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BIOKINETIC REHABILITATION OF SCOLIOSIS SUBJECTS

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BIOKINETIC REHABILITATION

OF

SCOLIOSIS SUBJECTS

by

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SUPERVISOR : DR E KRUGER

dedicated to our Creator
and
my wife Daleen

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SUMMARY

TITLE : Biokinetic Rehabilitation of Scoliosis Subjects

by

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DEPARTMENT : Human Movement Science

DEGREE : M.A. (Phys Ed)

Of back problems experienced in adolescence, scoliosis is the most frequent (Bradford et al, 1987; Lancard-Dusek et al, 1991). Several studies have been conducted to determine the effect of exercise on back pain. The results indicated that certain regimes are more successful than others.

The purpose of this study was to determine whether a corrective exercise programme, which was intensively and aggressively applied, will have a positive effect on adolescent scoliosis subjects.

The subjects were divided, randomly, into a control and rehabilitation group. The rehabilitation group followed an eight week programme comprising 24 sessions. Both groups were evaluated at session zero (0) and session twenty four (24).

A t-test for homogeneity was done at day zero, between the two groups for the variables V3 to V8. The results indicated homogeneity ($P > 0.05$). A paired t-test was done for group one; indicating that there was a meaningful difference in all the variables; except for standing height ($P > 0,05$). For group two the test indicates a meaningful difference for degrees, standing height and lateral flexion.

A t-test at day 24 indicated a meaningful difference for degrees and lateral flexion. This indicates that the group which had followed the programme had improved whilst the control group had deteriorated.

SAMEVATTING

TITEL : Biokinetika Rehabilitasie van Skoliose Pasiente

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Van die rug probleme ondervind by jeugdiges, is skoliose die mees veelvuldig (Bradford et al, 1987; Lancas-Dusek et al, 1991). Verskeie studies is reeds gedoen wat die effek van oefening op die rug evalueer. Die resultate dui aan dat van die programme meer suksesvol is as ander.

Die doel van die studie was om te bepaal of 'n korrektiewe oefenings program, wat intensief en aggresief toegepas is, 'n positiewe effek op geringe adolessent skoliose individue sal hê.

Die individue was willekeurig ingedeel in 'n kontrole en 'n rehabilitasie groep. Die rehabilitasie groep het 'n agt weke program gevolg van 24 sessies. Beide groepe was tydens sessie nul en sessie 24 ge-evalueer.

'n Toets vir homogeniteit was gedoen by dag nul, tussen die twee groepe, vir die veranderlikes V3 tot V8. Die resultate was homogeen ($p > 0.05$). 'n Gepaarde t-toets vir groep een het aangedui dat daar 'n betekenisvolle verskil vir al die veranderlikes was; behalwe staande lengte ($p > 0.05$). Vir groep twee was daar 'n betekenisvolle verskil in grade, staande lengte en laterale fleksie.

'n T-toets op dag 24 het 'n betekenisvolle verskil vir laterale fleksie aangedui. Dit dui aan dat die groep wat die program gevolg het verbeter het, terwyl die kontrole groep agteruit gegaan het.

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CHAPTER 1

THE PROBLEM

1.1. INTRODUCTION

Not enough has been done concerning Biokinetic rehabilitation. A quick review of the term Biokinetics "improvement of life through movement", substantiates this argument. Functional or mechanical unsymmetrical back problems and the conservative rehabilitation thereof is being neglected (Mead et al. 1991). Much, however, has been done on the conservative care of low back pain (McKenzie, 1981; Calliet, 1988; White and Panjabi, 1990) but little specifically for unsymmetrical deformities of the spine (Moe and Byrd, 1987).

In a society where the emphasis is on maximum achievement and goal attainment, one can ill afford to be debilitated and bed stricken for any lengthy period of time. This can be no truer than for a school child who cannot afford to miss classes. Many of the scoliotic cases can be conservatively rehabilitated by following a constructive program to correct the imbalancements. Bed rest should be avoided since atrophy may occur rapidly. Strict bed rest or maintaining a single position for a prolonged period must also be avoided as this promotes back spasm. Movements of the back through a pain free range of motion should be encouraged (Blount, 1971; Harvey and Tanner, 1991). Pope (1982) states that :

... "back pain is a national, personal and clinical problem; national because it is experienced by most of the population at the same time and is a strain on the nations resources; personal because it can remain a major unresolved dilemma and clinical because not only is diagnosis difficult, but methods of treatment are conflicting and often unrewarding". (Pope, 1982, p1).

Part of the problem in assessing treatment lies in the diagnosis (Morrison, 1983). One cannot implement the same remedy for all back pain, be it cervical, thoracic or lumbar.

The problem confronting physicians, specialists, therapists and biokineticist is that a very high percentage of back related literature is concentrated solely on the lumbar region, that is lordosis of the lumbosacral spine disc, tropism, degeneration, sacroiliac complications and so forth (Calliet, 1988; Seimon, 1983; Bolesta and Bohlman, 1991).

Research completed on thoracic and cervical spinal problems must be more methodical and precise. Doran and Newell (1975) and Coxhead et al (1981) compared traction, manipulation, corsets and exercises, for back pain treatment, and concluded that no one method was superior. What they did, however, agree upon is that physiotherapy, a second phase rehabilitation procedure, was beneficial in short term treatments.

This observation leads one to ask whether or not, and to what extent, Biokinetics, a third phase rehabilitation procedure, could benefit a back pain sufferer. It is in this area that there are short comings and there is a definite need for research. Porter (1986) stated that spinal structures are more subject to injury when fatigued. This statement being true, it is felt that if the musculo-skeletal system of the back can be strengthened, through Biokinetic procedures, the incidence of back injuries will be reduced. It must also be noted that the spine remains normal through the maintenance of a delicate and precarious balance. This balance depends on the precise functional status and dynamic symmetry. Scoliosis can result from either gross or delicate disruptions of the delicate balance (White and Panjabi, 1990; Fuller et al, 1991).

1.2 PROBLEM SETTING

The aim of this study was to rehabilitate scoliosis subjects conservatively as apposed to radically. In this case conservative versus radical refers to non-surgical versus surgical intervention. A definition of scoliosis, as defined by White and Panjabi, (1990) is accepted as :
..."an appreciable lateral deviation in the normally straight vertical line of the spine". (White and Panjabi, 1990, p7).

Back problems in adolescence is of a high percentage when compared to any other ailments experienced (Meinert, 1986; Bolesta and Bohleman, 1991). Due to bad postural habits young school going children develop various degrees of muscle imbalancements which result in structural malalignments.

These malalignments, in turn, become debilitating in various degrees, which ultimately negatively influence the individuals execution of his daily tasks (Nachemson, 1987; Harvey and Tanner, 1991).

Of the back problems experienced in adolescence, scoliosis is the most frequent (Loncar-Ducek et al, 1989; Bogduk and Amevo, 1990). The causes of scoliosis may either be structural or functional. Functional scoliosis presents a curve that is always present, except when a correctional force is applied, such as active muscular strain by the patient. This curve is maintained by muscular and gravitational forces. Compensatory curves are usually functional curves (Lancas- Ducek, 1989; Harvey and Tanner, 1991).

Structural curves, on the other hand, are rigid and cannot be corrected by active muscle forces due to vertebrae deformation (White and Panjabi, 1990). Although structural scoliosis may arise from a muscle or skeletal deformity it is almost always treated surgically or medically (Seimon, 1988; White and Panjabi, 1990). Functional scoliosis on the other hand, is a direct result of the one sided habits concerning posture and movement (Schrecker, 1979; Seimon, 1988). The causes could be the carrying of a school bag in the same hand constantly, the use of one arm or a specific posture or standing incorrectly for any length of time (Schrecker, 1979; Harvey and Tanner, 1991). Harvey and Tanner (1991), suggested that back injuries in sportsmen resulted from growth spurts, sudden training intensity increases, unsuitable sports equipment, improper technique and leg length inequality.

Besides the psychological affects of scoliosis the physical affects are very obvious. The physical affects encompass leg length discrepancies, scapula protrusions, iliac crest slant, acromion slant, and impaired pulmonary function (Schrecker, 1979; Rothman and Simoene, 1982). Leg length discrepancies cause an unequal transmission of forces across the spine. This is further complicated when an athlete or individual moves quickly and the stress transmitted through the spine is compounded by acceleration (Crisco, 1989 ; Harvey and Tanner, 1991).

For these above mentioned physical reasons it is important to detect and rehabilitate scoliosis early or as close to the onset as possible. The orthodox treatment of scoliosis today is by means of surgery or bracing (Drummond, 1991; White and Anderson, 1991). Both these procedures can have a psychological effect on the adolescent with the added cosmetic disadvantage of surgery.

It is felt , however, that in cases where surgery is not necessary in functional cases, corrective, structural rehabilitation should be attempted. Scoliosis can have a very limiting affect on the individual thus leading to various stages of withdrawal. By conservatively rehabilitating the condition through constructive exercises, we can also promote the importance of movement and exercise in the execution of daily tasks (Shaver, 1975; Fuller et al, 1991). This rehabilitation should take the form of exercises, where specific muscles, ligaments and tendons are strengthened as well as improving their flexibility, so as to counter imbalancements which result from the previously mentioned factors (Ford et al, 1984; Fuller et al, 1991).

It is important to note that structural rehabilitation does not begin and end with exercises alone; enlisting the parents cooperation and support in the improvement of the causative habits, is very important.

With widespread school screening programs for scoliosis, physicians are becoming increasingly involved in the initial evaluation of patients with abnormal spinal curvature. The general orthopaedic surgeon will be familiar with many of the clinical concepts but many may be unaware of the role of the Biokineticist in treating and monitoring scoliosis.

1.3 AIMS OF THE STUDY

The aims of the study were as follows :

1. To determine whether a Biokinetic Rehabilitation program can be beneficial as a means of scoliosis rehabilitation.

2. To determine whether a specific scoliosis rehabilitation program is effective and sufficient over an eight week period.

1.4 HYPOTHESES

The following hypotheses are related to the purpose of the study:

1. There is an improvement in the spinal scoliosis when following the eight week Biokinetic rehabilitation program.

2. A period of eight weeks is sufficiently long to rehabilitate scoliosis conservatively through corrective exercise.

3. There is an improvement in spinal scoliosis when following an eight week, conservative, Biokinetic rehabilitation program.

1.5 TERMINOLOGY

The following terminology is derived from the approved glossary of the Scoliosis Research Society from 1981 (De Smet, 1985):

1. **Adolescent Scoliosis:** Scoliosis appearing at or about the

onset of puberty and before maturity.

2. **Adult Scoliosis :** Scoliosis of any etiology present after skeletal maturity.

3. **Muscle Atrophy :** This is the wasting away of muscle tissue due to *immobilization* of a body part, inactivity or loss of nerve stimulation (Westcott, 1983).

4. **Curve measurement :**

(i) Select the most caudal vertebrae whose inferior endplates lifts to the concavity of the curve and erect a perpendicular from this endplate.

(ii) Select the most aphalad vertebrae whose superior endplate lifts to the concavity of the curve and erect a perpendicular from this endplate.

(iii) The curve value is the number of degrees formed by the angle of intersection of these perpendiculars.

5. **Extension :** The angle of the joint enlarges.

6. **Flexion :** The angle of the joint diminishes.

7. **Functional curve :** A curve that has no structural component.

8. **Muscle Hypertrophy :** It is the result of an increase in the size (and not the number) of individual muscle fibres resulting in an enlarged muscle or group of muscles.

9. **Idiopathic Scoliosis :** A scoliosis of unknown etiology.

10. **Infantile Idiopathic Scoliosis :** An idiopathic scoliosis appearing before the skeletal age of three years.

11. **Infantile Scoliosis :** Scoliosis developing in the first three years of life.

12. **Juvenile Scoliosis :** Scoliosis developing between skeletal age of three years and the onset of puberty.

13. **Major Curve :** Designates the larger(est) curve(s), usually structural.

14. **Minor curve :** Designates the smaller(est) curve(s).

15. **Myopathic scoliosis :** Scoliosis owing to a muscular disorder.

16. **Range of motion :** The degrees through which a body segment can move, about a pivotal axis.

