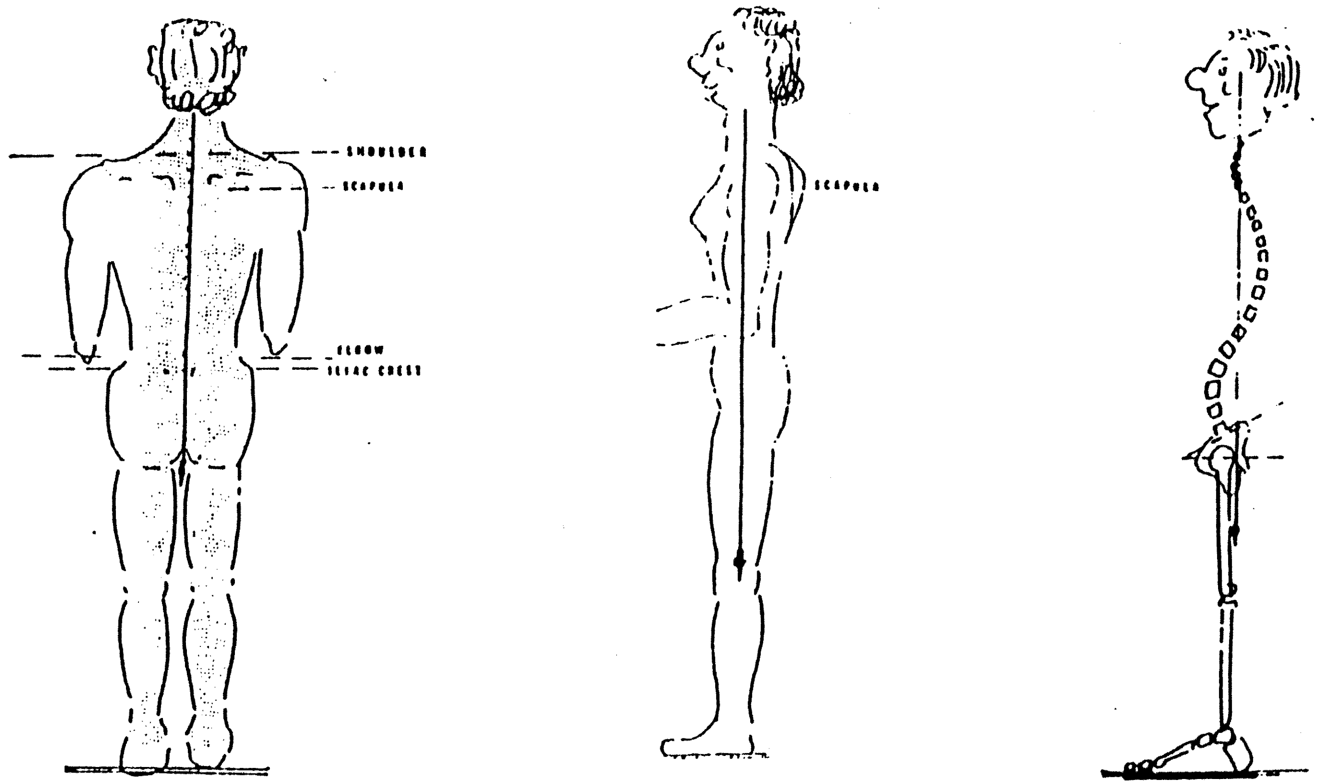


Figure 2.7. Standing posture: Center of gravity. An anterior-posterior and lateral view of the center of gravity with the plumb line passing through the axes of joints.
Adapted from: Cailliet, 1981.

trochanter of the femur, slightly anterior to the knee joint midline, and ending anterior to the lateral malleolus (Figure 2.7). Similarly, the centre of gravity, when viewed anteriorly-posteriorly, should pass from the occiput through the tip of the coccyx (Palmer and Elper, 1990).

Stance in the erect position is considered static and is termed posture. The erect body is intermittently supported by ligamentous tissues and muscles with good erect balance. When the spine moves in any direction away from the balanced erect stance, the direction and extent of movement vary at the various segments of the vertebral column. The direction of movement is determined by the plane of the posterior joints (facets), and the extent of the motion is limited by the joint capsules, the intervertebral disks, the ligaments, and the muscles (Cailliet, 1981).

2.3. Biomechanics and Spinal Mobility

The spine has three fundamental biomechanical functions. Firstly, it transfers the weights and the resultant bending moments of the head, trunk, and any weights being lifted to the pelvis. Secondly, it allows sufficient physiologic motions between these three body parts. Finally, and most importantly, it protects the delicate spinal cord from potentially damaging forces and motions produced by both physiologic movements and trauma. These functions are accomplished through the highly specialized mechanical properties of the normal spinal anatomy (Panjabi, 1978).

2.3.1. Planar Classification of Position and Motion

To define joint and segment motion and to record the location in space of specific points on the body, a reference point is required. In kinesiology, the three dimensional rectangular coordinate system is used to describe anatomic relationships of the body. The standard anatomic body position is defined as standing erect with the head, toes, and palms of the hands facing forward and fingers extended. Three imaginary planes are arranged perpendicularly to each other through the body, with their axes intersecting at the centre of gravity of the body (a point slightly anterior to the second sacral vertebra). These planes are called the cardinal planes of the body (Figure 2.8). Each of the three planes is divided into four quadrants by two of the three perpendicular axes frontal or coronal, sagittal, and horizontal or transverse (Lehmkuhl and Smith, 1984).

The frontal plane (coronal) divides the body into front and

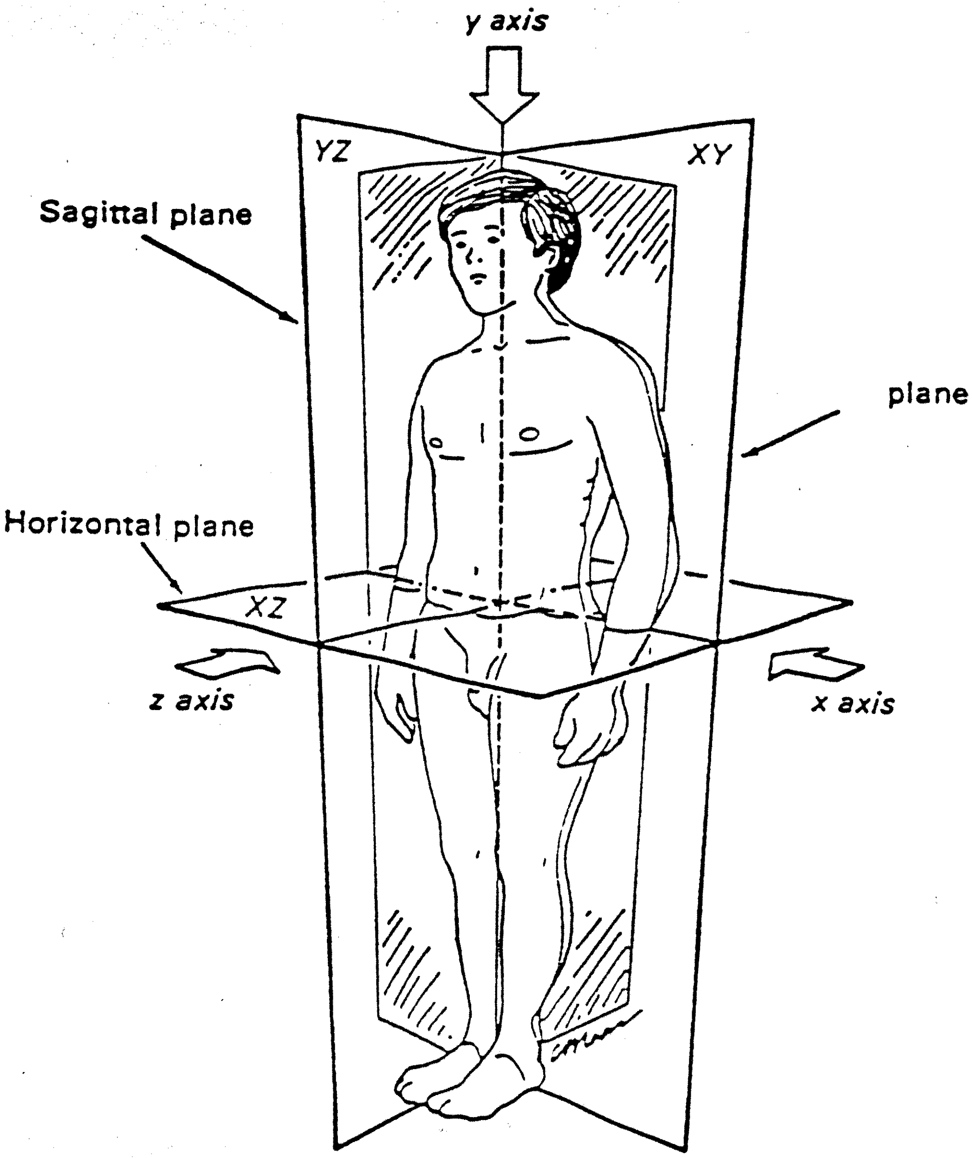


Figure 2.8. The three cardinal planes and axes of the body standing at ease.
Adapted from: Lehmkuhl, 1983.

back parts. Motions that occur in this plane are defined as right and left lateral bending.

The sagittal plane is vertical and divides the body into right and left sides. Joint motion occurring in this plane are defined as flexion and extension.

The horizontal plane (transverse) divides the body into upper and lower parts and is like a view from above. Rotations occur in this plane around the vertical axis.

The pattern of movements of the spine is dependent, among other factors, upon the shape and position of the articulated processes of the diarthrodial joints. It is the orientation of these joints in space that determines their mechanical importance. By their directional planes they simultaneously prevent or restrict movement in a direction contrary to the planes of the articulation.

The facets are arthrodial joints that function on a gliding basis. Lined with synovial tissue, they are separated by synovial fluid which is contained within an articular capsule. The plane of the facets, in their relation to the plane of the entire spine, determines the direction in which the two vertebrae will move. The direction, or plane, of the facets in any segment of the spine will determine the direction of movement permitted to that specific segment of the spine. The plane of the facets will simultaneously determine the direction of movement not permitted at that spinal segment. Movement contrary to the direction of the plane obviously is prevented or, at least, markedly restricted (Figure 2.9).

In the thoracic spine, the facets are convex- concave and lie essentially in a horizontal plane (Figure 2.10). Movement permitted by this facet joint (articular surfaces of the apophysial joint) in the thoracic spine is lateral flexion, such as side bending and rotation about a vertical line. A combined movement of lateral flexion and rotation occurs here, for,in spinal column movement, no pure lateral bending is possible without some rotation and no true rotation is possible without some lateral flexion. Due to this facet plane, no significant flexion or extension movement in an anterior posterior plane is possible in the adult thoracic-spine segment (Moll and Wright, 1992).

Because in the lumbar region the facet planes (articular surface of apophysial joint) lie in the vertical sagittal plane, they permit flexion and extension of the spine. Bending forward and arching backward are thus possible in the lumbar region. Due to the vertical sagittal facet plane, significant lateral bending and rotation are not possible. The male portion of the facets fitting into the female guiding portion permits movements in the direction of the guides, but lateral, oblique, or torque movement is mechanically prevented in the lordotic posture. In a slightly forward flexed position or posture in which the lordosis is decreased, the facets separates, thus allowing movement in the lumbar area, in a lateral and rotatory direction (Figure 2.11). In lumbar hyperextension the facets approximate or come near each other, thus eliminating completely any lateral or rotatory movement (Moll and Wright, 1992).

In summary, the direction of the facet plane that exists between two adjacent vertebrae in a functional unit determines the direction of movement of those two vertebrae. As the facets of the lumbar spine are vertical-sagittal in an anterior plane, movement of the lumbar spine exists mainly in an anterior-posterior flexion-extension direction. The planes of the thoracic spine relegate to this segment all significant lateral flexion such as side bending and rotation of the total spine. All other significant movement is barred to these segments (Cailliet, 1981). In this generalization of total spinal movement the cervical spine segment is intentionally excluded.

The intervertebral disc, which has many functions, is

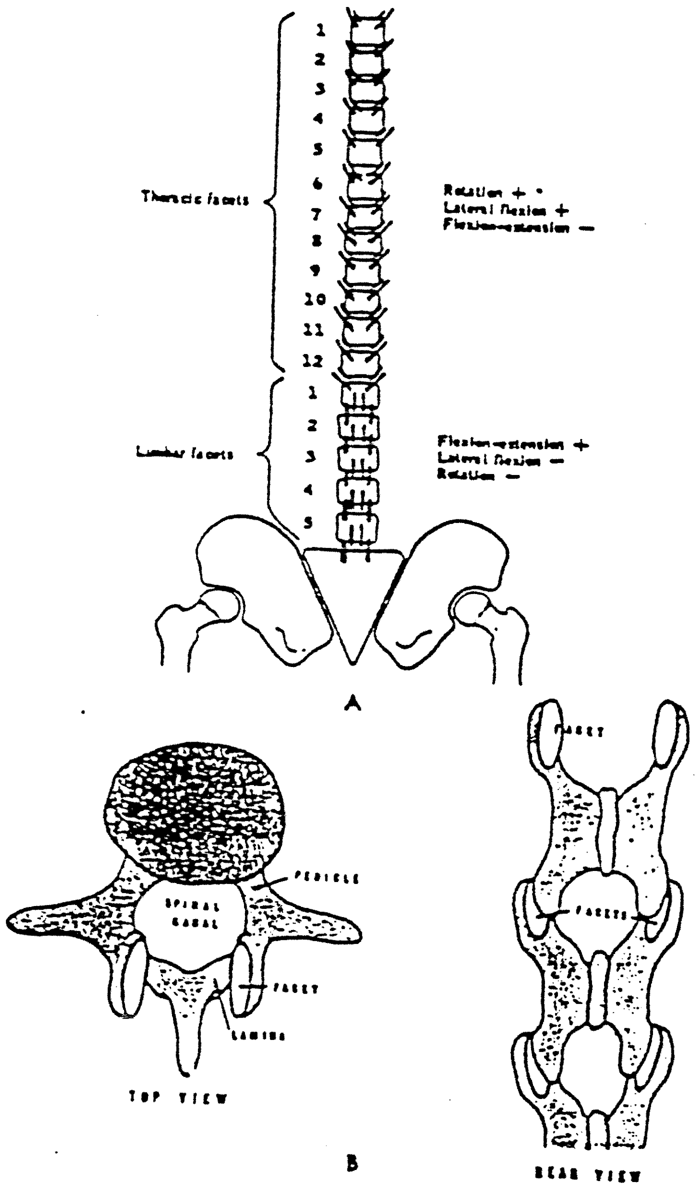


Figure 2.9. Planes of the articular facets. A) In thoracic and Lumbar regions. The signs indicate the motion permitted (plus sign) and the motion prevented (minus sign). B) Shows facets in details.
Adapted from: Cailiet, 1981.