CHAPTER 2

LITERATURE REVIEW

2.1 INTRODUCTION

Scoliosis refers to a lateral curvature of the spine. It may be secondary to a short leg, or standing in a tilted posture, if the subject finds that this alleviates pain. If sciatic pain is aggravated by bending to one side, the patient will reflexly stand flexed the other way. This is known as sciatic scoliosis. There may well be no reflex spasm due to pain, but instead a leg length discrepancy. This will reflect a true scoliosis, usually of long standing duration. Fuller et al (1991) indicated that non scoliotic subjects tended to be more flexible in their trunks than scoliotics.

Idiopathic scoliosis, which represents eighty five to ninety percent of scoliosis cases, occurs in normally healthy children. It may, however, be hereditary (Moe and Byrd, 1987; White and Panjabi, 1990).

In scoliosis there is a considerable deformation within a given vertebrae. There may be a long pedicle on the one side and a short pedicle on the other side, The transverse process may be asymmetrical in their spatial orientation. The spinous process may be deformed and bent out of the midline. The laminae and vertebrae bodies are asymmetrical (De Smet, 1985).

Loncar-Dusek et al (1991) in his study of growth velocity versus the onset of idiopathic scoliosis, noted that girls with scoliosis tended to be taller than girls of the same age who did not have scoliosis. His study group concentrated on subjects between the ages of nine and twelve years. He followed their growth for three years and discovered that the number of subjects with scoliosis tripled. He also observed that scoliotic subjects grew faster and that the prevalence of the onset of scoliosis was the highest during puberty. A possible cause could be that the paraspinous tissues do not grow at the same rate as bone resulting in tight lumbodorsal fascia and hamstrings stressing the spine unilaterally or non unilaterally (Yarom and Robin et al, 1979). Girls who developed scoliosis from a previously normal posture showed a peak height growth of 8.1 cm per year compared to the 7.1 cm in the girls who maintained a normal posture. This research is consistant with that of Willner (1979) and Nachemson (1987) who stated that apart from genetic factors, greater body height is a significant risk factor on the development of scoliosis.

Numerous clinical studies have been conducted to determine the causes of scoliosis. The theories investigated were neurological dysfunction (Barrack et al, 1984), reduced mustagmus response (Sahlstrand et al, 1978) and deficiencies in proprioception (Yekutiel et al, 1981). There was, however, no conclusive evidence that any of these factors causes idiopathic scoliosis.

A further form of scoliosis, rotoscoliosis, causes structural malalignment of two adjacent deformed vertebrae. This condition is termed spinal tropism and is usually found in the lumbar area L5-S1 or L4-L5 (Calliet, 1988; White et al, 1990).

Normal functional mechanics is impaired when the facets of the vertebrae are off centre. During flexion and extension the concave aspect of the curve becomes the point of rotation, thus increasing torque forces and eventual locking. This evidently reduces the spinal range of motion (Bradford et al, 1987; Calliet, 1988).

A new experimental direction has been to induce imbalance in the neuromuscular and osseous ligamentous structures of the spine in experimental animals. The reasoning is that the imbalancements resulting in a scoliotic pattern may be sought as a potential etiologic factor in idiopathic scoliosis . The presumption, then, is that weakness of a structure on the convex side of the curve or an over activity of its antagonist on the concave side may be the cause of scoliosis (Michelsson, 1965).

The Heuter-Volkmann's law is based on a traditional theory which suggest that increased pressure across an epiphyseal growth plate inhibits growth, whereas a decreased pressure across the plate tends to accelerate growth. This theory being true purports that the epiphyseal plates on the concave side of the curve have abnormally high pressures, decreasing growth, whereas the pressures on the convex side are less, accelerating growth (Volkman, 1962). Work by Stillwell (1962) on monkeys supports this hypothesis.

The above mentioned are but a few variation of scoliosis and their associated limitations. It would now be appropriate to examine the Anatomy, Kinematics and Biomechanics of the spine and the various techniques in dealing with and rehabilitating scoliosis. The methods of treatment are many, ranging from exercise to various forms of drug inducement, surgery, bracing, stimulation and relaxation.

2.2 ANATOMY AND BIOMECHANICS OF THE SPINE

The spine is a structure with three main biomechanical functions:

- it transfers forces and bending moments of the head and trunk to the pelvis;

- it allows for sufficient movement between the head, trunk and pelvis; and

- it protects the delicate spinal cord from forces, and movements produced by trauma (Ogilvie and Millar, 1983).

The 33 vertebrae (7 cervical, 12 thoracic, 5 lumbar, 5 sacral and 4 coccygeal) articulate with each other through a complex series of joints, ligaments and levers. Stability is also supplied by the rib cage and a highly developed, dynamic neuromuscular control system (Luttgens and Wells, 1982, Moore, 1985).

In the frontal plane, the spine is straight and symmetrical. There may be a slight thoracic curve to the right which is thought to be due to either the aorta or dominance of the right hand. In the lateral plane there are four normal curves. The curves are convex anteriorly in the cervical and lumbar region (lordosis) and concave anteriorly in the thoracic and sacral region (kyphosis). The mechanical basis for the curves is to provide flexibility, improve shock absorption and to maintain stability at the intervertebral joints (Ogilvie and Millar, 1983; Bradford, et al, 1987).

2.2.1 INTERVERTEBRAL DISC

2.2.1.1 Functional anatomy

The intervertebral disc constitutes 20 - 33 % of the height of the vertebral column. Along with the facet joints it is responsible for carrying all the compressive loading to which the trunk is subjected (Hirch, 1954; Parsad et al, 1974). It comprises three distinct structures namely the nucleus pulposus, annulus fibrosis and the catrilaginous end plates.

Nucleus pulposus

The nucleus pulposus is a structure composed of a translucent fine network of fibres that lie in a mucoprotein gel containing various mucopolysaccharides. In the thoracic region it is centrally located in the disc. In the lumbar and cervical regions it is more posterior and lies at the junction of the middle and posterior thirds of the disc. In cross section it fills 30 - 50 % of the total disc area. The water content of the disc varies from 70 - 90 % and is highest at birth but decreases steadily with age. The size of the disc as well as its capacity to swell is greater in the cervical and lumbar regions. (Lysell, 1969; Panagiotacopulos et al, 1987).

Annulus fibrosus

The annulus fibrosus is composed of concentric laminated bands of connective tissue fibres. The annulus fibrosus gradually becomes more differentiated from the centre to the periphery. The laminated bands are composed of fibres which run in the same direction in a band. The bands are all orientated at 30° to the horizontal but adjacent bands are orientated at 90° to each other (Fig 1). The fibres are attached directly to the osseous tissue of the cartilaginous end plate and are called

Sharpey's fibres (Luttgens and Wells, 1982; Brinckmann, 1986).

Cartilaginous end plate

The cartilaginous end plate is composed of hyaline cartilage. Comparatively little is known about the end plate. (Brunnstorm, 1966; Brinckmann, 1986).

2.2.1.2 Biomechanics of the intervertebral disc

The intervertebral disc exhibits specific biomechanical characteristics which depend on :

- the type of force applied (compressive, tensile, torsion or shear forces); and

- the inherent biomechanical properties of the disc (creep, relaxation, hysteresis and fatigue tolerance); (Kerkaldy-Willis, 1983)

Special techniques are used to document these characteristics and include the measurements of intradiscal pressure (White and Panjabi, 1990).

1. Compressive forces

The intervertebral disc has been subjected to compression forces using in vitro models such as applying compressive loads to a vertebra-disc-vertebra specimen. Load deformation curves have been used to document the biomechanical behaviour of the disc (Anderson and Shultz, 1979, Brown et al, 1957). The major biomechanical characteristics of the intervertebral disc are :

- the load deformation curve is sigmoid (indicating that the disc is flexible at low loads and becomes stiffer at high loads);

- very high loads cause plastic deformation (permanent) but no disc herniation occurs (even when a posterior longitudinal incision is made in the annulus fibrosus;

- during compression loading to failure the first structure to break is the vertebral end plate and not the disc (earlier and more extensive collapse occurs in osteoporotic vertebrae);

- using discography it was demonstrated that nucleus pulposus herniation occurs into that vertebral body in the above mentioned type of failure; and

- central compressive loading results in disc bulging in all directions and not only posterolaterally (Brown et al, 1957; Farfan , 1973; Crilad et al, 1986).

Computer simulation studies (Zorab, 1974) have also been conducted to predict the compressive load behaviour of the intervertebral disc. The distribution of forces in the disc have been predicted for normal and degenerated discs. The predicted compressive load transfer form one disc to the next in normal and degenerated discs are as follows :

Compression load transfer in a normal disc (Fig 2) : A central compressive load applied to a normal disc will result in increased pressure in the nucleus pulposus. In the early years of life (<30 years) there is sufficient fluid for the disc to act like gelatinous mass (Virgin, 1951 and White et al, 1975).

The increase in fluid pressure is distributed in all direction equally (Fig 2); the end plates are therefore pushed up and the annular rings radially outward. The stress in all the fibres of the annulus is a tensile stress but the magnitude and direction of tensile stresses in the inner and outer annular rings differ. The stress in the outer lamina is predominantly circumferential (lateral) whereas the tensile stress in the inner lamina is predominantly axial. Fluid pressure within the nucleus supports the inner lamina. (Brinckmann. P, 1986; Grieve G.P, 1991).

Fig 1 : Structure of the annulus fibrosus

(Adapted from Cailliet R, 1985)

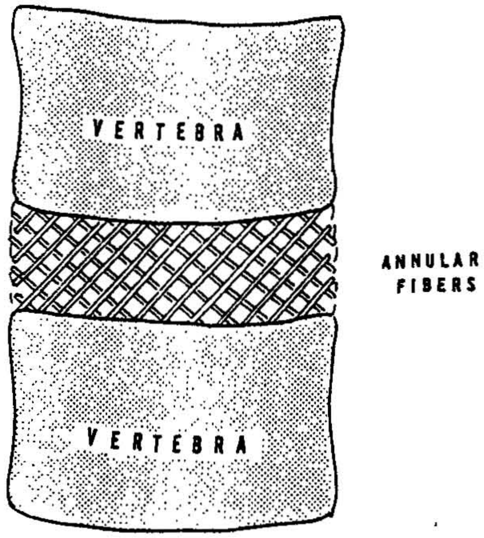
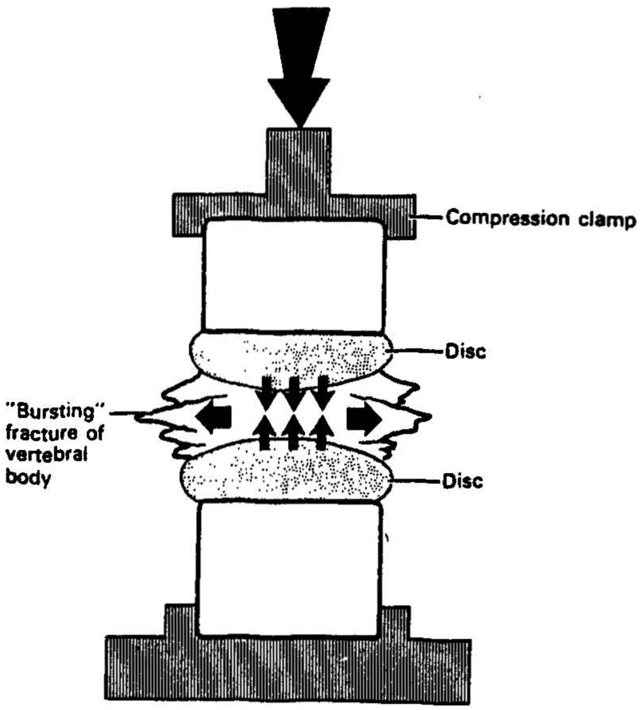


Fig 2 : Compression load transfer in a normal disc

(Adapted from Macnab <u>et al</u>, 1989)



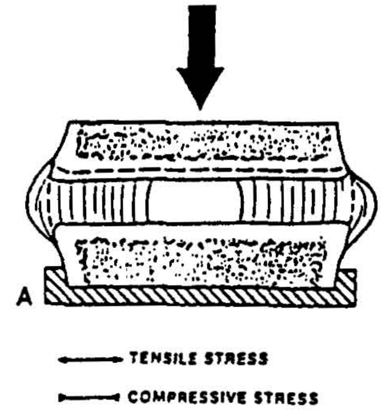
Compression load transfer in a degenerated disc (Fig 3): In a degenerated disc the nucleus is dry and the load transfer characteristics change because there is no increased fluid pressure in the nucleus (Fig 3A). Greater compression is exhibited at the periphery resulting in an increase in axial stresses which are compressive (Fig 3B). In the inner layers of the annulus the axial compression stress increases and there is an additional compressive stress in the direction of the fibres (Pope et al, 1988; Moore, 1985).

2. Tensile forces

During flexion, extension, lateral flexion and rotation movements of the spine the intervertebral disc is subjected to tension forces (Markolf, 1970). This causes tensile stress within the disc. During bending the disc rotates about an axis of rotation, which divides the disc into a segment that is compressed and a segment that is subjected to tension (Fig 4). Tensile stresses have been studied in two ways; sections of the disc have been cut in various directions (mapping of the disc) and subjected to tensile forces, or tensile forces have been applied to vertebra-disc- vertebra units. Tension deformation curves have been used during both these methods to study the biomechanical characteristics of the disc (Bradford et al, 1987, White and Panjabi, 1990)

Fig 3 : Compression load transfer in a depressed disc

(Adapted from White et al, 1990)



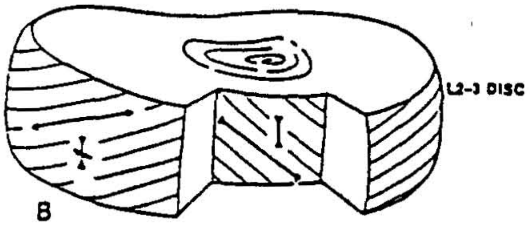
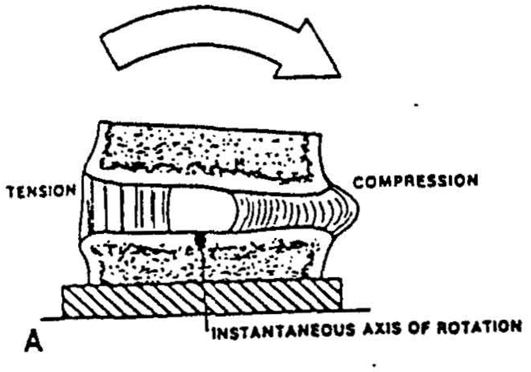
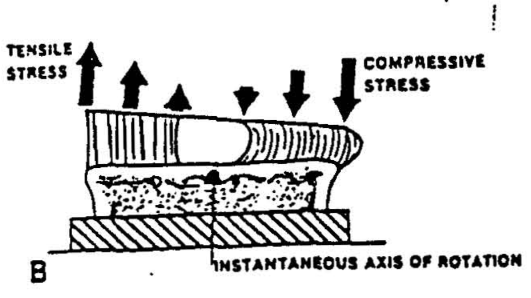


Fig 4 : Disc stress during bending

(Adapted from White et al, 1990)





Results from studies in which the axial tensile strength of segments of the disc was determined, known as axial tensile strength maps, show that the anterior and posterior regions are stronger than the central and lateral regions (Brown et al, 1957; White and Panjabi, 1990). Similar studies (White and Panjabi, 1990; Gilmore, 1986; Pope, 1982) have also been performed for forces directed in directions other than axial. In these studies tensile strength was found to be highest in a plane of 30° to the horizontal (Fig 5). This is the same direction of the fibre orientation of the annulus. The disc is therefore a structure which is highly adapted to accommodate tensile stresses in specific directions (Markolf, 1970; Gelante, 1973).

In studies (Markolf, 1970; White and Panjabi, 1990) where the tensile stress of vertebra-disc-vertebra specimens were examined the disc was found to be less stiff in tension than compression. This has been attributed to the increase in fluid pressures in the nucleus of the disc.

Computer simulation of the affect of tensile stresses on the disc have not been performed. However, a model has been proposed where tensile stresses that are applied to a disc are divided into two components; a normal stress which is parallel to the fibre orientation and the sheer stress is high but there is little provision to absorb the stress. The disc is therefore more likely to fail when tensile forces rather than compressive forces are applied to it (Shagnara, 1988; Brown et al, 1982).

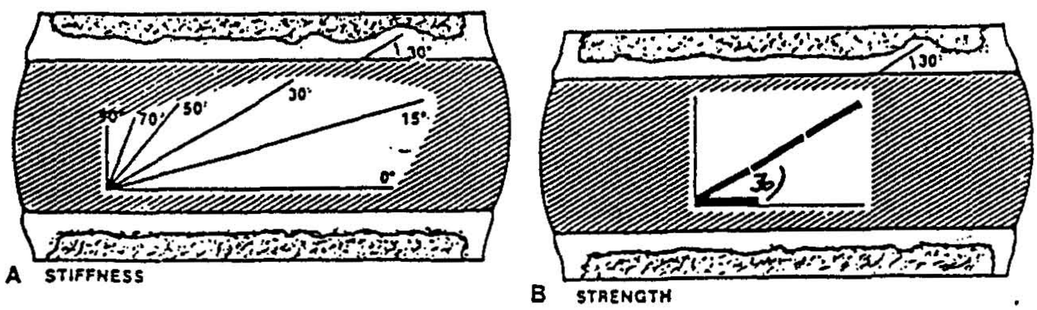
3. Bending

The effects of tensile and compressive forces on the disc are best demonstrated by bending. During flexion, extension or lateral bending there will be a specific point of rotation in the disc known an the instantaneous axis of rotation (Fig 6). On the concave side of the bending compressive forces will act on the disc and the magnitude of these forces will increase progressively from the centre to the periphery of the disc. Similarly, on the convex side the forces will be tensile and also increase progressively from the centre to the periphery (Road,1960; Schultz et al, 1982).

4. Torsion forces

The effect of applying a torsional or horizontal twisting force to the disc has been studied in vertebra-disc-vertebra specimens (Farfan et al, 1970; Farfan, 1973). Rotational forces applied to the disc generally resulted in failure of the disc rather than the vertebra or the end-plate. This occurred at about 15-20° rotation in normal discs and earlier in degenerated discs. It must be noted that the magnitude of torsional forces are greatest in the area of the disc which is furthest from the axis of rotation (Farfan et al, 1970; Farfan, 1973).

Fig 5 : Tensile strength and stiffness of disc areas (other than axial)
(Adapted from White et al, 1990).



Furthermore, torsional (rotational forces are associated with shear stresses (perpendicular to the axis of the spine in a horizontal direction). These shear stresses are however not uniform by studying torsional forces alone does not provide sufficient information on the shear characteristics of the disc (Nemeth et al, 1986; Panjabi et al, 1988).

5. Shear forces

It has been shown that high shear forces (horizontal forces as in antero-posterior and lateral directions) have to be applied to an intact disc before it will fail. This indicates that the disc is resistant to isolated shear forces (Nemeth et al, 1986;

Panjabi *et al* 1988; White and Panjabi, 1990).

6. Creep and relaxation

Creep and relaxation are biomechanical properties of viscoelastic tissue. Creep, a compressive load, and relaxation, a tensile load, refers to a progressive deformation of the tissue that occurs if a static load is applied (Hirsch and Nachemson, 1954; Markolf and Morris, 1974). The maximum deformation is reached after a specific time. Intervertebral discs react like viscoelastic tissue with respect to these characteristics. However, degenerated discs do not exhibit the same characteristics and reach their maximum deformation much earlier. It is well documented that shock attenuation is related to these viscoelastic properties. The implication is that degenerated discs have less shock absorbing capability than normal discs (White and Panjabi, 1990).

7. Hysteresis

Hysteresis is a biomechanical property that describes the ability of a tissue to absorb energy on repeated loading. Hysteresis has been observed in intervertebral discs and varies with respect to the following :

- Age : It is highest in the younger population and decreases with age.

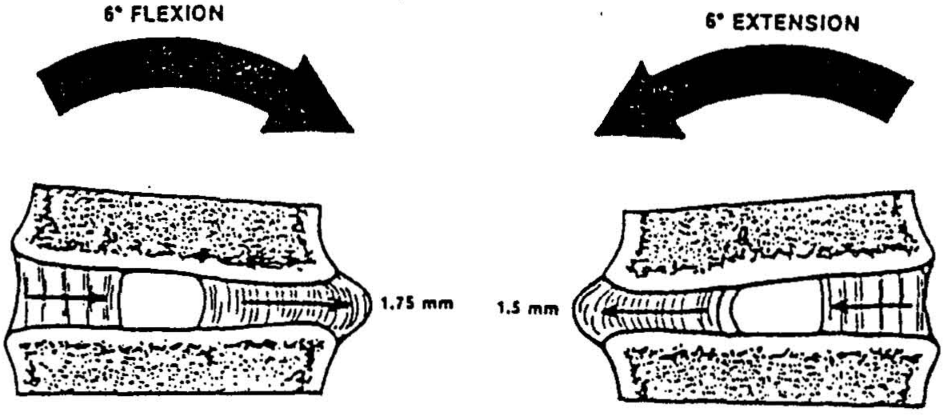
- Level of the vertebra : It has been observed that lower thoracic and upper lumbar vertebrae exhibit less hysteresis than the lower lumbar vertebrae.

- Type of loading : Repetitive loading causes progressive loss of this characteristic in vertebrae implying that this form of loading increases the risk of disc disease. In repetitive loading such as running, spinal shrinkage has been shown after exercise (30 min of running at different speeds). The degree of shrinkage was also related to running speed. The greater the speed the more the shrinkage. (Virgin, 1951; Kelsey and Hardy, 1975; White and Panjabi, 1990).

8. Fatigue tolerance

Fatigue tolerance refers to the resistance of tissue to fail under repetitive loading. There is very little known about this property in intervertebral discs. A fatigue test on a disc showed that if a constant small axial load is applied to a disc and repetitive flexion to 5° is then applied, failure occurs in the disc after about 1000 cycles. This indicates that the fatigue life of a disc in vitro is low. This information is not available in vivo (Crisco, 1989; White and Panjabi, 1990).

Fig 6 : The affect of extension and flexion on disc bending (Adapted from White et al, 1975).



9. Intradiscal pressure

The measurement of intradiscal pressure provides direct information on the pressure in the nuclear pulposus of the disc. It is performed by inserting a very thin gauge needle with a pressure transducer at the tip into the nucleus pulposus of the disc (Nachemson et al, 1964; White and Panjabi, 1990). The intradiscal pressure can be recorded during in vitro and in vivo. It has been recorded in a variety of postures and movements. The disc pressure during these movements and postures are usually expressed as a percentage of the disc pressure during standing or in absolute values. A summary of the disc pressures recorded in such studies are depicted in Fig 7 (Anderson and Shultz, 1989).

The major findings using this technique are :

- there is a compressive stress present in the unloaded state due to the posterior elements of the vertebrae. This is termed the pre-stress and is present even in supine lying;

- intradiscal pressure can increase from the value in standing by flexion during standing (50%), sitting (40%), flexion in sitting (85 %), and holding weights (120 % during standing and 175 % during sitting) (Fig 7A);

- positions such as standing on one leg, lateral flexion, coughing, straining, laughing and extension can increase the disc pressure by 15-50% (Fig 7B);

- specific exercises can increase the disc pressure by 30 - 110 %;

- the position of lying supine with the hips flexed, knees flexed and the feet supported on a chair decreases the disc pressure to a value almost as low as lying supine (Kirkaldy-Will, 1983; Anderson and Mc Neill, 1988).

2.2.2 SPINAL LIGAMENTS

The seven ligaments of the spine collectively provide stability to the spine while simultaneously allowing physiological movement in the structure, Fig 8 (Keim et al, 1982; White and Panjabi, 1990). The ligament of the spine have several functions:

- they bind the vertebral units together thereby providing stability;

- protect the spinal cord by controlling the limits of the spinal motion; and

- they govern the spatial motion of each vertebral segment in conjunction with the posterior facet orientation. (Dickson and Bradford, 1984).