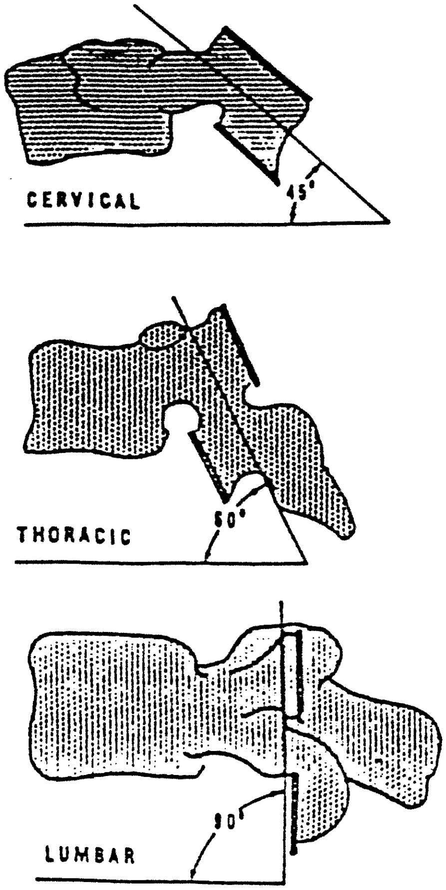


Figure 2.10. Angulation of planes of vertebral facets which determines the direction of movement at various vertebral levels is shown. Cailliet, 1981.

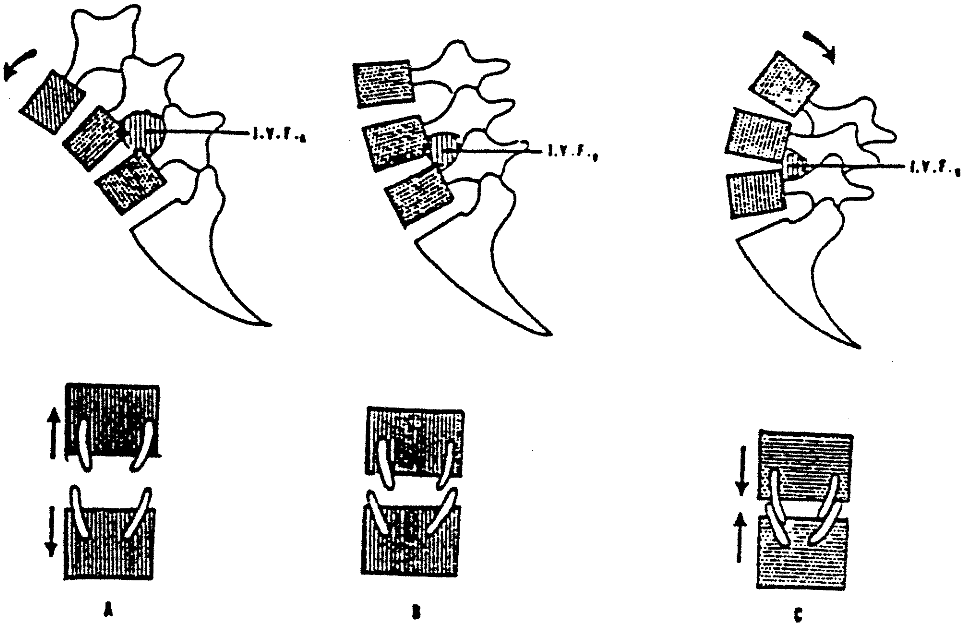


Figure 2.11. Facet movement in flexion and extension
Adapted from: Cailliet, 1981.

subjected to a considerable variety of forces and moments. Along with the facet joints, it is responsible for carrying all the compressive loading to which the trunk is subjected. When a person is standing erect, the force to which a disc is subjected are much greater than the weight of the portion of the body above it (Cailliet, 1981). Movement between adjacent vertebrae is maximal at spinal levels where the disc is thickest, such as in the cervical and lumbar region, and least where the disc is thinnest, as in the thoracic region (Moll and Wright, 1992).

2.3.2. Coupling of Intervertebral Motion

Most of the physiologic motions of the spine, such as bending and rotation are inherently connected. This phenomenon, which is called coupling, is due to the geometry of the individual vertebrae and connecting ligaments and discs, as well as the curvature of the spine.

Two or more individual motions are said to be coupled (e.g., lateral bending and axial rotation) when one motion is always accompanied by another motion. A vertebra can move in six different directions (it is said to have six degrees of freedom). In other words, the three-dimensional motion has six motion components:

three translations and three rotations. Theoretically speaking, any one of the motion components may be accompanied by five coupled motions, in addition to the sagittal plane coupled translations; there may be, out of the sagittal plane, coupled motions associated with flexion due to congenital, degenerative, or traumatic asymmetry of the facet joints (Panjabi, 1978).

The thoracic region is the least mobile part of the spine. In the thoracic region there is little or no alteration of the physiological kyphosis in forward flexion or extension. The plane of the facets denies this motion but allows lateral rotatory movement. By forward bending the dorsal spine already convex backward can be made somewhat more convex, but the extent of the movement is not great and by no means comparable to the same movement in the lumbar region (Cailliet, 1981). Flexion (forward bending) appears to be a pure antero-posterior movement without perceptible rotation.

Extension also appears to be a pure antero-posterior movement of the spine without perceptible rotation. It is not an evenly-distributed movement, but occurs almost wholly in the lumbar and lower two dorsal vertebrae. It is a motion of very slight extent in the dorsal region. It consists of a diminution of the backward convexity and is most noticeable in the lower half of the region (Lovett, 1905).

Side bending is to be considered as one part of a compound movement of which twisting or rotation forms the other part. In describing side bending it must be stated that the character and distribution of the movement vary widely according to the degree of flexion or extension of the spine when the side bending is made. It is also affected if the spine is twisted before it is bent to the side. In other words, there is no one type of spinal side bending as there are types of flexion and extension, but the character and distribution of the movements are wholly dependent upon the antero-posterior position of the spine.

Side bending from the erect position is, of course, the most important aspect, so far as scoliosis is concerned. In this position side bending causes rotation of the vertebral bodies to the concave side of the lateral curve. The dorsal region participates less and the lumbar region more in the movement.

Rotation or twisting of the spine is to be considered as part of a compound movement of which side bending forms the other part. Rotation is the most marked of dorsal movements. It reaches its greatest extent in the upper dorsal vertebrae and diminishes toward the lower end of the region. Rotation is always accompanied by side bending, the lateral curve being convex to the side away from which the bodies of the vertebrae turn. In a rotation of the top of the column to the left the lateral curve is to the right and vice versa (Lovett, 1905).

The practical points to be kept in mind in the study of the thoracic region are the facts that rotation is freer than side bending, that hyperextension is extremely limited, and that the rotation of the vertebrae in side bending in the dorsal region is always towards the convexity of the lateral curve.

2.4. Spinal deformity in Adolescent Idiopathic Scoliosis

Scoliosis is defined as an appreciable lateral deviation in the normally straight vertical line of the spine. Since the ultimate effect of the disease is an extensive alteration in the mechanical structure of the spine, a biomechanical definition of the disease is necessary. There is abnormal deformation between and within vertebrae, too much curvature in the frontal plane, too much vertical axis rotation in the wrong direction, and not enough curvature in the sagittal plane (i.e., a loss of normal kyphosis or a relative lordosis). The relative position of vertebrae in the

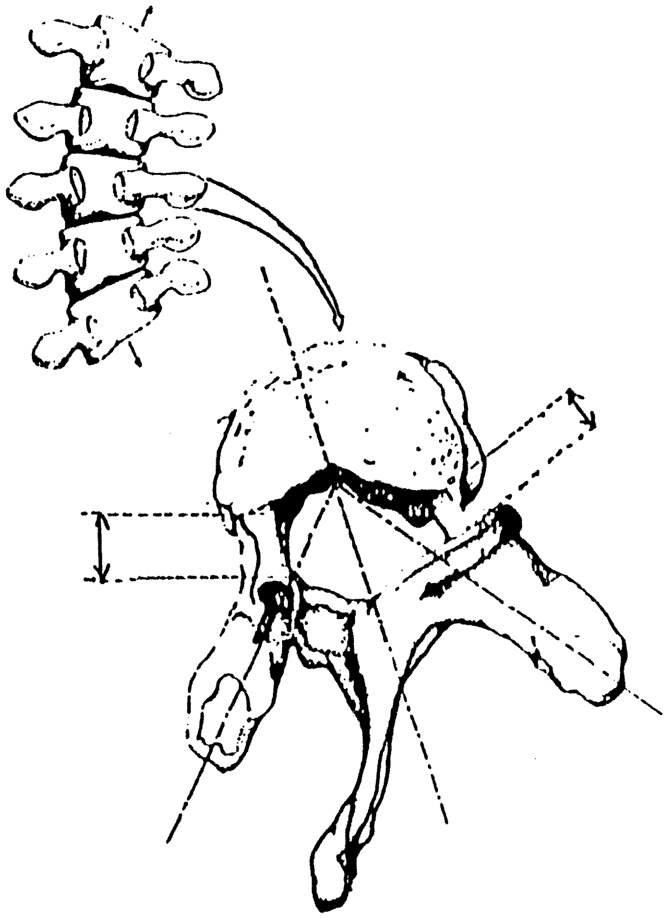


Figure 2.12. The diagram shows that in scoliosis there is deformity within as well as among vertebrae. Adapted from: Panjabi, 1978.

region of the spinal column is abnormal and deformation within an individual vertebra is present. Instead of a straight spine in the frontal plane or the subtle, right physiologic curve, there is an exaggerated curvature in the frontal plane. The curves are in the wrong plane. Curves in the sagittal plane are normal. The axial rotation is in a direction opposite of what would be expected from the physiologic coupling between lateral bending and axial rotation (Panjabi, 1978). As was mentioned every lateral curve must be accompanied by twisting of the bodies of the vertebrae toward the concavity of the lateral curve. This phenomenon is a normal mechanism. In structural scoliosis, the situation is reversed, and a lateral curve is accompanied by twisting of the vertebral bodies towards the convexity of the lateral curve which should be considered as a pathological change. There is also considerable deformation within a given vertebra. There may be a wide pedicle on one side and a short pedicle on the other. The transverse processes may be asymmetrical in their spatial orientation. The spinous processes may be deformed and bent out of the midline. The laminae and the vertebral bodies are asymmetrical (Figure 2.12).

It has been established that the deformity in structural scoliosis tends to increase more during period of rapid growth

(James, 1967). Growth is a remarkable factor in the progression of idiopathic scoliosis. Growth of the anterior column of a scoliotic spine is faster than that of the posterior column and results in reduced thoracic kyphosis. This reduced kyphosis makes the spine unstable to rotation, which may be a primary event in the progression of a small idiopathic curve (Dikson, 1984). Girls are more predisposed to a progressive idiopathic curve and this has been ascribed to their slender spine (Schultz et al, 1984). Spine slenderness relates horizontal vertebral body diameter to spine length. The spines of growing girls were more slender than those of boys of the same age. A more slender spine would be biomechanically predisposed to collapse or to progress more easily when loaded. This theory could explain the more common progression of idiopathic curves in girls (Poussa et al, 1989). In another study, Miller (1984) attributed the progression of the idiopathic curve to the earlier growth spurt of the girls and/or their more flexible ligaments. Many other provoking factors have been presented (Nachemson, 1984).

It has previously been demonstrated (Willner 1974; 1975) that children with scoliosis are significantly taller in height than children without scoliosis, even if the shortening of the trunk caused by the deformity is disregarded, and this was found in boys as well as in girls. The study of Burwell et al (1977) and Drummond et al (1980) also supports this finding. This seems to be contrary to the study of Poussa et al (1989) in which the scoliotic patients were shorter than the age-matched controls; but this difference was not statistically significant.

2.5. Spinal Mobility In Adolescent Idiopathic Scoliosis:

Very few studies concerning the joint flexibility in idiopathic scoliosis have been conducted. Flexibility is the ability of the structure to deform under the application of a load. Mattson et al (1983) found that the overall joint flexibility of scoliotic girls were not greater than those of the controls, but in forward flexion of the spine and in the mobility of some joints, the scoliotic patients were stiffer. Stiffness is the property of a structure by which resistance is offered to an imposed displacement. Miller (1984) conversely, found that the index finger flexibility of the scoliotic patients were about 17 per cent greater when compared with structurally normal control.

Mobility of the joints or range of the motion in the spine depends on, in addition to anatomic structures, the flexibility of ligaments and discs. Studies concerning the properties of connective tissue in idiopathic scoliosis have given confusing results, and it has been difficult to separate primary from secondary events (Taylor 1984).

Duval-Beaupere and her associates (1985) in the study of flexibility of scoliosis demonstrated two different and noncorrelated phenomena: the collapse and the reducibility of the structural curve. In 228 paralytic curves, these two phenomena were quantified and correlated with different parameters of scoliosis: sex, stage of maturation, curve pattern, number of vertebrae in the curve, spinal and abdominal test values, and the scoliotic evolution rate. Reducibility can be predicted since it is an elasticity process. Collapse is more complex, but it is a prognostic factor for evolution and effectiveness of treatment.

Poussa et al (1989) studied spinal mobility in adolescent girls with thoracic idiopathic scoliosis. Their results indicate that the structurally healthy girls were taller and heavier that the scoliotic; and the difference was statistically significant for weight. The positional inclines of the sacrum, upper lumbar and thoracic areas were significantly smaller in the scoliotic, resulting in smaller lumbar lordosis and thoracic kyphosis in them.

In the thoracic spine, forward flexion was smaller, whereas extension and the total sagittal mobility were greater in the scoliotic. In the healthy controls, the thoracic clockwise rotation was significantly larger than the counterclockwise. This side difference had disappeared in the scoliotic, and their total thoracic rotation was indicatively smaller than in the controls. In the lumbar spine, extension was smaller in the scoliotic than in the controls. All spinal mobility measurements noted there was no change of general spinal flexibility in the scoliotic which indicate a general spinal stiffening associated with adolescent idiopathic scoliosis.

In another attempt, Poussa et al (1992) studied spinal mobility and posture in adolescent idiopathic scoliosis. The patients were divided into three groups according to the curve magnitude. Group (A) had curves smaller than 25 degrees, group (B) had curves between 25 and 35 degrees, and group (C) had curves greater than 35 degrees. The positional inclines of sacrum, upper lumbar and upper thoracic areas became more vertical as the curve size increased resulting in smaller lumbar lordosis and thoracic kyphosis. In the thoracic spine, flexion and bending to the right was smaller in group (C) than in the other groups. Rotations in both clockwise and counterclockwise directions decreased as the curve magnitude increased. In the lumbar spine, only bending to the left decreased significantly with the curve size increase. All thoracic and lumbar movements except lumbar rotations had a general tendency to stiffening as the curve magnitude increased. Of the mobility measurements thoracic rotation most clearly decreased with increased curves, which together with straightening of the spine could be an important features in the pathomechanism of a progressive idiopathic thoracic curve.

2.6. Review of Measurement Techniques

Determining the range of motion of a patient's spine is a clinically useful procedure, and is one of the methods recommended for evaluating spine impairment. Estimates of trunk flexibility frequently affect diagnostic, prognostic, and therapeutic decisions for a variety of neuromuscular, orthopaedic, and rheumatologic disorders. Although measurements of trunk flexibility are an important part of a clinical examination, subjective methods are usually used to assess spinal mobility (Merritt et al, 1986).

Radiographic evaluation has been the standard and most reliable technique for documentation and measurement of spinal motion. However, it has a number of limitations such as involving unnecessary radiation exposure, costly, and being time-consuming. Photographic methods have been widely used for studies both of posture (Goff, 1952) and of movement (Davis et al,1965). Other workers (Goff and Rose, 1964; Klausen, 1965) have described methods for obtaining and classifying scale diagrams of the lateral projection of the spine. However, none of these methods allow accurate comparison between measurements other than by visual observation (Loebl, 1967)

A number of objective measurement techniques have also been developed to quantify range of motion of the spine (see Table 2.1). These include various types of goniometers (Keeley, 1986; Loebl, 1967; Mayer et al, 1984; Moll and Wright, 1971; Troup et al, 1968; Reynolds, 1975; and Salisbury and Porter, 1987). Another technique uses marks on the skin to measure the changes in those markings as motion occurs (Macrae and Wright, 1969; Sturroch et al, 1973). Other techniques involve the use of flexible rulers (Burton, 1986), measurement of floor-to-finger distance (Gill et al, 1988; Merritt et al, 1986) and various types of instruments such as a spondylometer (Hart et al, 1974) or a kyphometer (Salisbury and Porter, 1987), flexicurve (Salminen et al, 1992). Cybex electronic

Table 2.1. Comparison of the Techniques of Spinal Movement Measurement

Source	Technique	Motion G/S	Thoracic=1 Lumbar=2	Flex Ext=1 Lat Bend=2 Rotation=3	Reliability
Moll & Wright (1971)	Centimeter Tape	G	1 & 2	2	High
Chiarello & Savidge (1993)	Cybex Electronic Degital Inclinometer-320 Fluid Goniometer	G	1	1	High
Salisbury & Porter (1987)	Goniometer	G	1	1	High
Gill & associates (1988)	Two-inclinometer, Modified Schobber	G	1	1	High High
Keeley & associates (1986)	Inclinometer	G	1	1 & 3	High
Loebl (1967)	Inclinometer	G	1 & 2	1	High
Mayer & associates (1984)	Two and Single inclionmeter	G	2	1	High
Mellin G (1987)	Inclinometer	G	1 & 2	1 & 2	High
Mellin G (1986)	Inclinometer with Campass	G	1 & 2	3	High

Table 2.1. Continue

Source	Technique	Motion G/S	Thoracic=1 Lumbar=2	Flex Ext=1 Lat Bend=2 Rotation=3	Reliability
Cohn & associates (1989)	Low-frequency Magnetic Field technology	G	1	1, 2, 3	High
Williams & associates	Modified Schober	G	1	1	High
Gauvin & associate (1990)	Modified Fingertip-to-floor (MFTF)	G	1	1	High
Fitzgerald & associates (1983) (1993)	Plastic Tape Measurement & Goniometer	G	1 & 2	1 & 2	High

G = General: either control group or nonscoliotic patients
S = Scoliosis
Flex = Flexion
Ext = Extension
Lat Bend = Lateral Bending

Table 2.1. Comparison of the Techniques of Spinal Movement Measurement

Source	Technique	Motion G/S	Thoracic=1 Lumbar=2	Flex Ext=1 Lat Bend=2 Rotation=3	Reliability
Williams & associates (1993)	Double inclinometer	G	1	1	Medium
Salminen & associates (1992)	Flexicurve Technique,	G	1	1 & 2	Medium
Reynolds P G (1975)	Goniometer	G	1 & 2	1 & 2	Medium
Salisbury & Porter (1987)	Kyphometer Flexicurve	G	1	1	Medium Medium
Hass & associates (1990)	Roentgenological Evaluation	G	1	2 & 3	Medium
Frost & associates (1982)	Tape measurement & Stepstool	G	1 & 2	1, 2, & 3	Medium

G = General: either control group or nonscoliotic patients
S = Scoliosis
Flex = Flexion
Ext = Extension
Lat Bend = Lateral Bending

Table 2.1. Comparison of the Techniques of Spinal Movement Measurement

Source	Technique	Motion G/S	Thoracic=1 Lumbar=2	Flex Ext=1 Lat Bend=2 Rotation=3	Reliability
Gill & associates (1988)	Fingertip-to-floor, Photometric Technique	G	1	1	Low Low
Salminen & associates (1992)	Finger-to-floor test Tape Measurement	G	1	1 & 2	Low
Dillard & associates (1991)	Isostation B200 and	G	1	1, 2, 3	Low
Rondinelli & associates (1992)	Single Inclinometer, Double Inclinometer, Back Range-of-motion inclinometry method	G	1	1	Low
Reynolds P G (1975)	Spondylometer, Skin distraction method	G	1 & 2	1 & 2	Low Low
Haley S M (1986)	Tape measurement	G	2	1 & 2	Low
Salisbury & Porter (1987)	Tape Measurement Diasonograph Ultrasound	G	1	1	Low Low

G = General: either control group or nonscoliotic patients
S = Scoliosis
Flex = Flexion
Ext = Extension
Lat Bend = Lateral Bending

digital inclinometer (Chiarello and Savidge, 1993) is another technique.

All the measurement methods have been reviewed in the present study (Table 2.1). Most of them suffer problems in terms of reproducibility. When analyzing reproducibility, test- retest measurements should be compared and then assessment of the reliability of the technique can be made using appropriate statistical methods. Only a few methods have been tested adequately for reliability, and most of such studies have been limited to spinal measurement in the sagittal plane alone rather than in three planes of movement. All the measurement techniques of spinal mobility used by the investigators were classified in three groups in terms of the reported degree of reliability. Among the reliable techniques of measurement, seven out of fourteen studies (%50) used inclinometer technique and the remaining studies involved other techniques. Among the medium reliable technique group reported in the seven studies, only one study (%14) used the inclinometer. There were ten studies in which low reliable techniques of measurement were reported. Only one study (%10) used an inclinometer for spinal mobility measurement (see Table 2.1).

Of these noninvasive methods, the one generally acknowledged to be preferable is the inclinometric technique which appears to be the method of choice. It is a feasible and potentially accurate method of measuring spinal mobility, because the subcutaneous bony structures that mark the upper and lower ends of the three spine regions can be palpated readily. It relies on gravity to indicate motion on a 360 degrees scale and the reliability of the technique has been reported by several investigators. Reliability of the inclinometer technique involves the accuracy and repeatability of the tool and assessment of intra- and inter-observer error. Keeley et al (1986) found high interrater reliability using the inclinometer technique (r=.90 for 11 normal subjects and r=.96 for nine chronic low back pain). In the same study, measurements of intrarater reliability by two physical therapists ranged from r=.91 to r=.98. Mellin (1986) found high interrater (r=.86 for flexion,r=.93 for extension) and intrarater reliabilities (r=.97 for flexion and r=.95 for extension). Rondinelli et al (1992) reported intera- and inter-rater reliability of inclinometry technique between r=.8 and r=.9. The method revealed to be reliable and reasonably accurate. It also has been recommended by The American Medical Association, and finally it can be used to measure range of motion in three plane of movements.

This study examines spinal mobility among scoliotic patients as compared to an able-bodied control group. It is expected that there is a difference between the spinal mobility of the two groups; if so the difference are to be qualified and correlated with different biodemographic parameters of scoliosis. Biodemograghic variables are classified as: growth index, genetic background, anthropometry characteristics, radiographic examinations, diagnostic symptoms. The mechanism through which these variables operate will be discussed in the following:

A. Growth

Age: Most cases of idiopathic scoliosis fall into the adolescent category because they are discovered during the pubertal growth spurt. Curves tend to increase because of the rapid growth and the destabilizing effect this has on the curved spine. One of the factors that influence the probability of progression in the skeletally immature patient is the age of the patient at the time of diagnosis. The younger the patient the greater the risk of progression.

Menstruation: Menarche may be used as a sign of maturity. This is another indicator of growth in girls. There is a greater risk of progression before the onset of menarche. The risk of curve progression before menarche is 50%. Postmenarchal risk of progression is less than 20% (Bunnell, 1988).

B. Genetic

Heredity: The etiology of adolescent idiopathic scoliosis has long been sought and number of theories have been advanced. Generally, the most promising of these relates to genetic factors (Hildebrandt, 1978). Wynne-Davis (1968) found 27 per cent of patients with scoliosis had a family history of the disease. In some family, so many members are scoliotics that it suggested that a genetic metabolic factor must be involved. The risk to fist degree relatives appears to be between three and four times greater than to children of unaffected parents (Pope et al, 1984). Czeizel et al (1978) noted that occurrence increased to 40 per cent when both parents were affected. This genetic predisposition may be one of a biomechanical factor, creating a situation in which the mechanics of progression supercede (Danbert, 1989).

C. Anthropometry

Weight and height: Children with a scoliotic deformity are reported to be taller and heavier than average when skeletal maturation is taken into account (Drummond and Rogala, 1980). Willner (1975) reported that children with scoliosis ceased to increase their weight much earlier than the control children. In terms of height, he found the scoliotic patient were taller than the normal children. On the other hand, Poussa (1989) presented a contrasted picture. He found the healthy school girls were taller and heavier than the scoliotic patients. Results have been contradictory as to whether a greater length of the spine is related to greater risk for scoliosis.

Leg Length Discrepancy: In idiopathic scoliosis, leg length discrepancy may be one of the factor responsible for the progression of the disease. In some studies, a shorter left than right leg was found in eighty percent of young children (Pope et al, 1984).

D. Radiographic Measurements

Cobb Angle: The diagnosis of the scoliosis can be confirmed only by the presence of a curvature measured by the Cobb method (Cobb, 1948). The severity of a curve is important when predicting further progression. A curve of 30 degrees in a skeletally immature person is at risk of significant progression when compared with a curve of 30 degrees in a mature adult. In a skeletally immature patient, curves of 20 degrees are at a 20% risk for progression. Those patients with curves of 30 degrees are at 60% risk for progression, and those with curves of 50 degrees are at a risk of 90% (Brosnan, 1991).

Kyphosis, Lordosis, and Sacrum Inclination: The development of an abnormal shape of the sagittal curves of the spine has been suggested to initiate the development of adolescent idiopathic scoliosis. Flattening of the sagittal curves of the spine has been noted to be the basic deformity in structural scoliosis and a primary etiologic factor. The connection between the flattening of the thoracic kyphosis and the development of structural scoliosis was first described by Adams (1865). Poussa (1989) also found the spinal sagittal positional curves were reduced in the scoliosis patients. The sacrum and the posture of the upper lumbar and thoracic areas were more vertical in the scoliotics than in the controls. These three inclines determine the lumbar lordosis and thoracal kyphosis, which in scoliosis patients were consequently significantly reduced.

Apex Level: In natural history of adolescent idiopathic scoliosis, curve patterns (thoracic, lumbar, thoracolumbar, and double major) of the vertebrae involved and their apex level must be taken into consideration.

Risser sign: Skeletal growth is assessed by Risser sign which represent the extent of the ossification of the iliac epiphysis. Ossification normally starts at the anterior superior iliac spine and progresses posteriorly to the posterior superior iliac spine. The iliac crest is divided into four quarters, and the stage of maturity is designated as the amount of progression. The likely progression of scoliotic curve can be based on Risser grades. Studies have shown that the risk of curve progression decreases with increasing skeletal maturity in another words, the lower the Risser grade at curve detection, the greater the risk of progression (Weinstein, 1994).

E. Symptoms of the patient

Pain and Its Frequency: The incidence of back pain in patients with scoliosis is comparable to the incidence of back pain in the general population. A study of 161 patients with adolescent idiopathic scoliosis showed that 80% complained of some back pain. Twenty-four percent of the patients with scoliosis consulted to a doctor because of back pain, and 6% had been hospitalized for backache. The incidence of frequent or daily backache was slightly higher in scoliotic group (37%) compared with the control group (25%) (Weinstein, 1994).

The rationale of our study can be understood for two reasons:

a) knowledge of the impact of adolescent idiopathic scoliosis on spinal mobility could be useful in the evaluation and treatment of the disease; b) characterization of an abnormal motion may be of the prognostic value.

CHAPTER THREE

METHODOLOGY

The technique described in this chapter will be used to test the association between adolescent idiopathic scoliosis and spinal mobility defined as the maximum range of motion. Two groups, patients and able-bodied subjects, were selected and biodemographic variables as well as spinal mobility variables were measured and their relationships analysed.

3.1. Hypothesis

Two different hypotheses are examined in this study: (1) there is a difference between the spinal mobility of scoliotic patients and normals. (2) There is a relationship between some biodemographic variables and spinal mobility in scoliotic patients.

3.2. Sample Design and Data

This study is a prospective cohort study which consisted of two groups: scoliotic patients and able-bodied (healthy control) subjects. A preliminary pilot study was conducted prior to the study. This involved testing several versions of a data sheet on a few subjects with adolescent idiopathic scoliosis which led to improvement of the data sheet and standardisation of the method of measuring spinal mobility. The pilot study also involved three measurements on each patient at different time intervals to verify the reliability of the measurements. We then began the process of recruiting patients with adolescent idiopathic scoliosis and able-bodied subjects and measurements were recorded on the data sheet. An example of this data sheet is provided in Appendix A.

3.2.1 Inclusion and Exclusion Criteria

Considering that spinal mobility of scoliotic patients is our concern, some restrictions were applied in including or excluding the subjects in the sample. We included all scoliotic patients who were: (a) nonoperated; (b) had combined thoracic and lumbar curves; (c) girls; (d) aged between ten and eighteen years; (e) had an upper thoracic curve with the apex situated between T5 and T11 and the lower lumbar curve with the apex situated between T11 and L3; (f) had a curve magnitude above 10 degrees according to the Cobb method.

Boys were excluded because idiopathic scoliosis is more common among girls, the girl/boy ratio being approximately 9:1 (Cailliet, 1975; Hildebrandt, 1978). Considering that idiopathic scoliosis was our concern, curves below ten degrees were excluded because it is not clear wether these type of curves are idiopathic scoliosis or not.