2.2.2.1 Anterior longitudinal ligament

(i) Anatomy

This is a fibrous tissue structure which originates from the base of the occiput and is attached to the atlas, anterior surfaces of all the vertebral bodies, and the sacrum. The

Fig 7 A: Pressure Loads on Disk L3

(Adapted from Anderson et al, 1989)

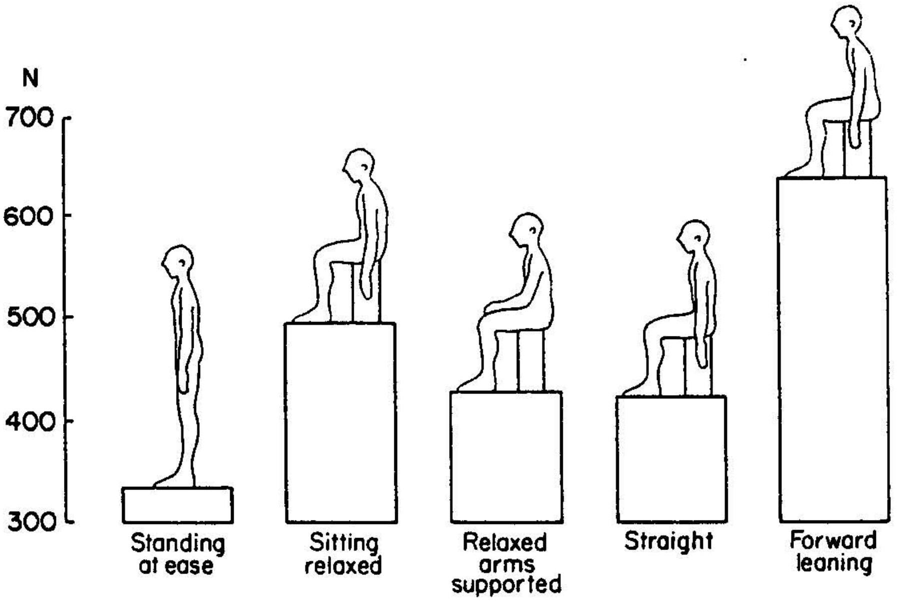
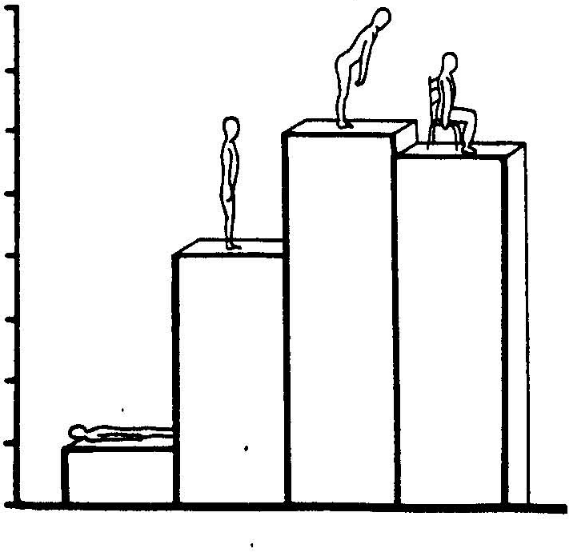


Fig 7B: Relative change in pressure in the third lumbar disc in various maneuvers

(Adapted from Macnab et al, 1989)



attachment to the vertebral bodies is firmer than the attachment to the disc. (Grieve G.P., 1991).

It is also wider at the bodies rather than at the disc. This ligament is also narrower and thicker in the thoracic region (Arutynow, 1962; Dickson and Arther, 1987).

(ii) **Biomechanics**

The anterior longitudinal ligament will be deformed if there is separation of the vertebral bodies anteriorly during extension movements or if there is anterior bulging of the disc during flexion movement (Hansson and Bjerkreim, 1980; Keim, 1982).

In addition there may be torsional stress in this ligament in rotational movements of the spine. The biomechanical characteristics of this ligament are age dependant. Advancing age is associated with a decrease in the resting force, the failure stress and the extension at failure. Finally, disruption of this ligament is likely only with rotational forces rather than tensile forces (extension movements) (Tkazuk 1968; White and Panjabi, 1990).

2.2.2.2 Posterior longitudinal ligament

(i) **Anatomy**

The posterior longitudinal ligament originates from the base of the occiput, covers the dens and transverse ligament, and then runs over the posterior surfaces of the vertebral bodies down to the coccyx. Differences between the anterior and posterior ligament are : the posterior ligament is wider at the disc level and narrower at the body and its connection with the disc is stronger than in the anterior ligament (Dickson and Sevitt, 1982; White and Panjabi, 1990).

(ii) **Biomechanics**

The biomechanics of the anterior and posterior longitudinal ligaments are similar except that the posterior ligament has:

- a higher pre-tension than the anterior ligament due to the fact that its centre of gravity is further away from the centre of the vertebrae; and

- a lower failure load than the anterior ligament (Bradford et al, 1987; White and Panjabi, 1990).

2.2.2.3 Intertransverse ligaments

(i) **Anatomy**

The intertransverse ligaments pass between the transverse processes in the thoracic region. They are characterized as rounded cords and have connections with deep muscles (Chazal et al, 1985; White et al, 1990).

(ii) **Biomechanics**

The biomechanical characteristics of these ligaments are not well described but are likely to have high tensile stresses in rotational and flexion movements due to the long lever arms. (Chazel et al, 1985; White and Panjabi, 1990).

2.2.2.4 Capsular ligaments

(i) **Anatomy**

The capsular ligaments are attached to the margins of the articular facets and run in a direction which is perpendicular to the plane of the facet. They are shorter and more taut in the thoracic and lumbar regions than in the cervical regions (White et al, 1975; Panjabi et al, 1986).

(ii) **Biomechanics**

The capsular ligaments provide support during flexion movements of the cervical spine. In the thoracolumbar region the ligaments are stretched during axial loading (Prasad et al, 1974; Panjabi et al, 1984).

2.2.2.5 Ligaments flavum

(i) Anatomy

These ligaments are composed of a large amount of elastic fibres (the most pure elastic tissue in the body). They extended from the antero-inferior border of the lamina above to the postero-superior border of the lamina below. They connect the lamina of the second cervical vertebra to the lamina of the first sacral vertebra. They are thickest in the thoracic region and are yellow in colour. (Chazal et al, 1985; Bradford et al, 1987).

(ii) Biomechanics

Very few studies have been conducted to examine the characteristics of this ligament. It has been shown that there is a significant pre-stress in this ligament which is higher than the anterior and posterior longitudinal ligaments. The reason for this is speculative but the following have been proposed :

- that protrusion of the ligament into the spinal canal is prevented during full flexion;

- that this together with the high elasticity of the ligament prevents impingement of the spinal cord in rapid full flexion; and

- that this provides stability to the spine in the unloaded state (Chazal et al, 1985; Goel and Njus, 1986; White and Panjabi, 1990).

2.2.2.6 Interspinous ligaments

(i) Anatomy

The interspinous ligaments connect the spinous processes of adjacent spines. These ligaments are broad and thick in the lumbar region, narrow and elongated in the thoracic region and not well developed in the cervical region (Dickson and Sevitt, 1982; White and Panjabi, 1990).

(ii) Biomechanics

There are very few reports on the biomechanical properties of these ligaments. In one study it was documented that the tension in these ligaments increased with progressive flexion (Silver, 1954).

2.2.2.7 Supraspinous ligaments

(i) Anatomy

This ligament originates in the ligamentum nachae and connects all the tips of the spinous processes of the vertebrae. It is round and slender except in the lumbar region where it is thicker and broader (Chazal *et al*, 1985; Goel and Njus, 1986; Dumas *et al*, 1987).

(ii) **Biomechanics**

The biomechanics of this ligament has not been studied and probably exhibits characteristics similar to that of the interspinous ligaments (Chazal *et al*, 1985; Goel and Njus, 1986; Dumas *et al*, 1987; White and Panjabi, 1990).

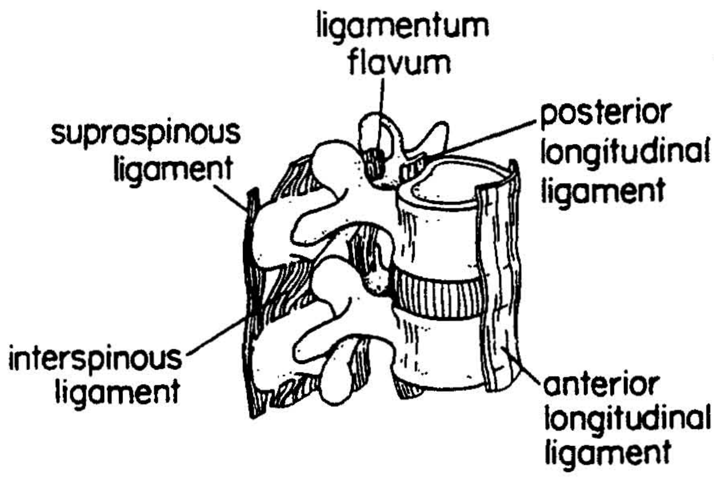
2.2.3 VERTEBRA

2.2.3.1 Anatomy

Vertebra consist of an anterior body and a posterior bony ring know as the neural arch. The body is a roughly cylindrical mass of cancellous bone surrounded by a thin shell of compact bone. The superior and inferior surfaces of the body are slightly concave and are known as the vertebral end plates. The neural arch consists of two pedicles and two laminae. Seven processes arise from the neural arch (Grey anatomy, 1981; Dickson and Sevitt, 1982; White and Panjabi, 1990). The basic shape of the vertebrae differs from region to region in the spine. The differences are related to the size and shape of the vertebrae and are designed for differences in

Fig 8: Ligaments of the Spine

(Adapted from Anderson and Mc Neill, 1988)



mechanical loading. (Hasue et al, 1983; Grieve G.P. 1991).

In addition, the vertebrae differ in the regions to accommodate specific anatomical structures such as vertebral arteries in the cervical spine and articular facets for ribs in the thoracic spine (Bradford et al, 1985; and White and Panjabi, 1990).

The superior and inferior articular facets of vertebrae are also shaped and positioned to allow specific movements in regions of the spine. In the lumbar region the facets are orientated primarily in the vertical plane. From L1 to S1, however, there is a gradual change in orientation form a saggital (L1/L2) to a frontal plane (L5/S1). This allows for movement mainly in the saggital plane (extension and flexion) and limits movement in the frontal and transverse planes (rotation) (Dickson and Sevitt, 1982; Stranara and Dove, 1988).

2.2.3.2 Biomechanics

(i) Vertebral body

The biomechanical characteristics of the vertebral body that has received most attention has been the compression strength. A number of factors appear to influence vertebral body compression strength. These are :

a. **Vertebral level :** There is an increase in vertebral compression strength as the level progresses from cervical to thoracic and lumbar (Fig 9) ;

b. **Age :** Vertebral compression strength decreases with age; and

c. **Bone density :** There is a direct relationship between bone density and compression strength (Bell et al, 1967; Perry, 1974; White and Panjabi, 1990).

(a) Cortical shell

The axial load on the vertebra is transmitted to the next vertebra by both the articular facets and the body. The relative contribution of the cancellous bone and the cortical shell to this transmission has been studied. (Andersson and Mc Neill, 1988; MacNab et al, 1990).