3.2.2 Sample Size

A variety of factors influence the size of the sample appropriate for any study. The following criteria were used for the sample size determination:

A. Confidence level

It is usually accepted to use the 95 percent level of confidence in determining sample size. The value of 1.96 is ninety-five percent of the cases fall +/- 1.96 standard deviation units from the mean. If one wishes to be 99 percent confident, a larger sample will be required.

B. Estimation of the population standard deviation from a major variable in the study group.

Since the most important variables in our study are the spinal mobility variables (dependent variables), the mean of the standard deviations of the spinal mobility variables (ten variables) was used for this purpose and was calculated as 8.2.

C. Determining the minimum accuracy which would be acceptable.

The accuracy is referred to in statistics texts as the confidence interval. In this study the confidence interval was chosen as 2 percent. If we want to double the accuracy, sample size must be quadrupled.

D. the sample size was computed according to the following formula (Jackson, 1988):

$$\text{Required Sample Size}=\left[\frac{\text{(confidence limit)(sd pop)}}{\text{accuracy}}\right]^2$$

$$n = \left[\frac{1.96(8.2)}{2}\right]^2 = 67$$

Sixty five girls with progressive adolescent idiopathic scoliosis and 20 age-matched adolescent as control group, 13 boys and 7 girls with structurally normal spine comprised the material.

The smaller size of able-bodied group (N=20) was determined by taking into consideration the lower standard deviation of able-bodied subject data (spinal mobility), the time limitations of this study, and the results of the test of normality. The test of normality (Kolmogorov-Smirnov test) was run to insure of the goodness of its size. This normality test is particularly useful for testing the shape and location of a sample distribution.

The scoliotic patients were recruited from the scoliosis clinic at Sainte-Justine Hospital in Montreal. The able-bodied subjects were recruited from the trauma clinic where they were consulted for minor orthopaedic problems and had no history of back problem. All the subjects were measured and evaluated in the clinic. The characteristics age, height, and weight of the two groups are presented in Table 3.1.

Table 3.1. Sample Characteristics

	Scoliotics		Controls		
	M	SD	M	SD	p
Age (years)	14.6	2.12	13.76	1.83	NS
Height(Cm)	158.12	7.87	159.12	11.17	NS
Weight(kg)	50.02	9.14	53.81	21.00	NS

SD =standard deviation; M =mean

3.3. Variables

Two groups of variables were evaluated: biodemographic and spinal mobility as independent and dependent variables respectively. In this section all variables and their values recorded on the data sheet will be presented:

A. Growth

Age.

For proper identification of each volunteer, the subject's hospital card was copied on the data sheet. Age was calculated on the basis of subject's birth date in years.

Menstruation.

Information about the date of first menstruation was obtained from each subject's history and its period calculated in years. Those who did not have menstruation were coded as 0.

B. Genetic

Heredity.

If there was any record of scoliosis in the subject's family, then it was denoted as 1, otherwise 2.

C. Anthropometry

Height.

It was measured in centimetres with a tape measuring device. The subject was asked to stand against a wall and measurement was done from top of the head to the heels.

Weight.

While the subject stood on a medical scale, weight was measured in kilograms.

Leg Length Discrepancy.

While the subject was in the supine position with the knees straight, the actual length of each leg was measured in cm from the anterior superior iliac spine (ASIS) of the ilium to the medial malleolus.

D. Radiographic Measurements

Cobb Angle.

Cobb angles were measured on standing postero-anterior radiographs of all subjects with adolescent idiopathic scoliosis. A line was drawn perpendicular to the upper margin of the vertebra which diverted towards the concavity. A line was also drawn on the inferior border of the vertebra with the greatest angulation diverted towards the concavity. The angle of those transecting lines was noted and recorded for both thoracic and lumbar curves (Cobb, 1948).

Sacrum Inclination.

It was determined from each subject's standing lateral X-ray. A line was drawn parallel to the superior border of the sacrum. The angle of this plane with the horizontal line was measured in degrees and recorded.

Kyphosis.

It was also taken from the lateral X-ray. A line was drawn parallel to superior border of T4. A line was also drawn parallel to the inferior border of L1. The angle of these transecting lines was noted as the kyphosis angle.

Lordosis.

It was also taken from the lateral X-ray. A line was drawn parallel to superior border of L1. A line was then drawn parallel to the inferior border of L5. The angle between the transection of these two lines was noted as the lordosis angle, and recorded.

Apex Level.

It was noted by the location of the vertebra most deviated from the vertical axis on the postero-anterior X-ray.

Risser Sign.

Ossification of the epiphysis usually starts at the anterior superior iliac spine and progresses posteriorly. It was noted on the postero-anterior X-ray (Risser,1958). The iliac crest is divided into four quarters, and the excursion or stage of maturity is designated by the amount of progression. If the first quarter was ossified it was noted as Risser 1, while the second quarter was a Risser 2, and so on.

E. Symptoms of the patient

Back Pain.

It involves the use of a "visual analogue pain scale". This scale consists of a line 100mm in length at the left hand of which is printed "No Pain", and at the right hand end maximum pain (can't be worse). The subject was given the scale and asked to make a mark on the line at a point where he felt the level of pain (Melzack, 1983).

Frequency of Pain.

The subject's frequency of pain was determined using the following criteria:

Frequency of Pain		Level of Pain
every day	=	5
more than 3 times in a week	=	4
more than 1 time in a week	=	3
less than 1 time in a week	=	2
Occasionally	=	1

Spinal Mobility

-Sagittal mobilities: motions occuring in the sagittal plane consist of flexion and extension.

-Frontal mobilities: motions that occur in this plane consist of right and left lateral bending.

-Horizontal mobilities: motions occuring in this plane consist of right and left rotation.

-Schober test: is measurement of lumbar flexion using tape measure.

3.4. Procedure

A Plurimeter-V was used to obtain measures of spinal mobility. The Plurimeter-V is a precision inclinometer for measuring the range of motion of joints, which was invented by Dr.Jules Rippstein in 1986. It has a free-moving needle that is counter-weighted for accurate reading. The housing is filled with oil which lubricates the bearings and dampens oscillation, to provide quick readings. The disc is graduated in two degree intervals over the 360 degrees range and is affixed to a straight edge base. When measuring the spine, adjustable legs can be added to the base of the instrument to stabilize the instrument against the spine and to position the legs between the spinal processes. It allows more accurate measurements as compared to conventional goniometer (Gerhardt and Rippstein, 1990). The vertical and neutral-zero starting position are automatically indicated changes of inclination of the base reflected on the dial in degrees as shown in Figures 3.1 and 3.2

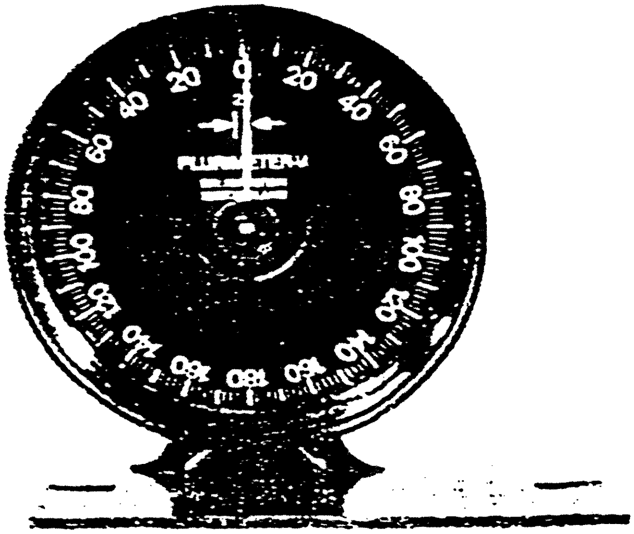


Figure 3.1. Plurimeter-V
Adapted from: Gerhardt, 1991

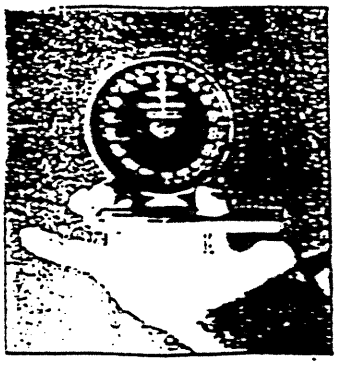


Figure 3.2. Plurimeter-V with adjustable legs
Adapted from: Gerhardt, 1991

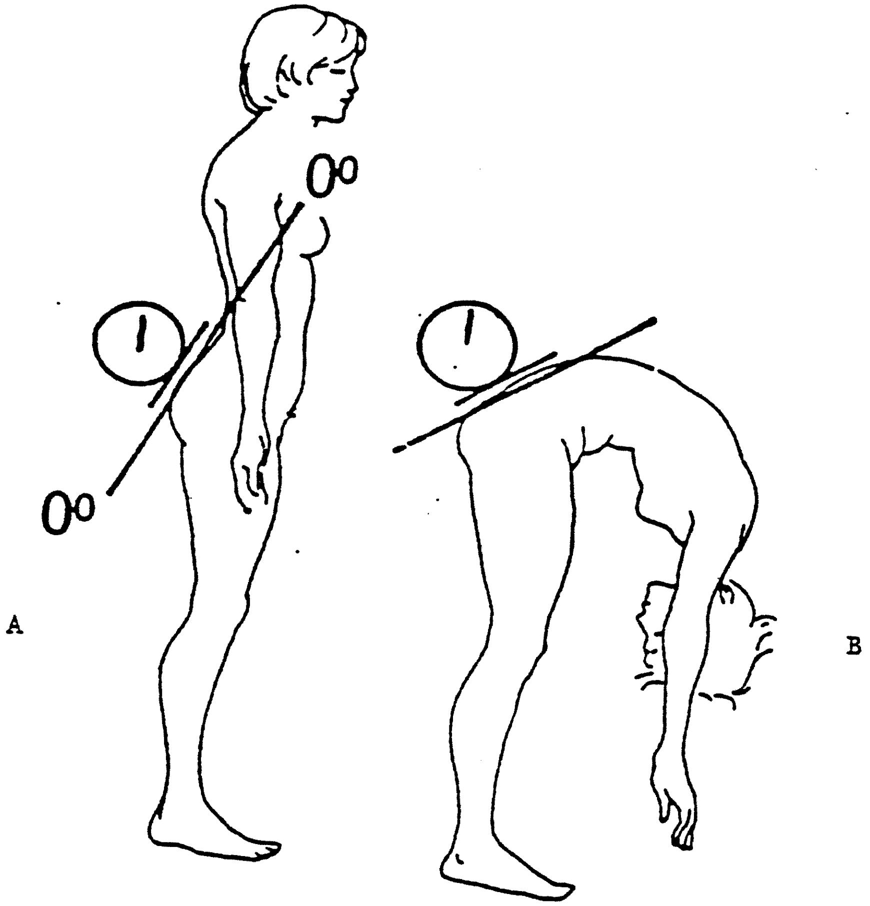
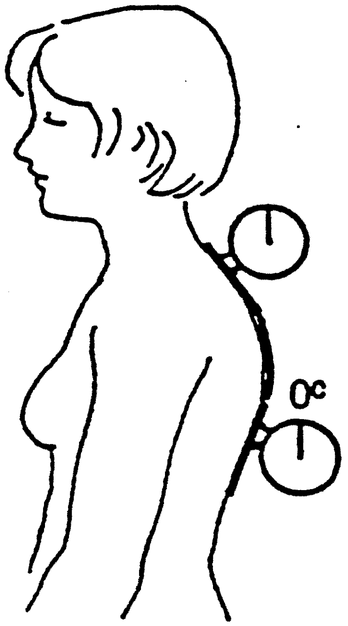


Figure 3.3. Measurement of spinal flexion.
A. Neutral position.
B. Forward bending.
Adapted from: Gerhardt, 1991.



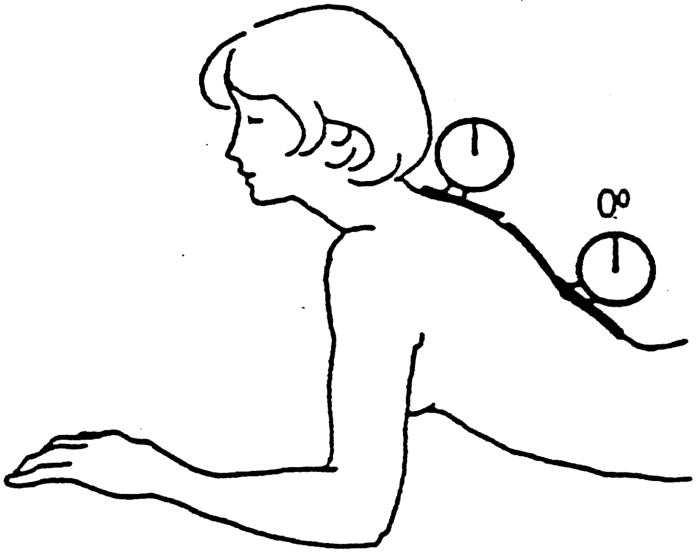


Figure 3.5. Measuring thoracic extension.
Adapted from: Gerhardt, 1991.

Figure 3.4. Measurement of kyphosis angle.
Adapted from: Gerhardt, 1991.

(Gerhardt & Rippstein 1990). The review of techniques in chapter two confirmed the reliability of this instrument in measuring the spinal mobility in various studies.

3.4.1. Levels of Measurement.

With the subject standing in neutral position, the spinous processes of T1, L1 and S1 were palpated and the skin over these bony prominence marked.

3.4.2. Measurement of mobilities.

Flexion Technique

Flexion of the spine was measured in standing position rather than sitting because in the sitting position, the sagittal curvatures of the spine, especially lordosis, change. This may affect the outcome of the measurement Therefore, all the measurements were taken with the subject standing (Figure 3.3). Spinal flexion was measured with the subject standing, and the instrument placed with its base tangential to the spine over the T1 spinous process and the dial set at 0. The subject then was asked to bend forward as far as possible trying to touch the floor without bending the knees, then the angle was recorded. This procedure was repeated for L1 and S1 to obtain spinal flexion. Bending forward is a combined flexion of the hip, pelvic tilt, flexion of lumbar and thoracic spine. To determine thoracic flexion, the T12 inclinometer reading was subtracted from the L1 reading. To obtain lumbar flexion, the S1 inclinometer reading was subtracted from L1 reading (Gerhardt and Rippstein, 1990).