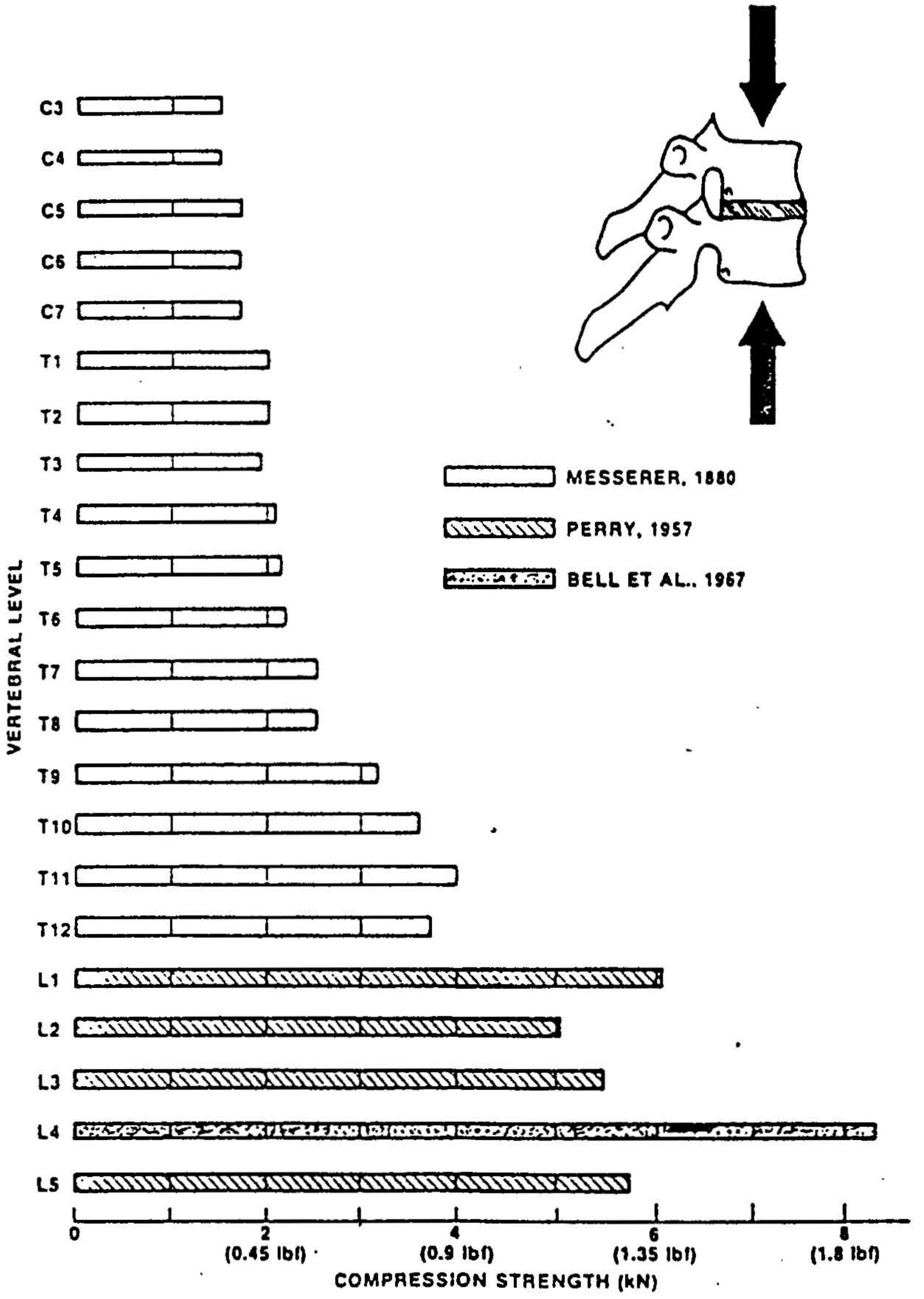
It has been estimated that 45 - 75 % of the load is transmitted via the cortical shell. This larger variation is due to the effects of age and bone density. The cortical bone is also much stiffer than the cancellous bone (Bartley et al, 1966; McBroom et al, 1985).

(b) **Cancellous core**

The role of the cancellous bone in load transmission has also been studied. Cancellous bone contributes about 22 - 55 % of axial load transmission and again depends on age and bone density. In addition the presence of bone marrow in the cancellous bone contributes to shock absorption (Hayes and Carter, 1976; Eurell et al, 1982). The cancellous core can be regarded as a structure consisting of vertical trabeculae (vertical columns) extending between the two end plates and horizontal trabeculae which support the vertical trabeculae. The compressive strength of such a structure is directly proportional to the cross sectional area of the vertical columns and inversely proportional to the square of the unsupported length of the vertical columns (Euler's formula). Compressive strength will therefore decrease if there is a decreased surface area or an increased unsupported length

Fig 9: Vertebral compression strength in the spine

(Adapted from White _et al_, 1990)



of the vertical columns (Eurell and Caesarean, 1982; White and Panjabi, 1990)

The effects of osteoporosis and age on the structure of the cancelous bone have been documented (Tollison and Griegel, 1989, James 1976). The earliest changes in age are loss of horizontal trabeculae particularly in the central region of the vertebral body. Despite some compensatory but insufficient thickening of the vertical trabeculae the structure therefore becomes weaker with age. In osteoporosis the decrease in osseous tissue results in both loss of vertical and horizontal trabeculae.

This causes progressive weakening of the cancellous bone structure (Lindahl 1976; Keller et al, 1989).

(c) **Vertebral end-plates**

It has already been stated that axial loading will result in failure of the end plate (Nachemson, 1960; Anderson and Schultz, 1979). Three failure patterns have been observed; central, peripheral and one involving the entire end plate. Non degenerated discs appear to fail centrally while degenerated discs fail peripherally. The mechanism of failure therefore differs. In normal vertebrae the central failure is as a result of increased pressure in the nucleus pulposus. In degenerated discs the peripheral failure is due to the transmission of the load to the next vertebra via the periphery because the central area gives way due to loss of fluid pressure in a degenerated disc (Brickmann and Horst, 1985; Reuber et al, 1983).

2.2.3.3. Neural arch

In most investigations the neural arch has been considered as a unit and not as separate components. Furthermore, the methods of applying the loads has varied greatly and the results of studies are therefore difficult to compare (Balasubramanian et al, 1979; Hakim and King, 1979).

However, if studied as a single unit undergoing loading, most failures of the neural arch occur in the pedicles (Miller et al, 1983; White and Panjabi, 1990).

Axial loads to the vertebra-disc-vertebra unit are transmitted by both the disc and the facet joints. The relative contribution of these two structures to load transmission has been studied. The relationship is complex but it has been established that only between 0 and 33 % of the load is transmitted through the facet joints in axial loading (Panjabi et al, 1976; Panjabi et al, 1986).

The relative contributions of the disc, longitudinal ligaments,facet joints and interspinous ligaments to torsional strength has also been investigated. In a study by Posner et al (1982) the relative contributions were documented as follows ; disc and two longitudinal ligaments (45 %), facet joints (45 %) and interspinous ligaments (10 %).

The facet joints also provide significant stability to the spine in flexion movements. This has been shown (MacNab et al, 1990) with the contribution of the facet joints in cervical spine flexion injury. A flexion producing load of 30 % body weight, with the disc and longitudinal ligaments transected, resulted in a 33 % increase in horizontal translation (compared to the intact spine).

When the facets were transected, the increase in horizontal translation was 140 % (White and Hirsch, 1971; Panjabi et al, 1975).

Finally, facet orientation, particularly in the lumbar spine, also plays an important role in the development of back pain (Farfan and Sullivan, 1967; Ahmed et al, 1988).

2.2.4 RIB CAGE

The ribs which join the spine to the sternum forms a cylindrical cavity, the thorax (Moore, 1985; White and Panjabi, 1990). The rib cage is protective to the spine for any force directed from anterior and lateral directions. It also provides stability to the spine by additional ligaments around the costovertebral joints and by its inherent moment of inertia. The increased moment of inertia stiffens the spine against rotatory forces (Ross et al, 1983; Moore, 1985).

Computer simulation studies have determined the biomechanical effects of the rib cage on stiffness properties of the spine during flexion, extension, lateral bending, axial rotation and axial compression. The stiffness properties of the spine were found to be greatly increased by the rib cage (Fig 10) (Schultz et al, 1982). This was most marked for extension. In addition the axial compression strength was increased four times by the presence of the rib cage. In all the above effects, the intact ring is important. All these effects were completely negated by the removal of the sternum (Fig 10) (Schultz et al, 1982).

2.2.5 MUSCLES OF THE SPINE

The muscles of the spine are very important to :

(i) provide stability to the trunk; and

(ii) to produce physiological movements of the trunk.

They also play a role protecting the spine during trauma (Lucas and Brester, 1961; White and Panjabi, 1990).

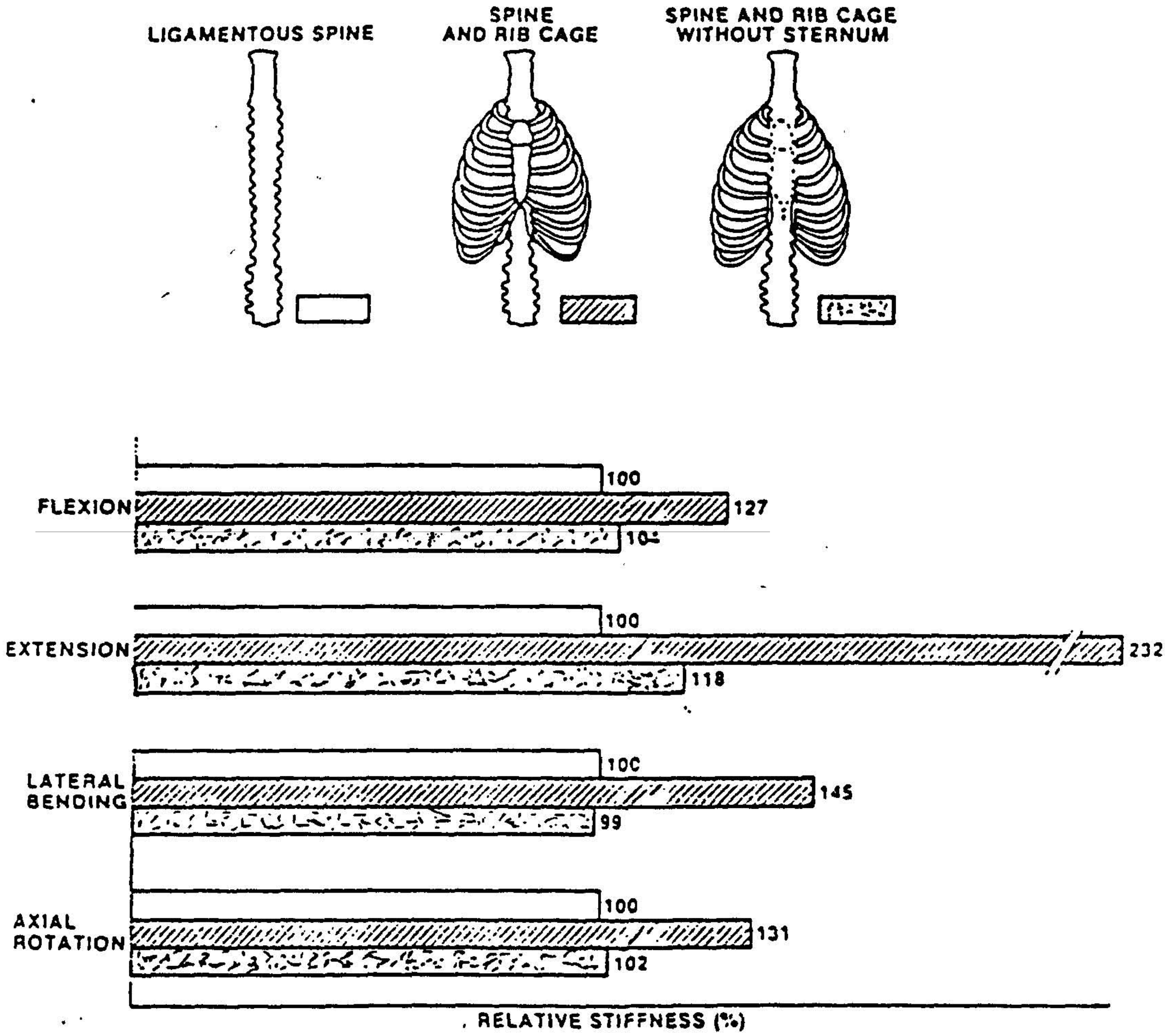
2.2.5.1 Anatomy

The muscles of the spine can be divided into pre-vertebral which is anterior to the spine and post-vertebral which is posterior to the spine (Moore, 1982; White and Panjabi, 1990).