Extension technique

The same landmarks that were described for the flexion technique were used for measuring extension. To determine thoracic extension, first the kyphosis angle was obtained by instructing the subject standing in neutral position. The inclinometer was placed on the lower part of the kyphosis and the dial set on zero degree (Figure 3.4). The instrument was then repositioned on the upper part of the kyphosis and the angle was recorded. The subject then was instructed to lie prone on the examining table with arms braced ahead and raised the head and shoulders until the upper arms were perpendicular to the table. Then the measurement was repeated as in the standing position. The angle of kyphosis was read. The difference between the former and the latter angles indicated

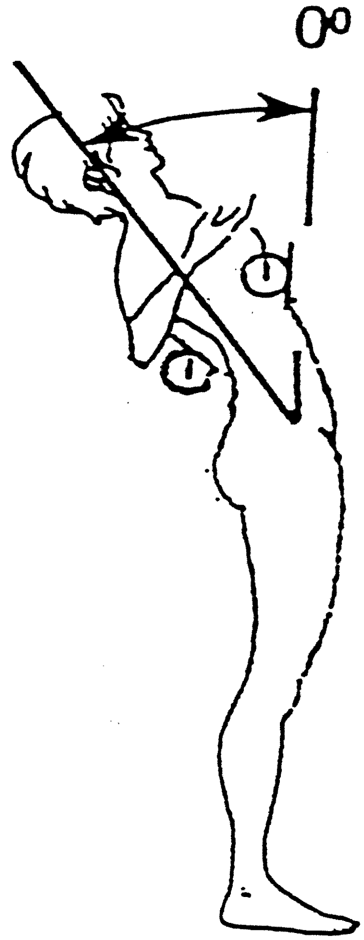


Figure 3.6. Measurement of lumbar extension.
Adapted from: Gerhardt, 1991.

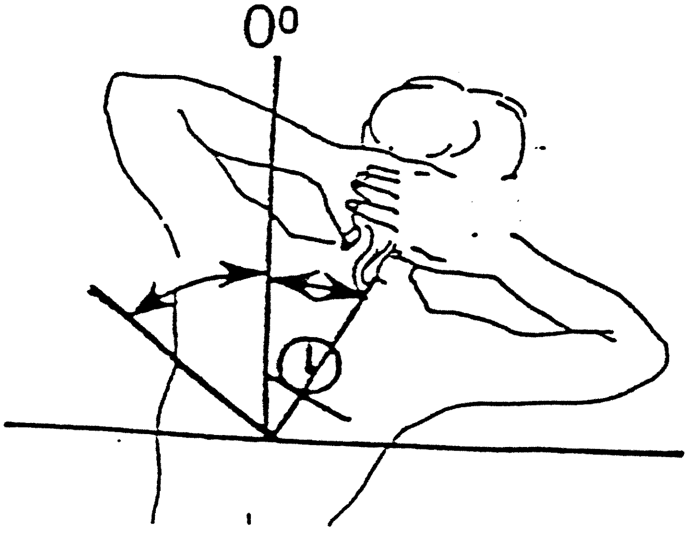


Figure 3.7. Measurement of lateral bending.
Adapted from: Gerhardt, 1991.

thoracic extension (Figure 3.5). For obtaining total sagittal mobility of thoracic spine, thoracic flexion was added to the thoracic extension.

Measurement of lumbar extension began with the subject in a standing position. The inclinometer was placed over L1 and the dial set at zero degree. The subject was then instructed to bend backward with the knees straight, and the angle was recorded (Figure 3.6). The same technique was applied for S1. To determine lumbar extension, the S1 inclinometer reading was subtracted from the L1 reading (Gerhardt and Rippstein, 1990). For obtaining total sagittal mobility of the lumbar region, lumbar flexion and lumbar extension were added.

Lateral bending technique:

Lateral flexion was measured with the subject standing in a neutral position, with the feet 20 cm apart and hands behind the neck. The inclinometer was placed with its base horizontal at the T1 level and the dial set at zero degree. The subject was then asked to bend laterally (first to the right and then to the left) as far as possible, to look ahead and avoid forward flexion, extension and/or rotation, and to hold this maximum bending position. The angles were then recorded. Similar measurements were made when inclinometer was placed over T12 and S1 (Figure 3.7). To obtain thoracic bending, the T12 inclinometer reading was subtracted from the T1 reading. The differences between T12 and S1 inclinometer readings indicated lumbar bending (Gerhardt and Rippstein, 1990). For obtaining thoracic lateral bending sum, thoracic right bending and thoracic left bending were added. The similar calculation was done for obtaining lumbar lateral bending sum.

Rotation Technique:

The subject was asked to lie supine on the examining table in a neutral position the pelvis was stabilized on the table. The inclinometer was held over the sternum below the sternal notch and the dial set at zero (Figure 3.8). The subject was asked to rotate maximally to the left and to the right while the pelvis was supported in order not to move. The angle was recorded (American Medical Association, 1986). For obtaining rotation sum, right rotation was added to the left rotation.

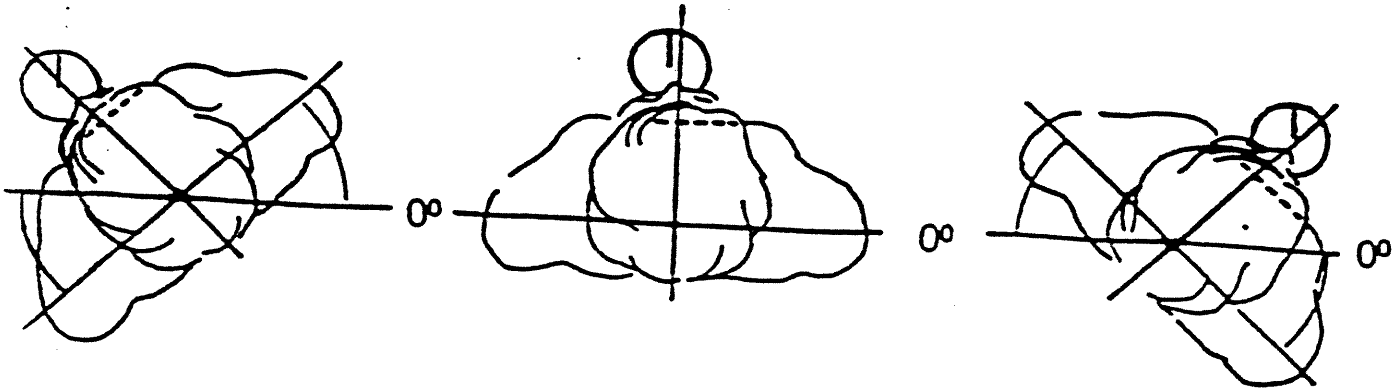


Figure 3.8. Technique for measuring rotation.
Adapted from: Gerhardt, 1991.

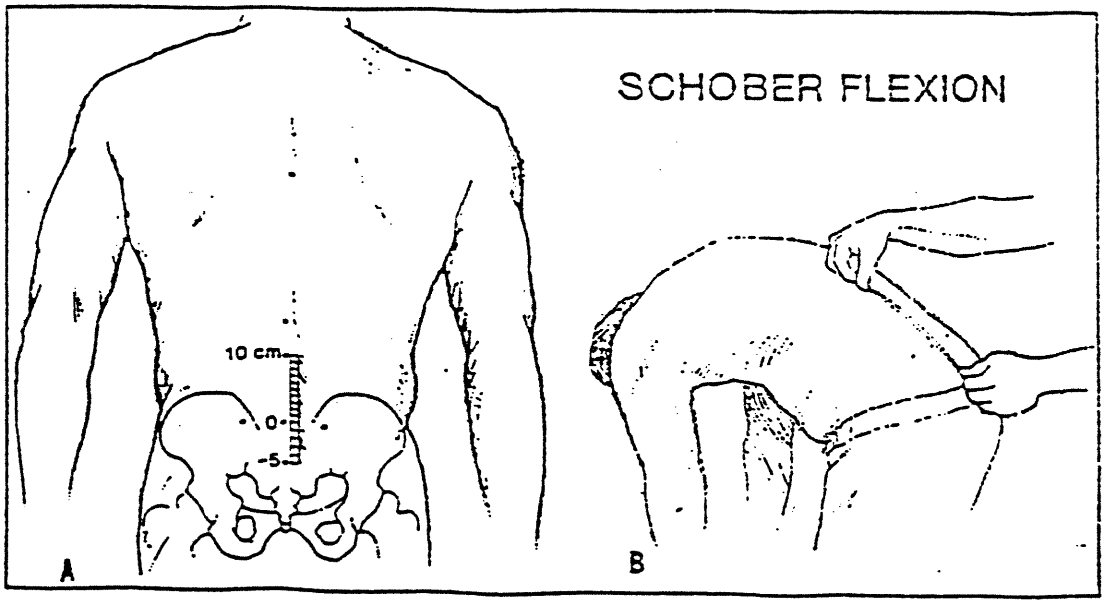


Figure 3.9. Schober test.
Source: Merritt, 1986.

Schober Test:

This is a method using a tape measure in which three marks are inked on the skin overlying the lumbosacral spine with the subject standing erect. The first mark is placed at the lumbosacral junction which is represented by the spinal intersection of a line joining the dimples of Venus. Further marks are inked 5 cm below and 10 cm above the lumbosacral junction (Figure 3.9). The subject is then asked to touch his toes, and the new distance between the upper and lower marks is measured (Macrae and Wright, 1969).

3.5. Statistical Analysis

Statistical data analysis consists of the long process of hypothesis formulation, instrument construction, and data collection. To conduct our study properly it was necessary to analyze the data so that (1) we can properly test our hypotheses or answer our research questions, and (2) we can present the results of the study to our readers in an understandable and convincing form (Bailey, 1982). This can be achieved through the processes of description, explanation, and prediction. Description will be conducted by descriptive statistics: univariate analysis, tabulation and crosstabulation (bivariate presentation). Our first hypothesis contains two variables, making a bivariate table sufficient to test the hypothesis.

Explanation and prediction are generally more complicated than description and require more computation as well as more interpretation that can be done by explanatory and predictive statistics. Explanatory statistical analysis can take a number of forms but generally consists of the analysis of a relationship between two or more variables. The first task was to use the laws of probability to see whether we can say with confidence that a relationship exists between two of our selected variables. This was accomplished through the computation of statistical tests of significance. The student t-test was run with Systat software on a Macintosh computer to determine if a difference was found to exist between the experimental and control groups. In the next step, a correlation analysis was utilized to assess the strength of relationship between the dependent and independent variables. By strength of relationship we mean how much one variable affects the other. In our case, for example, how much the various independent variables affect the spinal mobility. If we either suspect or have shown that a relatively strong relationship exists between variables, we can use a statistical technique that enables us to predict the score of one variable from the knowledge of the other variable. The most popular statistical method for prediction is regression analysis. Regression analysis also forms the basis for the most so-called causal models, which attempt to show causal relationships rather than mere correlations among variables.

The correlation analysis was run between each dependent variable and independent variable by using SPSS software on a PC computer and the products were arranged into single tables which will be demonstrated in next chapter.

The forward stepwise multiple regression analysis was run for each dependent variable and the independent variables by using SPSS software.

CHAPTER FOUR

RESULTS

The results of data analysis will be presented in four sections: parameters' descriptive statistics, biodemographic and mobility differentials (t-test), bivariate analysis, and multivariate analysis.

4.1. Parameters' descriptive statistics

Table 4.1 displays the statistical characteristics of the parameters of our study. Some of the parameters, especially those which are expected to play a role in the range of motion of the spine, have a greater standard deviation: these include thoracic Cobb angle (13.5 degrees), lumbar Cobb angle (10.59 degrees), lumbar lordosis (12.8 degrees), thoracic kyphosis (10.3 degrees), and sacrum inclination (9.6 degrees). There is a large standard deviation in weight and height of the subjects, 9.1 kg and 7.8 cm respectively. Fifty percent of the subjects have mentioned that they had scoliosis in their families. The average leg length discrepancy was 1.9 cm indicating that a few of the subjects had some leg length discrepancy.

Table 4.1 Descriptives of biodemographic variables of the patient group.

VARIABLES	MEAN	S.D	MINIMUM	MAXIMUM
Age (years)	14.6	2.1	10.4	18.6
Menstruation (years)	1.8	1.8	0.0	7.2
Heredity	1.5	0.5	1.0	2.0
Weight (kg)	50.0	9.1	29.0	69.0
Height (cm)	158.1	7.8	139.0	181.0
Leg Length Discrepancy(cm)	1.9	0.2	1.0	2.0
Thoracic Cobb Angle(degrees)	34.2	13.5	10.0	72.0
Lumbar Cobb Angle(degrees)	32.3	10.6	10.0	65.0
Sacrum Inclination(degrees)	46.9	9.6	29.0	69.0
Kyphosis (degrees)	20.1	10.3	0.0	45.0
Lordosis (degrees)	46.1	12.8	15.0	77.0
Thoracic Apex Level	T7	0.9	T5	T10
Lumbar Apex Level	L2	0.8	T12	L3
Risser Sign	2.4	1.7	0.0	6.0
Pain (mm)	21.2	28.1	0.0	100.0
Pain Frequency	1.3	1.8	0.0	5.0

4.2. Biodemographic and Mobility Differentials

The significance of differences of the means between the scoliotics and the able-bodied were calculated using the student t-test for independent groups. Table 4.2, 4.5, 4.6 and 4.7 present the results of the t-test.

4.2.1. Biodemographic Differentials

Some of the biodemographic characteristics are compared between the scoliotics and able-bodied. Table 4.2 shows that there is no statistically significant difference between the height, weight, and age of the two groups. The large value of standard deviation for height and weight variables pertain to the fact that both variables are growth indicators which highly depend on the age of the subjects who are between 10 to 18 years old. It is obvious that some of the subjects are before their pubertal growth spurt and some after, which can affect their height and weight as well as flexibility. The two groups were not comparable for sex parameter.

Table 4.2 Data on the material and statistical significance between the scoliotics and controls

	Scoliotics		Controls		
Variables	M	SD	M	SD	p
Age(years)	14.5	2.1	13.7	1.8	NS
Height (cm)	158.1	7.8	158.1	12.2	NS
Weight (kg)	50.0	9.1	53.7	16.2	NS

Source: calculated by the survey data
M = mean; SD = standard deviation; NS = not significant.

4.2.2 Mobility Differentials

In this section, spinal mobility (thoracic, lumbar, and thoracolumbar rotations) will be discussed separately. Before doing this, spinal mobility of normal subjects and those of other studies will be compared in order to identify whether there is any discrepancy among them.

Table 4.3 presents the data pertaining to the measurements of normal range of lumbar mobility of the available studies published in the literature. Lumbar mobility measurements of able-bodied subjects measured by inclinometer in the current study agree with most of studies presented in Table 4.3. Mayer et al (1984), Rondinelli (1992), Williams (1993), Keely (1986), Dillard (1991), and Chiarello (1993) reported mean values of 55, 51, 51, 64, 63, and 59 degrees for lumbar flexion and 27, 20, 27, 28, and 32 degrees for lumbar extension respectively, except for Rondinelli (1992) study. Lumbar extension measurement was not available in Rondinelli (1992) study. Mean values of current study for lumbar flexion and lumbar extension are 55.1 and 22.4 degrees respectively.

Merritt (1986), Portek (1983), Sullivan (1994), and Poussa et al (1989) in their studies reported different mean values as 31, 43, 33, and 25 degrees for lumbar flexion and also 9, 12, 54, and 37 degrees for lumbar extension respectively.

In case of lumbar lateral bending measured by inclinometer there were two studies available. Dillard (1991) reported mean values of 39 degrees for right bending and 38 degrees for left

Table 4.3 Comparison of measurement of lumbar spinal mobility in normal subjects in the available studies.(the values are in degrees)

Inclinameter								Other devices					
Source	N	Flx	Ext	RtB	LtB	RtR	LtR	Flx	Ext	RtB	LtB	RtR	LtR
Cohn,1989	19	-	-	-	-	-	-	50	16	17	18	4	5
Chiarello, 1993	12	59	32	-	-	-	-	59	29	-	-	-	-
Dillard, 1991	20	63	28	39	38	27	27	59	37	39	39	39	39
Keely, 1986	12	64	27	-	-	-	-	-	-	-	-	-	-
Merritt, 1986	50	31	9	-	-	-	-	-	-	-	-	-	-
Mayer et al, 1984	13	55	27	-	-	-	-	-	-	-	-	-	-
Portek, 1983	11	43	12	-	-	-	-	54	16	-	-	-	-
Poussa, 1989	25	25	37	21	20	36	37	-	-	-	-	-	-
Rondinelli,1992	8	51	-	-	-	-	-	55	-	-	-	-	-
Sullivan, 1994	33	33	54	-	-	-	-	-	-	-	-	-	-
Williams, 1993	15	51	20	-	-	-	-	-	-	-	-	-	-
Current Study	20	55	22	19	17	41*	40*	-	-	-	-	-	-

N = Sample size
Flx = Flexion
Ext = Extension
RtB = Right Bending
LtB = Left Bending
RtR = Right Rotation
LtR = Left Rotation
*: Thoracolumbar rotation

Table 4.4 Comparison of measurement of thoracic spinal mobility.

Source		Inclinometer						
	N	Group	Flx	Ext	RtB	LtB	RtR	LtR
Poussa, 1989	25	C	62	-3.3	32	34	17	13
Current study	20	C	20	32	37	41	41*	40*
Poussa, 1989	29	S	54	16	32	34	13	13
Current study	65	S	18	18	32	36	34*	33*

N = Sample Size
C = Control subject
S = Scoliotic subject
Flx = Flexion
Ext = Extension
RtB = Right Bending
LtB = Left Bending
RtR = Right Rotation
LtR =Left Rotation
*: Thoracolumbar rotation

bending. Poussa et al (1989) reported mean values of 21 degrees and 20 degrees for right bending and left bending respectively. The mean values of current study for lumbar right bending is 19.1 degrees and 17.9 degrees for lumbar left bending which agree with those of Poussa et al (1989).

Since the thoracic and lumbar rotation have been considered together in this study no comparable data were found in earlier studies.

In the case of normal thoracic mobility measurement, there was one study available based on inclinometric measurement. Poussa et al (1989) in their study reported different values for thoracic flexion and thoracic extension but their total sagittal mobility value is almost the same as this study (Table 4.4). The mean values of thoracic lateral bending to the right, lateral bending to the left, and the sum of lateral bending in current study (37 and 41 degrees for right and left bending respectively) agrees with the results of Poussa et al (1989) (32 and 34 degrees for right and left bending respectively).

It may be concluded that the differences in the measurement values could be attributed to the techniques of measurement. This is the reason why there is no accepted standardized techniques of measurements of the range of motion of spinal mobility. In the absence of accepted standardized techniques of measurements, it is required to standardize the quantitative evaluation of these motions by clinicians in the local treatment settings with trial and error criteria as we did in this study.

4.2.2.1. Thoracic Mobility

Table 4.5 and Figure 4.1 illustrate the thoracic mobility and its difference between the scoliotics and control groups. In the thoracic spine, forward flexion was reduced by 12 per cent in scoliotics, which was not statistically significant, whereas extension (p <0.001) and total sagittal mobility (p <0.001) were significantly smaller in scoliotics. Thoracic extension was reduced by 43 per cent and total sagittal mobility was reduced by 31 per cent. The left, right, and total lateral bending were smaller in scoliotics but not statistically significant. They were reduced by 11, 13, and 12 per cent respectively. This means that the only significant difference in thoracic region was extension which could be due to reduced thoracic kyphosis.

Table 4.5 Mobility measurements of the thoracic spine in scoliotics and controls, and level of statistical significance of differences -

	Scoliotics		Controls		
	M	SD	M	SD	p
Flexion	17.8	7.4	20.3	6.1	NS
Extension	18.3	11.9	32.3	7.6	<0.001
Flexion + Extension	36.1	13.8	52.6	8.3	<0.001
Lateral bending right	32.3	10.5	37.3	7.7	NS
Lateral bending left	36.3	11.9	41.0	8.9	NS
Lateral bending sum	68.6	18.9	78.3	14.8	NS

Source: calculated by the survey data
M = mean; SD = standard deviation; NS = not significant.

Table 4.6 Mobility measurements of the lumbar spine in scoliotics and controls, and level of statistical significance of differences -

	Scoliotics		Controls		
	M	SD	M	SD	p
Flexion	46.8	10.6	55.1	12.0	<0.001
Extension	23.0	9.0	22.4	9.6	NS
Flexion + Extension	69.9	13.7	77.5	12.0	NS
Lateral bending right	16.8	7.1	19.1	6.5	NS
Lateral bending left	15.2	6.9	17.9	7.5	NS
Lateral bending sum	32.0	11.9	37.1	12.6	NS

Source: calculated by the survey data
M = mean; SD = standard deviation; NS = not significant.

4.2.2.2. Lumbar Mobility

The mobility measurements of the lumbar spine demonstrated that flexion is significantly reduced (p <0.001) in scoliotics. Lumbar flexion was reduced by 15 per cent in scoliotic patients. All other mobility measurements of scoliotics were not significantly different from the controls. Interestingly enough, extension in scoliotics was slightly greater than in controls. It was increased by three per cent. Right, left, and total lateral bending were reduced by 12, 15, and 14 per cent. Also total sagittal mobility was reduced by ten per cent. Table 4.6 and Figure 4.2 show the result of the test of significance between the two groups. The results show that lumbar flexion in scoliotic patients is the only mobility that is significantly different from those of able-bodied group.

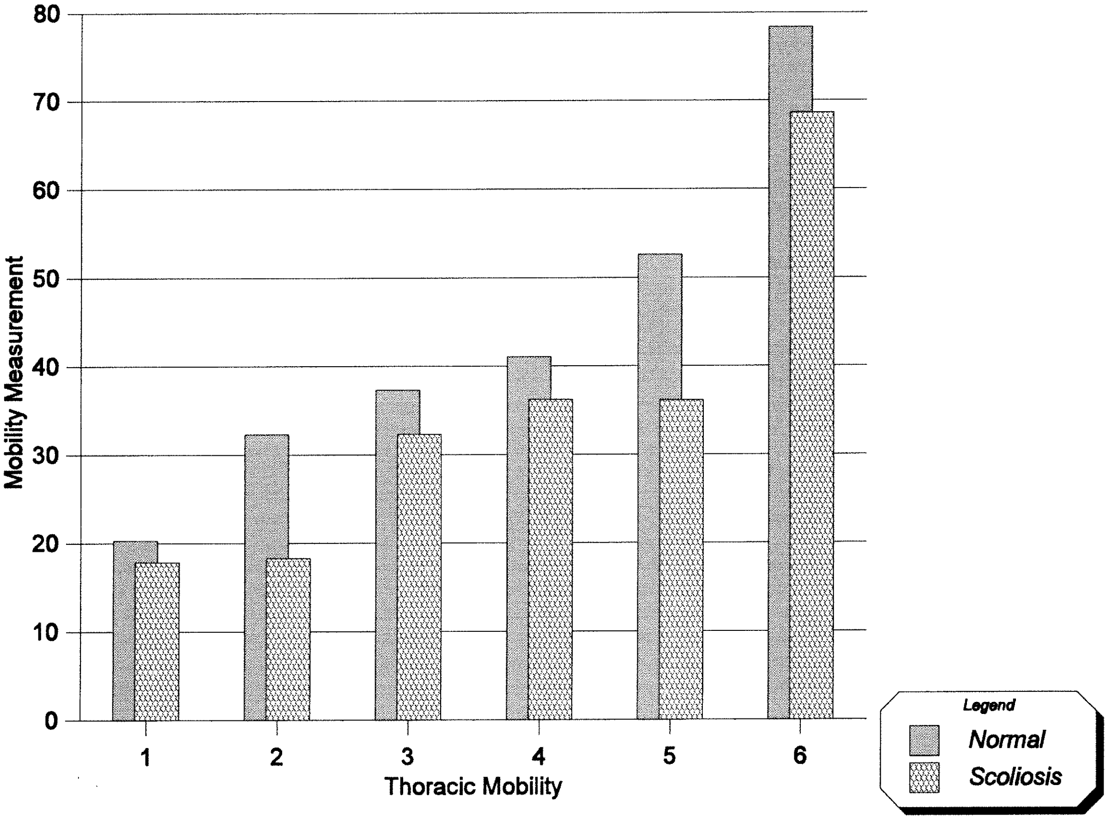
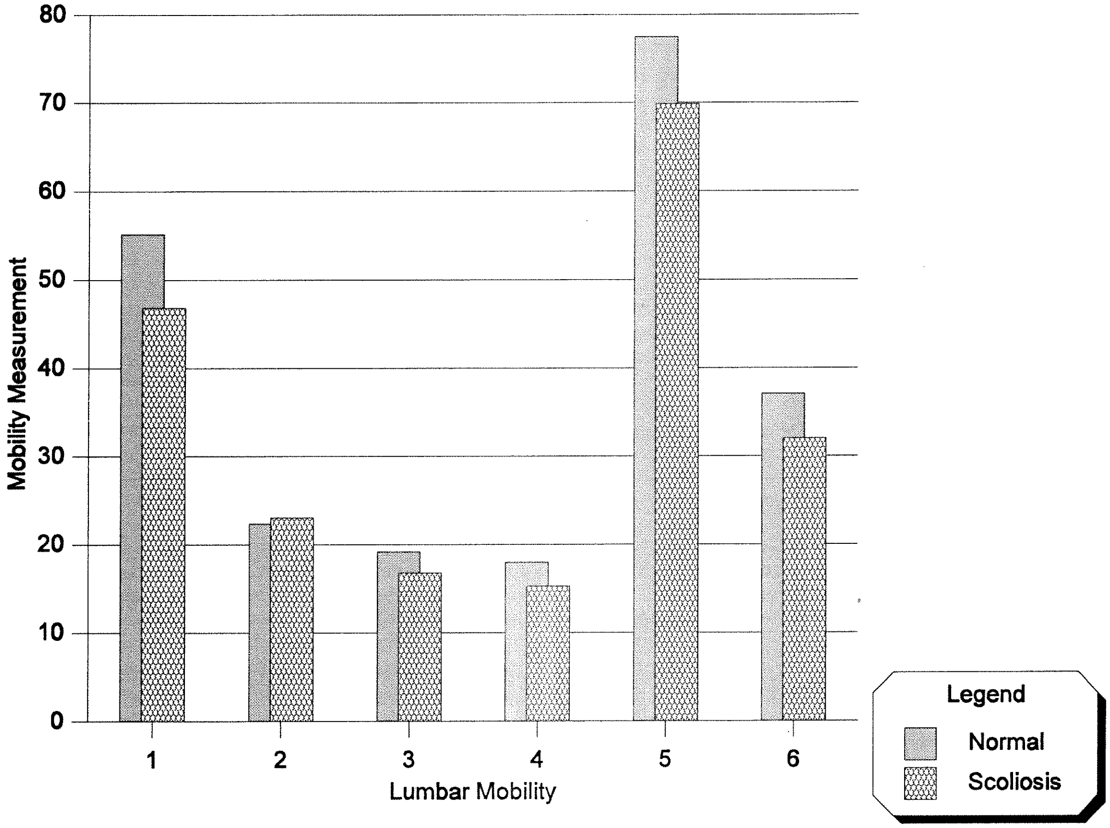


Figure.4.1 Thoracic Mobility Comparison

1= Thoracic Flexion ==============> not significant
2= Thoracic Extension =============> significant
3= Thoracic Right Bending ==========>not significant
4= Thoracic Left Bending ===========>not significant
5= Total Thoracic Sagittal Mobility ====> significant
6= Total Thoracic Side Bending ======> not significant

Figure 4.2 Lumbar Mobility Comparison



1= Lumbar Flexion ===================> significant
2= Lumbar Extension===================>not significant
3= Lumbar Right Bending=============== >not significant
4= Lumbar Left Bending=================> not significant
5= Total Lumbar Sagittal Mobility========> not significant
6= Total Lumbar Side Bending===========>not significant

4.2.2.3. Thoracolumbar Rotation Mobility

Table 4.7 and Figure 4.3 compare thoracolumbar rotation mobility of the spine between the scoliotics and controls. In all planes of rotations, left and right rotation as well as combined rotations , there were significant differences from the controls (p<0.001). Right, left, and rotation sum (left plus right) were reduced in scoliotic patients by 18, 20, and 19 per cent respectively as compared to the able-bodied group. The results show that there is significant differences in axial plane of movement between the two groups.

Table 4.7 Rotation mobility measurements of the thoracolumbar spine in scoliotics and controls, and level of statistical significance of differences

	Scoliotics		Controls		
	M	SD	M	SD	p
Rotation right	33.8	7.5	41.1	7.4	<0.001
Rotation left	32.8	7.8	40.8	6.7	<0.001
Rotation sum	66.6	12.6	81.9	12.6	<0.001

Source: calculated by the survey data
M = mean; SD = standard deviation; NS = not significant.

The result show that in general scoliotic patients have less mobility than healthy controls.