The pre-vertebral muscles are the external oblique, internal oblique, transverses abdominous, which are dicumferential, and the rectus abdominous, which is only anterior. Other important pre-vertebral muscles that contribute to the biomechanics of the spine are quadratus lumborum and iliopsoas (Moore, 1982; White and Panjabi, 1990).

The post-vertebral muscles can be divided into superficial, intermediate and deep. The superficial muscles are iliocostalis (lateral), longissimus, and spinalis (medical). Collectively these are known as the erector spinae (Moore, 1982; White et al, 1990). The intermediate muscles are more diffuse, but components have been identified. These muscles are attached to the transverse processes of the lower vertebrae and the spinous process of the vertebra above. In the different regions of the spine they are named as follows : multifidus (lumbosacral), semispinalis thoracis (thoracic), semispinals cervicis (cervical) and semispinalis capitis (C1) (Aorab, 1974; Luttgens and Wells, 1982). The deep muscle consist of short muscles that are named according to the structure they connect. They are as follows: spinous processes (inter-spinales), transverse processes (intertransversarii), transverse process below to lamina above (rotatores) and transverse process to ribs (levatores costarum)

Fig 10 : The role of the rib cage in enchanging the overall stability of the spine (Adapted from White _et al_, 1990).



(Williams et al, 1980; Moore 1982; White and Panjabi, 1990).

2.2.5.2 Biomechanics

The biomechanics of the muscles related to the spine have been studied mostly by documenting electromyographic activity during specific movements (Hill, 1983; Farfan, 1975; White and Panjabi, 1990).

(i) Standing and sitting

In the relaxed standing position there is continuous activity of the longissimus dorsi and rotatores muscle groups. Minimal muscle activity can be documented in some of the other muscle groups as follows; back muscles (to counteract flexion), abdominal muscles and psoas major (to counteract extension) (Asmussen and Klausen, 1964, Nachemson, 1960; Anderson and Ortengren, 1974; White and Panjabi, 1990).

In the unsupported sitting position the muscle activity in the lumbar region is similar to that observed in standing. In the thoracic region back muscle activity was higher in sitting than in standing (Moore, 1982; White and Panjabi, 1990).

(ii) **Flexion**

Forward flexion is a complex movement involving both movement of the spine and the pelvis. The first 60° of movement generally occurs in the lumbar spine and is due to flexion of the lumbar spine segments. This is followed by an additional 25° flexion of the hip joint. The muscle EMG activity closely follows this pattern (Davis et al, 1965; Farfan, 1975; White and Panjabi, 1990). Initially the pelvis is locked as indicated by strong EMG activity of the gluteus maximums, gluteus medius and the hamstrings. With progressive flexion there is increasing EMG activity of the erector spine and superficial back muscles. This is to counteract the effect of the increasing bending moment due to gravity. At full flexion there is little or no EMG activity in these muscles, with the exception of iliocostalis and the ligaments provide the force to counteract the bending moment (Anderson and Shultz, 1979; Schultz et al, 1985).

(iii) **Extension**

EMG activity of the back muscles during extension, without a load, occurs throughout the movement but is predominant at the beginning and at the end of the movement (Schultz et al, 1985; White et al, 1990). The abdominal muscles show progressively increasing activity as the movement proceeds. Extension of the trunk against a load increases the EMG activity of the extensor muscles (Schultz et al, 1985; White and Panjabi, 1990).

(iv) **Lateral flexion**

During lateral flexion there is increased EMG activity in both the ipsilateral and contralateral muscles (mostly on the ipsilateral side). If this movement is against resistance the EMG activity differs in the regions and is higher on the contralateral side in the lumbar region so as to counteract lateral flexion, and higher on the ipsilateral side in the thoracic region (Morris et al, 1963; Anderson and Shultz, 1977; White and Panjabi, 1990).

(iv) **Axial rotation**

During axial rotation of the spine the following muscles were found to have increased EMG activity : contralateral side (Rotatores, multifidus), ipsilateral disc (erector spinae). In addition to abdominal muscles, the tensor fascia latea and the gluteus medius also show increased activity (Donish and Basmajian, 1972; Pope et al, 1986).

2.2.6 SPINAL CORD

The spinal cord, spinal nerve roots, and their coverings are located within the vertebral canal. The vertebral column provides a partially rigid and partially flexible axis for the body and a pivot for the head. Thus the vertebral column has an important role in posture, in support of body weight, in locomotion, and in protection of the spinal cord and spinal nerve roots (Moore, 1985; White aND Panjabi, 1990). The following important principals apply to the spinal cord :

- When stretched the spinal cord is initially very flexible if subjected to small tensile forces. As the length reaches a certain point the stiffness increases dramatically and a large force is required to stretch the cord further.

- During flexion the spinal cord is subjected to a tensile force. In this movement it unfolds in an accordion-like fashion. During flexion the spinal cord folds.

- The spinal cord is protected from traumatic forces by two fluid filled spaces and three membranes.

- The dentate ligaments of the spinal cord provide additional protection and stability to the spinal cord (Moore, 1985; Rausching, 1987; White and Panjabi, 1990).

2.2.7. BIOMECHANICS OF MOVEMENT IN THE SPINAL REGIONS

2.2.7.1. Introduction

The biomechanics of the movements in the spine is complex and differs in the spinal regions. The characteristics of the movements in each region of the spine will be discussed under the following headlines :

- range of motion;
- coupling (refers to motion in which rotation of translation of a body about or along one axis is consistently associated with simultaneous rotation or translation about another axis)
- function of specific anatomic elements

2.2.7.2 Cervical spine

The biomechanics of the cervical spine movements differ in the upper or occipital-atlanto-axial complex and the lower cervical spine, Fig 11 (Bradford et al, 1987; Breig, 1978).

(i) **Range of motion**

In the upper cervical spine the following average ranges of motion have been described :

- Occipital-altantal joint : flexion (13°), lateral flexion (8°) and axial rotation (0°);

- Atlanto-axial joint : flexion (10°), lateral flexion (0°) and axial rotation (47°) (Grieve, 1991).

It is important to note that most of the axial rotation or the cervical spine occurs at the atlanto-axial joint (Worth, 1985; Clark _et al_, 1986; Dvorak _et al_, 1987; White and Panjabi, 1990). In the lower cervical spine the average ranges of motion in degrees for the interspaces have also be described (Table 1). Note that the predominant flexion/extension movements occur in the central region with the C5 - C6 interspace being the predominant one.

The upper region is more predominant in lateral flexion and axial rotation (Lysell, 1969; White and Hirsch, 1973; White and Panjabi, 1990).

Table 1 :

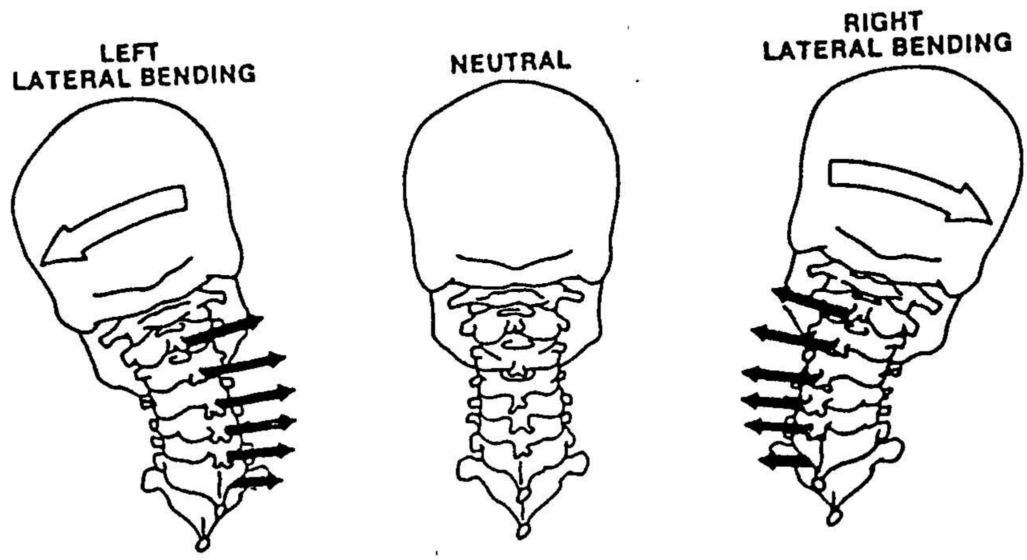
AVERAGE RANGES OF MOVEMENT (DEGREES) OF THE LOWER CERVICAL SPINE

Interspace	Flex/ext :	Lat flex :	Axial rot :
C2 - C3	8	10	9
C3 - C4	13	11	11
C4 - C5	12	11	12
C5 - C6	17	8	10
C6 - C7	16	7	9
C7 - T1	9	4	8

(Adapted from White and Panjabi, 1990).

Fig 11: Cervical spine coupling

(Adapted from White and Panjabi, 1990)



In a summary the cervical spine range of movement is predominantly axial rotation and flexion/extension.

(ii) **Coupling characteristics**

The coupling characteristics of the lower cervical spine are clinically important. In lateral bending there is associated axial rotation. The direction of the rotation is such that the spinous processes move towards the convex side of movement (Fig 11) (Lysell, 1969; Panjabi et al, 1986). The amount of axial rotation that occurs with lateral flexion is called the coupling ratio. At C2 2° of axial rotation occurs with each 3° of lateral flexion (coupling ratio of 0.67). This ratio decreases from C2 to C7 (ratio of 0.13). This coupling phenomenon is clinically important as some ratios may predispose to unilateral facet dislocation facet dislocation (Panjabi et al, 1986; Moroney et al, 1988).

(iii) **Function of the anatomic elements**

The following functions are of importance :

- the developed attachments of the annulus are strong and therefore very important in limiting horizontal translation of the vertebrae; and

- the degree of flexion/extension is dictated to some extent by the height and antero-posterior (A-P) diameter of the disc. Greater height and smaller A-P diameter allow more motion (White et al, 1975 & 1990).

2.2.7.3 Thoracic spine

(i) **Range of motion**

The average range of motion of the thoracic spine interspaces is indicated in Table 2. It is important to note that flexion/extension movement increases and axial rotation decreases from T1 to T12. Lateral flexion is constant but rather limited in each segment (Gregersen and Lucas, 1967; White and Panjabi, 1990).

(ii) **Coupling characteristics**

The coupling characteristics of lateral flexion and axial rotation as described for the cervical spine are similar in the thoracic spine. This coupling is strongest in the upper thoracic spine area (White, 1969; Panjabi et al, 1976; White and Panjabi, 1990).

(iii) **Functions of anatomic elements**

The following important function of specific anatomic elements in the thoracic spine need to be mentioned :

- extension is limited by the posterior elements (spinous processes and intervertebral joints); and

- axial rotation is most likely limited by the ligamentum flavum, the posterior ligaments and the facet joint capsules and not the bony articulation (White, 1969; White and Panjabi, 1990).

2.2.7.4 Lumbar spine

(i) **Range of motion**

The average range of motion of the lumbar spine is depicted in Table 3. The flexion/extension movement is predominant in the lumbar spine and the degree of flexion/extension increases progressively from L1 to S1 (Lumsden and Morris, 1968; Pearcy, 1985). There is a limited axial rotation and lateral flexion in the lumbar spine except the slight increased axial rotation in L5 - S1. It can also be noted that L4 - L5 and L5 - S1 undergo the greatest movement and bear the greatest loads. It is therefore not surprising that these regions are frequently involved in degenerative disease processes (Posner et al, 1982; White and Panjabi, 1990).

(i) **Coupling characteristics**

The important coupling mechanism in the lumbar spine is that lateral bending is associated with axial rotation as in the thoracic and cervical spines. However, the direction of the axial rotation is opposite to that in the other two regions. The direction of axial rotation in the lumbar spine is such that the spinous processes point in the same direction as the lateral flexion (Pearcy and Tibrewal, 1984; Panjabi et al, 1989).

(iii) **Functions of anatomic elements**

The main anatomical structures that have a specific function in lumbar spine movement are the intervertebral joints. The intervertebral joints limit axial rotation but allow flexion/extension movements of the lumbar spine (Nachemson, 1963; White and Panjabi, 1990).

2.2.7.5 Summary of the biomechanics of movement in the spinal regions

The mid-cervical, lower thoracic and specifically the lumbar region provide most of the flexion/extension movement of the spine. Lateral flexion is non-specifically provided by all the regions with the exception of the lower cervical and lower lumbar regions.

Axial rotation occurs mostly in the atlanto-occipital joint. The cervical and upper thoracic regions also provide axial rotation (Panjabi et al, 1989; White and Panjabi, 1990).

Table 2 :

AVERAGES RANGES OF MOVEMENT DEGREES OF THE THORACIC SPINE

Interspace :	Flex/Ext :	Lat flex :	Axial Rot :
T1 - T2	4	6	9
T2 - T3	4	6	8
T3 - T4	4	6	8
T4 - T5	4	6	8
T5 - T6	4	6	8
T6 - T7	5	6	8
T7 - T8	6	6	8
T8 - T9	6	6	7
T9 - T10	6	7	4
T10 - T11	9	8	2
T11 - T12	12	9	2
T12 - L1	12		2

(Adapted from Grieve, 1991)

Table 3 :

AVERAGE RANGE OF MOTION DEGREES OF THE LUMBAR SPINE :

Interspace :	Flex/Ext :	Lat flex :	Axial rot:
L1 - L2	12	6	2
L2 - L3	14	6	2
L3 - L4	15	8	2
L4 - L5	17	6	2
L5 - S1	20	3	5

(Adapted from Grieve, 1991)

2.3 ORTHOTIC BRACING

Spinal bracing originated during the Middle Ages when the wealthy instructed armorens to mould metal corsets in an attempt to halt the progression of scoliosis (Keim, 1982; Stagnara, 1988). In 1945 Dr Blount and Schmidt developed the Milwaukee brace. The initial purpose of the brace was to prepare the way for surgery and to maintain the correction obtained by operation (Blount, 1972; Keim, 1982; Stranara and Dove, 1988).

The role of the brace is not to provide distraction (Bunch et al, 1976; Dickson et al, 1984; Stagnara, 1988). The science of spinal orthotics is the application of forces in order to control the spine. The application of forces, lateral forces for scoliosis, alters the existing patterns of deformation and kinematics of the spine (Bradford and Hensinger, 1985; Nachemson, 1987;). The brace should provide a passive support to the spine and reduce the degree of curvature. It should stimulate muscle activity, and permit free motion of the spine, allowing correction to occur (Blount, 1972; Blount and Moe, 1980).

The Milwaukee brace which is predominantly used in scoliosis treatment, comprises the following : (1) a moulded pelvic girdle; (2) two posterior uprights; (3) a single anterior upright; (4) a comfortable fitting cervical ring; and (5) straps and pressure pads (Blount, 1972; Moe, 1973; Keim et al, 1982; Stranara and Dove, 1988).

The most important factor to be considered when constructing a brace is growth potential. It is during the adolescent growth spurt that the greatest risk of curve progression occurs (Moe, 1973; Blount and Moe, 1980; Bradford et al, 1987). Another important indicator for treatment is the curve deviation and its flexibility. The size and shape of the rib deformity is also important as the larger the rib deformity the poorer the cosmetic appearance (Tanner, 1962; Blount, 1980; Bradford et al, 1987).

Careful note must be taken as to the placing of the pressure pads. For a lumbar curve, a pad is applied to the transverse process area above the iliac crest just over the apex of the lumbar curve. For high thoracis curves involving the T1 to T5 area, a shoulder ring is used (Blount, 1972; Clarke et al, 1971). When initiating brace treatment it is necessary to apply an axillary sling to counteract the lateral thoracic pad forces (Blount, 1972; Dickson, 1984; White et al, 1990).

The Milwaukee brace is effective for mild to moderate curvatures in the range of 20 - 40°. The reasoning is that the brace is used primarily to prevent enlarging of curves and not to correct larger curves into smaller curves (Moe and Kettleson, 1970). In 1970 Moe and Kettleson conducted a study (Moe and Kettleson, 1970; James, 1976) of 228 major idiopathic curves in 169 subjects who had completed their Milwaukee brace treatment and were wearing the brace at night only.

They concluded that after a medium total brace wearing time of 34.3 months; (1) the best correction occurred within the first 25 months; (2) high thoracic curves gave the worst results; (3) the median loss for correction after brace removal was 1 % and 5 % in thoracic and lumbar curves respectively; (4) certain small curves treated in the Milwaukee brace showed little or no correction; and (5) deformities in some young patients were kept from progressing (Moe and Kettleson, 1970; Keim et al, 1982). Long term follow-up results have shown that bracing would initially improve a curvature; but during a long term follow-up the curve average was the same before and after treatment (Carr and Moe, 1980; Dickson, 1984).

A trend has developed, in using the underarm, or Boston, brace for treating idiopathic scoliosis (Rothman and Simoene, 1928; Stagnara, 1988). Earlier studies by Watts et al, (1979) and Bunnell and MacEwen (1980) found the brace to be most effective for flexible lumbar and thoracolumbar curvatures of less than 40°. Laurnen et al, (1983) conducted a study on 300 curves with an apex up to T7. They recommended a Boston brace with superstructure for curves with a higher apex (Lauren et al, 1983; Bradford et al, 1987). Rothman and Simeone (1982) do warn that these braces may lead to chest wall deformity through decreased pulmonary function, if it is used for thoracic curvatures.

Carr and Moe (1980) did a follow-up of seventy four patients after the cessation of wearing a brace. They concluded that after five years the average correction for thoracic curves was two degrees and for thoracolumbar curves, four degrees.

A highly regarded study on the Milwaukee and Boston braces was performed by Miller et al (1984). They studied 250 females between the ages of 8 and 17. Their group was matched for maturity and curve severity. One group was treated with either the Milwaukee or the Boston brace, whilst the other group was untreated. The results indicated that there was a slight, but not statistically significant, trend of less curve progression in the treated group.

According to De Smet (1985) the effectiveness of bracing is measured according to three parameters. The first parameter is the curve reduction in bracing. He states that curve reduction has been significant with both the Milwaukee and Boston braces. Carr and Moe, (1980) also noted that curve reduction is initially good with bracing, with an average of 30 - 50 % in curve size. The second parameter is the comparison of the pre- and post bracing wearing curve size. A concerning problem with the cessation of brace wearing is that all to frequently the curve size settles back to that of the pre-brace measure. Hasson and Bjerkeim (1983) found that the mean curve progression was two to three degrees per year for the first four years after treatment and a half to one degree per year after that. The third parameter is the completion of curve reduction at the completion of brace therapy. Although the initial reduction is large, there is usually some subsequent increase in curve size during the period of full-time bracing and wearing. The average curve reduction at the completion of brace therapy is 20 - 30 % (Edmonson and Morris, 1977).

Certain prerequisites such as a competent orthotist, an experienced orthopaedic surgeon, and experienced physical therapist and a co-operative patient are required for satisfactory results (Blount, 1972; Bradford et al, 1987.

The advantages and complications of spinal orthoses is summarized in table 4.

TABLE 4 :

ADVANTAGES AND COMPLICATION OF BRACING

Advantages	Complications
1. Resting of the spine through substitution of the brace of the actions of the muscles; (Moe et al; 1970).	1. If the previous mentioned advantages are satisfied (Bradford et al, 1985).
2. Limits range of motion to the pain free range (James, 1976)	2. Contraindicated for curves above 45° (Moe, 1973).
3. Protects the vital cord and nerve roots immediately post surgery (White et al, 1990).	3. Contraindicated for skeletally mature individuals (Moe, 1973).
4. Miscellaneous effects (massage, heat, psychological placebo) (Nachemson, 1987).	4. Contraindicated for patients with un-acceptable cosmetic appearance (Bradford et al, 1985).
	5. Curve progression in 10-15 % of all patients (Hasson et al, 1983).
	6. Psychiatric complica-tions due to adjustment and acceptance (Aptera et al, 1978).
	7. Skin irritation due to pressure sores (Bradford et al, 1985).

2.4 SURGICAL TECHNIQUES

"The primary aim of surgical arthrodesis of the spine is to promote a physiologic state in the skeletal tissue that will ultimately result in bone formation, maturation and union" (Rothman and Simeone, 1982).

In 1891 Hibbs performed the first spinal fusion to immobilize and control the spine (Keim et al, 1982). Later, in 1914, he performed the first scoliosis spinal fusion. His reasoning was that the curvature could be checked by fusing vertebrae together; as if trying to weld the links of a chain to immobilize it (Keim et al, 1982).

Distraction is the most superior means by which to correct severe lateral scoliosis deformity (Harrington, 1970; Wegner et al, 1970). Between 1949 and 1962 Harrington developed his instrumentation which comprised a distraction rod placed on the concave side of the curve and a compression devise which is applied to the convex side for the correction of scoliosis (Keim, 1982; Bradford, 1984). The Harrington distraction can achieve 60 % correction of the supple curve (Erwin et al, 1976). It does, however have three disadvantages. Firstly, the distraction may worsen or flatten the sagittal contours through lack of rotation. Secondly, the system is only attached to the spine at two points, namely the two sites at either end of the curve (Grinssburg et al, 1979; Bradford et al, 1987). Thirdly, because it's principle function is distraction, its ability to correct a curve is dependant on bone-metal interface

(Ulin and McGinnis, 1983). The advantages and disadvantages of the Harrington instrumentation are summarized in table 5.

New advances in distraction techniques have taken the Harrington short-comings into account. These techniques attempt to firstly correct scoliosis in the sagittal and axial planes and secondly improve the load sharing, which is a weakness of the Harrington distraction. With the newer segmental spinal instrumentation system (SSI) there are multiple points of attachment to the spine (Drummond, 1991). Most SSI systems provide two rods that are linked together which promotes load sharing and fusion protection.

Two popular SSI systems which are preferred are the Luque (Drummond, 1991) and Dwyer (Hsu et al, 1982) instruments. A Luque rod is placed posteriorly along the left and right sides of the spine. Transverse forces are created by passing a wire under each lamina and by twisting the wire around its respective rod. By securing the spine at multiple points the force is distributed across multiple levels with resultant greater curve stability (Wegner et al, 1970; Bradford, 1984).

The Dwyer instrumentation is excellent for correction and fixation of thoracolumbar and lumbar scoliosis. It more completely corrects lateral deviation and spinal rotation (Hsu et al, 1982).

TABLE 5 :

ADVANTAGES AND DISADVANTAGES OF HARRINGTON INSTRUMENTATION

Advantages	Disadvantages
1. Preoperative correction is mostly unnecessary;	1. Increased blood loss due to extended operation time;
2. Improved correction of the deformity;	2. Increased risk of infection;
3. Improved correction of stability;	3. Subcutanious protrusion of the instrument;
4. Postoperative mobilization is shortened;	4. Posterior instrumentation is often incapable of stabilizing severe spondylolisthesis;
5. Postoperative casts are shorter and used for immobilization;	5. Slipping or dislocation of the hooks and breakage of the rod are positioning problems;
6. Reduced incidence of pseudoarthrosis;	6. Some patients are psychologically affected.
7. Minimal loss of correction;	
8. Used to delay definitive treatment and permit stages of correction in young patients.	

(Adapted from Bradford and Hensinger, 1985)

The SSI system is not without it's disadvantages. The most important one is that its use requires the passage of wires deep to the lamina which risks penetrating the implants close to the dural sac (Carol et.al, 1988).

2.5 PHYSIOTHERAPY WITH RELATION TO SCOLIOSIS

The Maitland evaluation technique is largely used to evaluate cervical, thoracic and lumbar scoliosis.

The patient partakes in a subjective medical history question - answer session prior to treatment. This includes questions concerning pain, stiffness, sport participation, social circumstances, profession, medication and x-rays. Hereafter an objective physical evaluation is done.

The physiotherapists approach comprises the following :

1. Treatment of pain;

2. Reduction of muscle spasms;

3. The de-activation of trigger points in the shortened tissues; and

4. Correction of the spinal column with passive mobilization.

1. Treatment of pain

Demanding on the cause of the pain, certain modalities can be used to relieve the pain. Only the symptoms can be treated in this manner which lasts for a limited period of time. These modalities include ultra sound, interferential therapy, short wave diathermy, laser and passive mobilizations. (Tollison and Kriegel, 1989; Grieve, 1991).