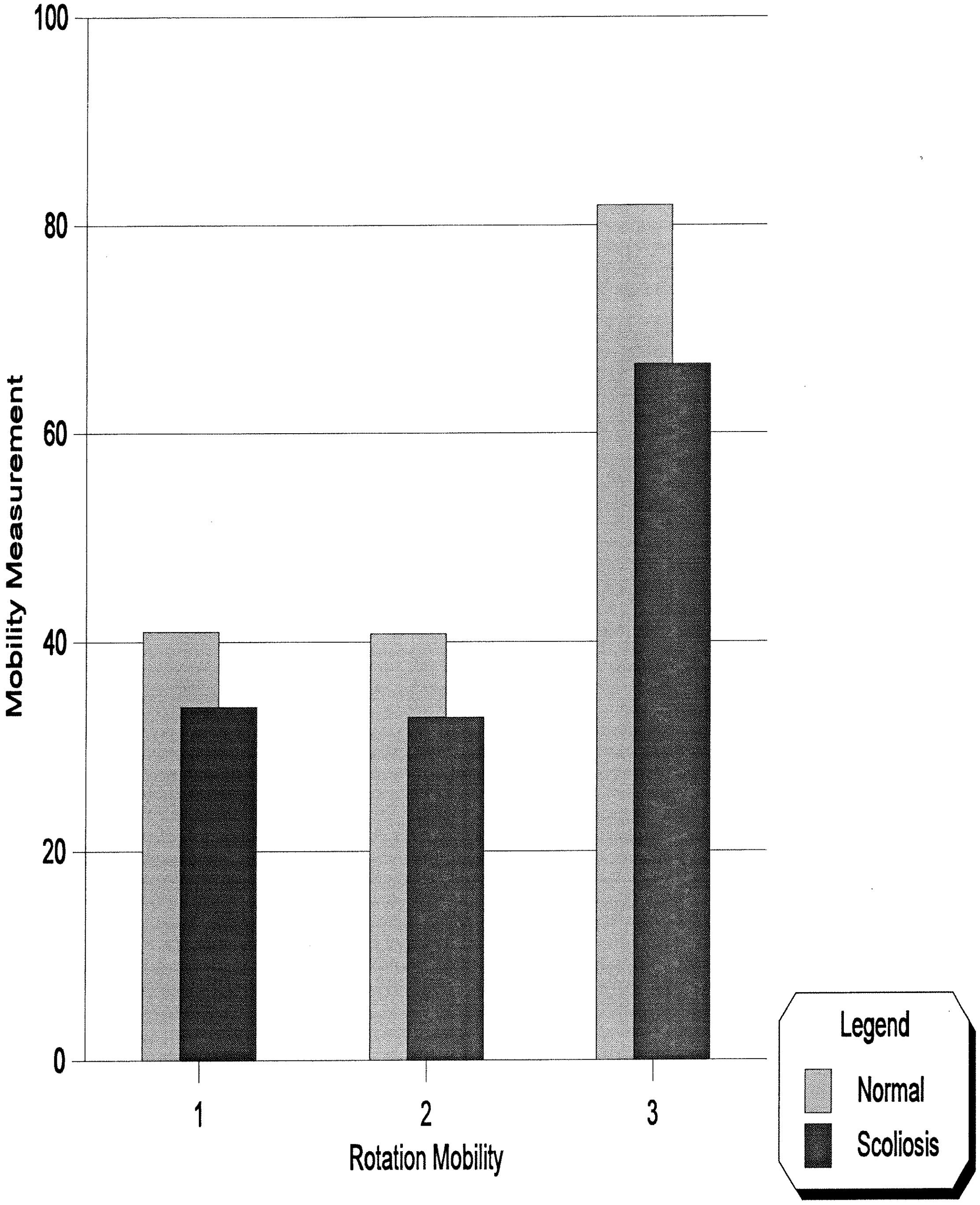


Figure 4.3 Thoracolumbar Rotation

1 = Right Rotation=========> significant
2 = Left Rotation==========> significant
3 = Total Rotation =========> significant

4.3. Bivariate Analysis

In the second stage a correlation matrix was run to investigate the interrelationship between variables as a whole in the scoliotic group. The correlation coefficients and their corresponding probability provide a general view of the relationship, but not the net effects. Correlation coefficients of spinal mobility measurements with other anthropometric factors and their probabilities are listed in Tables 4.8, 4.9, and 4.10.

Table 4.8 presents the intercorrelation between thoracic spinal mobility and other parameters. Thoracic extension displayed a significant negative correlation with thoracic cobb angle ($r= -0.38$; $p<0.001$), and pelvic inclination ($r= -0.34$; $p<0.05$) but significant positive correlation with kyphosis ($r= 0.39$; $p<0.001$).
Thoracic left lateral bending had significant negative correlation with pelvic inclination ($r= -0.29$; $p<0.05$), and had significant positive correlation with thoracic apex level ($r= 0.29$; $p<0.05$. No other significant correlations could be detected between these variables.

Table 4.9 presents the intercorrelation between lumbar spinal mobility and other parameters. Lumbar flexion had significant negative correlation with weight ($r= -0.29$; $p<0.05$) whereas lumbar extension had significant positive correlation with weight ($r= .25$; $p<0.05$). Lumbar left lateral bending had significant negative correlation with kyphosis ($r= -0.27$; $p<0.05$).

Table 4.10 presents the intercorrelation between thoracolumbar

Table 4.8 Pearson Intercorrelation: Thoracic Spinal Mobility and Related Parameters; [] represents probability

	Thoracic Spinal Mobility			
Variables	Flexion	Extension	Rt.Lateral Bending	Lt.Lateral Bending
Age	-0.051 [0.639]	-0.088 [0.420]	0.008 [0.936]	0.118 [0.278]
Menstruation	0.088 [0.485]	0.074 [0.555]	-0.061 [0.627]	-0.037 [0.767]
Heredity	-0.101 [0.420]	0.036 [0.772]	-0.087 [0.488]	0.129 [0.304]
Height	0.005 [0.966]	0.079 [0.527]	-0.037 [0.766]	0.219 [0.079]
Weight	0.007 [0.951]	0.079 [0.545]	0.001 [0.992]	0.238 [0.055]
Leg Length Discrepancy	-0.140 [0.263]	0.001 [0.993]	-0.020 [0.871]	0.063 [0.615]
Thoracic Cobb Angle	-0.042 [0.736]	-0.378 [0.001]	-0.161 [0.199]	0.054 [0.665]
Lumbar Cobb Angle	0.056 [0.657]	-0.210 [0.091]	-0.027 [0.826]	-0.047 [0.707]
Pelvic Inclination	-0.057 [0.656]	-0.266 [0.034]	-0.146 [0.251	-0.290 [0.020]
Kyphosis	-0.076 [0.554]	0.393 [0.001]	-0.035 [0.783]	0.027 [0.833]
Lordosis	0.056 [0.658]	0.069 [0.589]	0.048 [0.705]	-0.131 [0.304]
Thoracic Apex Level	-0.023 [0.853]	0.048 [0.702]	0.158 [0.208]	0.288 [0.019]
Lumbar Apex Level	-0.009 [0.941]	-0.033 [0.788]	0.147 [0.241]	0.203 [0.104]
Risser	0.133 [0.289]	0.057 [0.647]	0.083 [0.510]	0.066 [0.598]
Pain	0.036 [0.772]	0.046 [0.714]	-0.150 [0.217]	-0.074 [0.557]
Pain Frequency	-0.014 [0.906]	0.045 [0.721]	-0.203 [0.103]	-0.195 [0.119]

Table 4.9 Pearson Intercorrelation: Lumbar Spinal Mobility and Related Parameter; [] represents the probability

Variable	Lumbar Spinal Mobility			
	Flexion	Extension	RT.Lateral Bending	Lt.Lateral Bending
Age	-0.195 [0.073]	0.059 [0.589]	-0.037 [0.731]	0.022 [0.838]
Menstruation	-0.162 [0.196]	0.213 [0.087]	-0.130 [0.300]	0.142 [0.256]
Heredity	-0.071 [0.571]	-0.025 [0.839]	-0.131 [0.296]	-0.188 [0.133]
Height	-0.154 [0.219]	0.143 [0.255]	-0.033 [0.793]	-0.028 [0.822]
Weight	-0.295 [0.016]	0.254 [0.040]	0.062 [0.619]	0.094 [0.455]
Leg Length Discrepancy	-0.154 [0.220]	-0.110 [0.381]	-0.118 [0.348]	-0.238 [0.056]
Thoracic Cobb Angle	0.000 [0.995]	-0.099 [0.431]	0.053 [0.670]	-0.010 [0.936]
Lumbar Cobb Angle	-0.007 [0.951]	-0.099 [0.430]	0.162 [0.196]	0.030 [0.809]
Pelvic Inclination	0.005 [0.968]	0.153 [0.230]	0.145 [0.255]	0.218 [0.085]
Kyphosis	-0.050 [0.697]	-0.201 [0.116]	-0.200 [0.117]	-0.268 [0.034]
Lordosis	-0.015 [0.902]	0.156 [0.220]	0.081 [0.523]	0.126 [0.322]
Thoracic Apex Level	0.031 [0.801]	-0.007 [0.953]	0.051 [0.682]	-0.023 [0.507]
Lumbar Apex Level	-0.034 [0.783]	-0.162 [0.196]	-0.064 [0.608]	-0.154 [0.219]
Risser	-0.152 [0.226]	0.057 [0.651]	-0.081 [0.519]	0.186 [0.136]
Pain	-0.102 [0.416]	-0.142 [0.256]	-0.111 [0.378]	-0.036 [0.775]
Pain Frequency	-0.143 [0.253]	-0.146 [0.245]	-0.049 [0.698]	-0.030 [0.808]

Table 4.10 Pearson Intercorrelation:Spinal Mobility (Thoracolumbar Rotation) and Related Parameter; [] represents the probability

Variable	Thoracolumbar Rotation Mobility Right Rotation	 Left Rotation
Age	-0.197 [0.076]	-0.193 [0.064]
Menstruation	-0.162 [0.177]	-0.132 [0.273]
Heredity	0.310 [0.021]	-0.041 [0.741]
Height	-0.153 [0.229]	-0.104 [0.423]
Weight	-0.071 [0.566]	-0.042 [0.723]
Leg Length Discrepancy	0.075 [0.548]	-0.155 [0.216]
Thoracic Cobb Angle	-0.178 [0.157]	-0.178 [0.167]
Lumbar Cobb Angle	-0.194 [0.127]	-0.302 [0.012]
Pelvic Inclination	0.171 [0.178]	0.302 [0.015]
Kyphosis	0.191 [0.136]	-0.002 [0.982]
Lordosis	0.043 [0.734]	0.356 [0.004]
Thoracic Apex Level	-0.104 [0.409]	-0.059 [0.640]
Lumbar Apex Level	-0.185 [0.139]	-0.205 [0.101]
Risser Sign	-0.083 [0.507]	-0.083 [0.510]
Pain	-0.096 [0.446]	-0.099 [0.428]
Pain Frequency	-0.094 [0.455]	0.006 [0.956]

rotation mobility and other parameters. Left rotation had significant positive correlation with pelvic inclination (r= 0.30; p<0.05) and lordosis (r= 0.36; p<0.05), and significant negative correlation with lumbar Cobb angle (r= -0.30; p<0.05). Right rotation had significant positive correlation with heredity (r= 31; p<0.05). The results show that very few correlation was found between the spinal mobility and biodemographic variables.

4.4. Multivariate Analysis

Generally, there is no single cause of a given phenomenon. Thus, a single independent variable will not explain all the variance. In order to explain the dependent variable in more detail, we have to add some other variables. Multiple regression is the statistical term for predicting Y, the dependent variable, from two or more optimally combined independent variables. In our case, to predict the spinal mobility through some biodemographic variables. The equation of a multivariate prediction of the Y, spinal mobility, given scores on m independent variables is as bellows:

$$Yi=b1X1i + b2X2i + \ldots + bmXmi + c$$

Forward stepwise regression program was run for every dependent variables on the independent variables. In forward selection, the first independent variable considered for entry into the equation is the one with the largest positive or negative correlation with the dependent variable. The F test for the hypothesis that the coefficient of the entered variable is 0 is then calculated. To determine whether this variable (and each succeeding variable) is entered, the F value is compared to the established criterion, PIN with a default of 0.05. A variable enters into the equation only if the probability associated with the F test is less than or equal to the default 0.05.

If the first variable selected for entry meets the criterion for inclusion, forward selection continues. Otherwise, the procedure terminates with no variables in the equation. Once one variable is entered, the statistics for variables not in the equation are used to select the next one. The partial correlations between the dependent variable and each of the independent variables in the equation, are examined. The variable with the largest partial correlation is the next candidate. Choosing the variable with the largest partial correlation in absolute value is equivalent to selecting the variable with the largest F value. If the criterion is met, the variable is entered into the equation and the procedure is repeated. The procedure stops when there are no other variables that meet the entry criterion.

Based on the above mentioned criteria, the regression coefficients of spinal mobility variables and the independent variables were estimated and the summary tables of the regression coefficients and their corresponding statistics were built to clarify our interpretation of the results.

4.4.1. Thoracic Mobility

Table 4.11 demonstrates the result of a regression analysis of thoracic flexion on the independent variables. There was no significant effect of the independent variables on thoracic flexion. Table 4.12 presents the relationship between thoracic extension and the independent variables. Two variables were selected. At first step, kyphosis met the selection criteria and entered into the model and explained 15 percent of variances. In the second step, thoracic Cobb angle met the selection criteria and entered into the equation and constituted the second model which explained 21 percent of variances. The selection criteria stopped at this stage because no variable met the selection requirement. Table 4.13 shows that there is no relationship between thoracic right bending and the independent variables. Pelvic inclination had some effect on thoracic left bending (Table 4.14). The results show that kyphosis and thoracic Cobb angle have merely effect on thoracic mobility (thoracic extension).

4.4.2. Lumbar Mobility

Lumbar flexion has shown a reverse relationship with weight, the regression coefficient is -.39. This means that, with one unit change in independent variable, weight, the dependent variables, lumbar flexion, will change by -.39. The model explains 10 percent of variances (Table 4.15). Menstruation and pain have shown to have some effect on lumbar extension (Table 4.16). In the first model, menstruation explains .06 percent of variances; with the entry of pain variable into the equation, the model explains 15 percent of variances.

Lumbar right bending has shown no relationship with the independent variables (Table 4.17). Kyphosis has a reverse relationship with lumbar left bending and the model explains .07 percent of variances (Table 4.18). It is concluded that only two variables, weight and pain, among biodemographic variables had significant relationship with lumbar flexion and extension respectively which can be supported by a logical explanation.

4.4.3. Thoracolumbar Rotation Mobility

Heredity and lumbar Cobb angle have some effect on thoracolumbar right mobility and explains 17 percent of variances (Table 4.19). Lordosis and lumbar Cobb angle also have relationship with thoracolumbar left mobility and explains 19 percent of variances. Table 4.20 shows the regression coefficients and the directions of relationship. The results show that there is no logical interpretation for the relationship between thoracolumbar rotation and other variables especially Cobb angle.

Table 4.11 Regression of thoracic flexion on independent variables

Independent Variable
No variable meets the selection criteria

Table 4.12 Regression of thoracic extension on independent variables

Independent Variable	Model I (B)	Model II (B)
Kyphosis	.3774	.3155
Thoracic Cobb Angle		_.2192
Constant	10.5343	19.3388
R Square	.1544	.2171
Significant F	.0016	.0007

Table 4.13 Regression of thoracic right bending on independent variables

Independent Variable
No variables meets the selection criteria

Table 4.14 Regression of thoracic left bending on independent Variables

Independent Variable	Model I (B)
Pelvic inclination	_.3686
Constant	53.1337
R Square	.0894
Significant F	.0182

Table 4.15 Regression of lumbar flexion on independent Variables

Independent Variable	Model I (B)
Weight	_.3905
Constant	66.0762
R Square	.1099
Significant F	.0085

Table 4.16 Regression of lumbar extension on independent variables

Independent Variable	Model I (B)	Model II (B)
Menstruation	1.2382	1.8541
Pain		_.1003
Constant	21.0039	22.1386
R Square	.0662	.1530
Significant F	.0435	.0074

Table 4.17 Regression of lumbar right bending on independent variables

Independent Variable
No variables meets the selection criteria

Table 4.18 Regression of lumbar left bending on independent Variables

Independent Variable	Model I (B)
Kyphosis	_.1537
Constant	18.5187
R Square	.0723
Significant F	.0345

Table 4.19 Regression of thoracolumbar right rotation on independent variables

Independent Variable	Model I (B)	Model II (B)
Heredity	4.8949	5.3806
Lumbar Cobb Angle		_.1742
Constant	26.2836	31.2050
R Square	.1080	.1699
Significant F	.0091	.0041

Table 4.20 Regression of thoracolumbar left rotation on independent variables

Independent Variable	Model I (B)	Model II (B)
Lordosis	.2153	.1987
Lumbar Cobb Angle		_.1922
Constant	22.6393	29.6606
R Square	.1261	.1955
Significant F	.0046	.0016

CHAPTER FIVE

DISCUSSION

Several important considerations prompted us to undertake this objective study of spinal mobility in adolescent idiopathic scoliosis. Foremost was the fact that progressive curves may lead to serious medical and physical complications in which spinal mobility may be involved. The key questions in this study were to determine whether there is restriction of spinal mobility in scoliotic patients as compared to normals and to verify whether any sociobiodemographic factor may be associated with these changes in adolescent idiopathic scoliosis.

Very few studies concerning spinal mobility in idiopathic scoliosis have been conducted and have suggested contradictory findings. For this reason determination of an appropriate program for assessment of spinal mobility was deemed essential.

This study is based on the data collected from 65 idiopathic scoliotic patients at the scoliosis clinic of Sainte-Justine hospital and 20 normal matched individuals. The data contained biodemographic questions plus standardized and reproducible evaluation of spinal mobility in three planes--sagittal, frontal, and horizontal movements.

The findings suggest that there is restriction of spinal mobility in scoliotic patients. This finding tends to contradict the hypothesis that idiopathic scoliosis results from an excessive flexibility of spine. The outline of the findings are as follows:

5.1. Height and weight

There was no difference between the height of the two groups. It is worth noting that the control group consisted of both girls and boys and its size is smaller (N=20) than the scoliotic group (N=65). Regarding that the test of normality (tests whether control group has a normal distribution) was run, there shouldn't be any problem in inference from the statistical analysis. It should be noted that when measuring the height of scoliotic patients in current study, no attempt was made to correct for the height reduction caused by scoliosis.

This finding is contrary to the finding of Willner (1974), Burwell et al (1977), and Drummond and Rogala (1980), in which the scoliotic patients were taller than the control group. Poussa et al (1989) did not find significant statistical difference between the height of the two groups either.

The difference between the weight of the two groups illustrates that scoliotic patients were lighter than the healthy controls but it was not statistically significant. This finding supports the studies of Poussa et al (1989) and Willner (1975) in which the healthy controls were heavier than scoliotic patients.

5.2. Thoracic Mobility

Significant differences were noted in the mobility of the thoracic spine between the two groups. The statistically significant difference between extension curve means that scoliotic patients have less extension in the thoracic area. This difference between the two groups is partly due to the reduced kyphosis of the scoliotics and partly due to the magnitude of the thoracic Cobb angle, which have been correlated with thoracic extension in scoliotic patients. This implies that as the curve size increases, thoracic kyphosis decreases and so does thoracic extension. The reduced thoracic kyphosis as an etiopathogenetic factor in the development of a scoliotic curve has been emphasized by Dickson (1984), who points out that the apex of a scoliotic curve is always lordotic and the curve itself is a rotated lordosis. It should be noted that Poussa et al (1989) had different findings in their study, in which the scoliotic patients had more extension even though they found that thoracic kyphosis was significantly reduced in scoliotic patients.

Other statistically significant difference was the total sagittal mobility of the scoliotic patients, which was less than those of control groups. This also seems to be contrary to the study of Poussa et al (1989), in which the scoliotic patients had more sagittal mobility in total. Thoracic flexion was reduced in scoliotic patients, but not statistically significant. A reduced flexion in scoliotics have also been observed by Poussa et al

(1989), in which they found it statistically significant. Mattson et al (1983), also presented the same finding, but they measured the whole spine with a tape.

In thoracic lateral bending, scoliotic patients had less mobility than those of control groups but this was not statistically significant. Poussa et al (1989) in their study found no differences in thoracic lateral bending between the two groups (this will be discussed further at the end of chapter. Also thoracic left bending has shown to have inverse relationship with the pelvic inclination; it seems that this relationship is spurious, because there is no logical reasoning or justification for such a relationship.

5.3. Lumbar Mobility

In the lumbar area, forward flexion was remarkably reduced in scoliotic patients, which probably is related to the changes in lumbar lordosis. As Poussa et al (1989) and Willner (1981) pointed out in their study, the spinal sagittal curves (thoracic kyphosis and lumbar lordosis) were reduced in scoliotic patients. This may explain the reduced lumbar flexion in scoliotic patients. In another study Mellin (1987) presented that forward flexion of the lumbar spine increases with lordosis, whereas extension decreases, but his study was based on low back pain patients. Our result concerning lumbar flexion are contrary to the findings of Poussa et al (1989), in which there were no great differences between lumbar flexion of the two groups. Lumbar flexion also has a significant inverse relationship with weight in scoliotic patients. This has been pointed out by Mellin (1987) in low back pain patients. In lumbar extension and lateral bending to the right and left, our result shows no statistically significant differences between the two groups. Poussa et al, (1989) presented different finding for lumbar extension, in which scoliotic patients had less extension as compared to those of the control group.

Menstruation and pain have positive and negative relationship with lumbar extension respectively. The effect of menstruation is an ambiguous one; because the mechanism through which it operates is not clear and cannot be detected from this study. The effect of pain is very straightforward because with the beginning of pain, the subject reacts by restriction of the movement. Lumbar left bending has negative relationship with kyphosis. It may be secondary due to the scoliotic curve and indicates that compensatory lumbar curves have a greater degree of flexibility. It has also been pointed out by Weinstein (1994).

5.4. Mobility of Thoracolumbar Rotation

Thoracolumbar rotation (right, left, and rotation sum) was reduced in the scoliotic patients, and was statistically significant. There were no great side disparity in both groups. This difference between the two groups can be secondary because a scoliotic curve in itself has a certain amount of rotation and consequent vertebral tilting. Poussa et al, (1989) reported different findings, in which there were no great differences between the two groups. It should be noted that in the measurement of rotation, thoracic and lumbar rotations have been considered together for two reasons: 1-rotation occurs mostly in the thoracic segment and there is no significant rotation in the lumbar area as it has been mentioned earlier. 2- It is believed to be impossible to measure rotation of the lumbar spine in supine position with accuracy, because there are no ventral reference points for L1. Because we considered thoracic and lumbar rotations together we have used the term 'thoracolumbar' mobility throughout this presentation. Thoracolumbar rotation to the right and to the left have negative relationship with lumbar Cobb angle, this may be due to the decrease in lordosis, because lordosis has a direct relationship with left rotation. These relationships can also indicate structural stiffness in the horizontal plane of the spine in a scoliotic patient. Also it seems apparent that the decrease in rotation with the curve size increase is synchronous with the reduced sagittal curvature.

5.5. Biodemographic Variables

Very little correlation was found between spinal mobility and biodemographic variables especially with the Cobb angle. Thoracic extension had a significant reverse relationship with Cobb angle which is secondary to thoracic kyphosis. It seems that an increase in Cobb angle has no effect on spinal mobility. Although Poussa et al (1992) in their study, which was based on three groups of scoliotic patients according to their curve magnitude, concluded that mobility decrease as curve size increase. But in another study, they compared spinal mobility between the two groups of idiopathic adolescent scoliosis and healthy control. They did not find significant differences between the mobility of two groups (lateral bending and rotation) except in sagittal mobility (Poussa et al, 1989). These two studies of Poussa et al (1989) and (1992) seem to contradict with each other. Since if the increase in Cobb angle are associated with the decrease in spinal mobility especially in lateral bending and rotation, then Poussa et al (1989) would had found significant differences between the spinal mobility of scoliotic patients as compared to healthy controls.

In general, some of the present findings are different from the only earlier study done by Poussa et al (1989). According to Table 4.2 and 4.3 the findings of Poussa et al (1989) can be criticized on the following grounds:

1) the values of thoracic flexion and lumbar flexion of present study are different from the Poussa et al (1989) for both scoliotic and control groups. They reported greater value for thoracic flexion (54 for scoliotics and 62 for normals) than lumbar flexion (26 for both scoliotics and normals). This does not seem reasonable since thoracic area is the least mobile part of the spine and because of the direction of the facet plane and also attachment of the ribs to the thoracic vertebrae. The only movement that is freer in the than lumbar region is rotation. The reason why they reported higher value

for thoracic flexion than lumbar flexion may be partly due to the identifying the level of measurement for lumbar level. This was determined by drawing a line 20 centimetre above a line connecting the posterior superior iliac spines instead of palpating the thoraco-lumbar junction. The other reason may be because they measured flexion in sitting position a position which is well known to decrease lumbar lordosis.

2) Poussa (1989) reported greater value of thoracic extension for scoliotic group (16 degree) than control group (-3.3 degree) which also seems unreasonable; because extension consists of a diminution of backward convexity which is already reduced in scoliotic patients and can not be greater than the control group. This is also contrary to his finding about kyphosis which was less in scoliotic patients than control group.

3) His finding about lateral bending is contrary to his more recent study (Poussa, 1992) in which he found a significant difference between three groups of scoliotic patients which were distinguished according to their curve magnitude.

4) Finally, his method of statistical analysis, student t-test, is not appropriate for comparing three groups of population. Because whenever more than one t-test is made, the probability of one or more type-I errors is greater than .05, and the probability of incorrectly rejecting at least one null hypothesis is far greater than .05 (Glass and Hopkins, 1984). The appropriate statistical technique was developed for comparing three or more groups is known

as the analysis of variance (ANOVA). ANOVA permits the control of alpha at a predetermined level when testing the simultaneous equality of any number of means.

CHAPTER SIX

CONCLUSIONS

6.1 Summary of findings

The following conclusions can be drawn from this study:

1. Spinal mobility among the scoliotic patients with adolescent idiopathic scoliosis is different from those of normals.

2. Spinal mobility is more restricted among scoliotic patients especially in the sagittal and axial planes. This seems understandable because in scoliotic patients, sagittal curves (kyphosis and lordosis) decrease and also because scoliotic curves are accompanied by vertebral axial rotation. This study does not support the hypothesis that idiopathic scoliosis results from an excessive flexibility of the spine.

3. There is a discrepancy among the methods of measurement of spinal mobility that resulted in different magnitude of mobility when comparing to other studies reported in the literature. This may affect interpretation of the finding.

4. Very little correlation between biodemographic variables specially Cobb angle which measure severity of curves and range of motion variables was detected even though spinal mobility is reduced in scoliotic patient. This may imply that there is a threshold of magnitude of curve beyond which the limitation of range of motion may emerge as a late change.

6.2 Implications:

The main implication resulting from this study is the identification of the problem of limited range of motion in adolescent idiopathic scoliosis.

This study does not support the hypothesis that increases in flexibility and spinal mobility may be important in producing deviation of spine. This finding implies that conservative treatment of adolescent idiopathic scoliosis should be directed at maintaining of normal range of motion, but wether an appropriate physiotherapy program may help to maintain normal range of motion remains to be demonstrated.

6.3 Limitations:

Considering that the study of spinal mobility in adolescent idiopathic scoliosis is a complex subject, the study should cover as many variables as possible, for example muscle ligaments and other structures around spine.

The difficulty in recruiting normal subjects in this research project brought about some limitations and affects the sample size of the control group which is not optimal. The able-bodied subjects who were recruited from the trauma clinic were mostly boys. However, it is believed that there is no difference between the spinal mobility of able-bodied boys and girls in this range of age as there is no literature has been found to reject this supposition.

The advantages of this study as compared to the earlier ones can be described as follows: a) adequate sample size for the scoliotic group, b) measurement of biodemographic variables, c) use of X-ray technique for measuring positional incline of spine, d) comparison of our findings with those of the others.

6.4 Suggestions:

1. The number of studies of spinal mobility in scoliotic patients is very small (limited). It is necessary to continue research on this subject in order to provide more evidence on the anomalies of spinal mobility in adolescent idiopathic scoliosis.
2. Some of biodemographic parameters had some effect on spinal mobility of scoliotic patients. The effects are spurious in terms of mobility, but we may infer that these parameter are correlated with scoliosis in general as compared to the normals.
3. Although the technique of measurement has shown promising results, there is a need for more investigation and standardization of the methods for objective clinical measurement of spinal mobility. Training is needed in the methods, manipulation of the

instruments, and instructions to give the subjects before the measurements can be considered reliable. The landmarks chosen are very important because variation in the starting position may affect the outcome of the study.

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APPENDIX. A

PATIENT INFORMATION SHEET

Sainte-Justine File No.:____________ Subject No.:_________ Date:__________

A) General Information:

Name:____

Sex: F ☐ M ☐

Heredity: (anyone in patient's family or relative has or had scoliosis?)

Yes ☐ No ☐ Doesn't know ☐

Menstruation: Yes ☐ Date: D ☐ M ☐ Y ☐

No ☐

B) Anthropometric:

Height__________________ cm

Weight:_________________ lb

Leg length discrepancy: Yes ☐ No ☐

C) X-Ray:

Cobb angle:______________________________

Sacrum inclincation:______________________

Kyphosis:________________________________

Lordosis:_________________________________

Apex level:_______________________________

Rotation of vertebra: Yes ☐ No ☐

Risser sing:______________________________

D) Pain:

Pain index: ________________________________

Subject number:______________________

Kinematics

Thoracic Flex			Thoracic Ext		
A	B	C	A	B	C
Lumbar Flex			Lumbar Ext		
Thoracic Rt Lateral Bend			Thoracic Lt Lateral Bend		
Lumbar Rt Lateral Bend			Lumbar Lt Lateral Bend		
Rt Rotation			Lt Rotation		