2. Reduction of muscle spasms

There is usually a unilateral muscle spasm present on the concave side of the curve due to the inter vertebrae compression. Treatment is by means of massage, ultra sound, interferential, laser and ice respectively. (Tollison and Kriegel, 1989; Grieve, 1991).

3. De-activation of trigger points

The shortened fibres on the concave side of the abnormal curve often have trigger point characteristics. De-activation takes place by applying local pressure in the area while stretching the muscle or muscles. (Tollison and Kriegel, 1989; Grieve, 1991).

4. Passive mobilization

Using this technique, a variety of methods may be implemented. In the thoracic and lumbar region transverse movements of the vertebrae in the direction of the convex curve produces good results. This technique results in an opening effect of the apophysial joints on the concave side as well as a stretching of the tiny interstitial muscles and ligaments which are in the shortened position. (Tollison and Kriegel,1989).

2.6 EXERCISE PRESCRIPTION

Blount and Moe (1980) Keim (1982), Stagnara (1988) and White and Panjabi et al (1989) all categorically state that through their experience exercise programs are of no value in the treatment of scoliosis. Kendall and McCreary (1983) state that an adequate muscle balance between opposing muscle groups is essential to maintaining a good posture. Muscle imbalancement and malalignments occur when muscles or muscle groups are not strengthened proportionately to each other, or if the muscle remains in a shortened position while the opposing muscles remain lengthened. This imbalancement in the back could develop into a scoliotic condition.

One does not want to strengthen short, strong muscles or stretch already stretched muscles. The reverse of this is the ideal. Structural rehabilitation programs must restore muscle balance through improved flexibility, muscle strength and muscle endurance (Zorab, 1974).

Except in flexible subjects the postural faults seen at the time of the examination will probably correlate with the habitual faults of the individual. With children it is necessary and advisable to do repeated tests of alignment, and to obtain information regarding the habitual posture from the parents (Kendall and McCreary, 1983).

It is of particular importance that girls between the ages of 10 and 14 have periodic examination of the spine because at this age more spinal curvatures occur in girls than in boys (Jackson and Brown, 1983).

When the patient performs the exercises, the first few sessions are performed one-on-one with the therapist, where-after the exercises are completed as a member of a group (White and Anderson, 1991). Care must be taken to ensure correct form and slow exercise repetition speed. Milwaukee brace exercises both in and out of the brace have been defined by Blount and Moe (Blount and Moe, 1980). The exercises outside the brace include : (1) pelvic tilt, supine, with knees flexed; (2) pelvic tilt with knees straight; (3) sit ups with pelvic tilt held; (4) pelvic tilt in standing position; (5) breathing exercises; (6) spine extension in prone position; and (7) pushups, with pelvic tilted.

Exercises done in the brace are : (1) pelvic tilt, supine, with knees straight and flexed and standing; (2) prone spine extensions; (3) pushups with pelvis tilted; (4) correction of the thoracic kyphosis and rib hump; and (5) active correction of the major curve by tilting the pelvis and moving the torso away from the thoracic pad (Blount, 1972; Keim, 1982). It is stated that these exercises are most effective when done under supervision daily (Blount, 1972; Keim, 1991).

The improvement in patients who have done exercises whilst wearing a brace is greater when compared to those who did no exercise. Without exercise, the treatment of a sedentary patient with a brace will be unsatisfactory because poor muscle tone will allow deterioration of the deformity in the brace, and collapse of the spine when the brace is removed (Blount and Moe, 1980).

A vast amount of research has been done concerning lumbar rehabilitation through exercise. This prompted Koes et al, (1991), by means of a blind study, to establish the best exercise regime. This, however, has not be done for scoliosis. Schrecker (1965) compiled a working manual on posture deformities. Unfortunately, no document or research has been compiled to parallel his work.

White and Panjabi (1990) state that in their opinion it is doubtful as to whether exercise can correct scoliosis. However, they do not substantiate their statement with any references. They proclaim that the forces applied by the muscles are of a low amplitude and frequency and should not be relied upon to hold or even correct a curve when used alone.

2.7 PULMONARY FUNCTION

A deformed or rigid thoracic cage that is present in moderate to severe thoracic scoliosis results in a restrictive type of lung disease characterized by a reduction in lung volume, vital capacity, and maximum voluntary ventilation. It is well established that an individual with severe scoliosis dies not from anatomic deformity but from cardiopulmonary failure (Neilsonne et al, 1986). A sympathic patient with curves in the 40 - 60° range have symptoms of restrictive lung disease (Weber, 1975).

Shannon et al (1970) found a reduced total lung capacity in all patients with curvatures exceeding 65°. Those with curvatures exceeding 90° had a reduced vital capacity of approximately 50 % of the total lung capacity. Maximum breathing capacity also has been found to be reduced in scoliosis patients, the degree of reduction being proportional to the degree of curvature (Yong-Hing and Mac Ewan, 1979).

2.8 RADIOGRAPHIC EVALUATION

Radiographics are fundamental for identifying and recording spinal deformities (de Smet, 1985; Stagnara, 1988).

Radiographic projection can be used to evaluate scoliosis in the standing anteroposterior, standing posteroanterior, supine anteroposterior and supine posteroanterior with lateral bending positions (Keim, 1978; de Smet, 1985). Until recently a single standing anteroposterior or posteroanterior radiograph was use in scoliosis evaluation.

Recently more use is being made of the posteroanterior projection to reduce breast cancer (Andran et al, 1980; Anderson and Mc Neill, 1988).

Patient irradiation has always been a concern with radiographic evaluation (Raia and Kolfoyle, 1982; Thomas, 1983). The following methods are used to reduce irradiation : (1) proper grid selection; (2) high-speed film-screen combinations; (3) the use of posteroanterior projection to reduce breast irradiation; and (4) gonadal shielding over the anterior superior iliac spine. (Andran et al, 1980; Thomas, 1983 de Smet, 1985).

The positioning of the patient is important to obtain the desired film and quality. The patient stands normally with the arms at the sides for the antero or posteroanterior films. The x-ray beam is centred in the sagittal midline of the patient halfway between the first thoracic and first sacral vertebrae. The films are taken at the end of inspiration. The patients shoes must be removed so as to eliminate the effect of shoe heels and lifts (Christennsenee et al, 1978; de Smet, 1985).

The Scoliosis Research Society has recommended that scoliosis, kyphosis and lordosis must preferably be measured by the Cobb technique (de Smet, 1985). This method consists of drawing a horizontal line along the superior border of the superior end vertebra and along the inferior border of the inferior end vertebra. Perpendicular line to these tangential lines are then drawn. The intersecting angles produced are then read as the Cobb angle (George and Rippstein, 1961; de Smet, 1985).

The Risser-Ferguison method requires small dots placed in the centres of the superior and inferior end vertebrae. A further dot is placed in the centre of the apex vertebra. Straight lines are drawn from the dot in each end vertebra through the dot in the apical vertebra. The intersecting angle is measured with a protractor (Sevastikogulou and Berquist, 1969; de Smet, 1985).

The Scoliosis Research Society classifies forms of scoliosis into any one of seven groups :

(1) curves 0 - 20 degrees
(2) curves 21 - 30 degrees
(3) curves 31 - 50 degrees
(4) curves 51 - 75 degrees
(5) curves 76 - 100 degrees
(6) curves 101 - 125 degrees
(7) curves 126 degrees and over (Keim, 1982)

CHAPTER 3

METHODS AND PROCEDURES

3.1 METHODS

3.1.1 Subjects

Because, in the study, we concentrated on conservative rehabilitation, our subjects were drawn from those who had functional scoliosis. The subjects that participated in this study were 62 school going children between the ages of 12 and 19 years old, from both sexes, with a mean age of +/- 14.7 years. There were 45 girls and 17 boys involved. The subjects were recruited from school visits, arranged through the school head, and physician referrals. All diagnoses' were made by orthopaedic surgeons. It is important to note that the participation in this study was voluntary and with the consent of the family physician.

Criteria used to determine the eligibility of a subject, for the study were :

a. **Physicians consent** : No subjects were accepted for this study without full written consent form his/her family physician. It was understood by the physician that only those with functional or mechanical scoliosis who did not require surgery, could be accepted.

b. **A current medical history :** This report stipulated that the subject had no lower back problems, besides scoliosis, within the last twelve months and have no kidney, cardiac or neuromuscular dysfunctions.

c. **Subject/Parent consent :** All participants completed and signed a consent form prior to participating in the study (Appendix A).

d. **Previous weight training :** No current involvement in a weight training program which had, as a large component, torso training. The subjects attained were randomly assigned to a group. Group A being the rehabilitation group and Group B being the control group.

The control group subjects were requested to continue with their present lifestyles, while the rehabilitation group partook in an eight week training program. Training was done three times a week, namely, every second day, starting on Monday.

3.1.2. Equipment

A Cybex 340 isokinetic dynamometer was used to measure hip flexion and extension strength as well as range of motion prior to the first rehabilitation session as well as at the end of the rehabilitation period. By means of these evaluations we were able to establish whether there had been any improvement in the above mentioned parameters.

To complete the evaluation of the subject the following equipment was utilized :

a. Anthropometer : A Harpenden Anthropometer was used to measure standing height, seated height as well as the landmark heights.

b. Marking Pen : To mark the vertebrae in the forward bending position.

c. Plumbline : From which to measure the centimetre deviation.

d. A measuring tape to measure flexibility and leg lengths.

Further equipment required for the execution of the study and which were used specifically for the rehabilitation program itself were :

a. Tunturi Protainer exercise bicycle.

b. Gymnastic mats.

c. A cable-pulley system.

d. Hand weights varying from 2 kg to 15 kg.

e. Training bench.

f. Peck Deck.

g. Hyperextension bench.

h. Seated Calf raises.

i. Knee flexion apparatus.

3.2 PROCEDURES

The evaluation commenced with a questionnaire which lead into the physical evaluation of the subject. The questionnaire (Appendix B) started off with a general information on the subject and the problem. Section B of the evaluation form encompasses the forward bending test (Loncar-Dusek et al, 1991), test for range of motion, subjective muscle atrophy and hypertrophy observations, standing iliocristal height, most medial distal and posterial border of the scapula and the acromion heights. Section C consisted of a sit and reach test, X-rays report and a summary of the Cybex evaluation.

3.2.1 X-rays

The x-rays from the radiologist was then examined and the degrees of scoliosis noted. X-rays were taken at the commencement of the program and at the end of eight weeks. The curves were measured by the radiologist using techniques explained earlier (de Smet, 1985).

3.2.2 Leg length Measurements

The subject was instructed to supine lie on the plint. Careful note was made of the patients relaxed comfort. Two measurements were taken in this position :

a. Firstly, the anterior supra-iliac leg length was measured to the centre of the medial malleolus. This was done for both legs (Fig 12).

b. Secondly, the umbilicus leg length was measured from the centre of the umbilicus to the inside centre of the malleolus. This was also done for both legs. (Fig 13).

3.2.3 Forward Bending Test

The subject was then requested to stand free facing away from the tester, and bend forward as far as possible with the head and arms hanging loosely, downwards. It is important that the subject removes his/her top and that the light falls symmetrically on the subjects back. Each spinous process is then marked with a marking pen. The subject was then requested to stand erect whereupon the most medially distal posterior point of the scapula was marked so that their heights could be measured, Fig 14A (Grieve, 1991).

Here-after, the subject was asked to stand with his/her back to the plumbline so as to allow the tester to measure the deviation, in millimetres. Measurement was taken from the plumbline, perpendicular to the most deviated spinous process. (Calliet, 1985). The distance and vertebrae was then noted. This test was repeated biweekly. (Calliet, 1985). On completion of this evaluation, the subject's height was measured in both the standing and seated positions.

3.2.4 Standing Height

When measuring the subject in the standing position, as in Fig 15, the following landmarks must be aligned : acromial, radial, trochanterion tibial and the sphyrion.

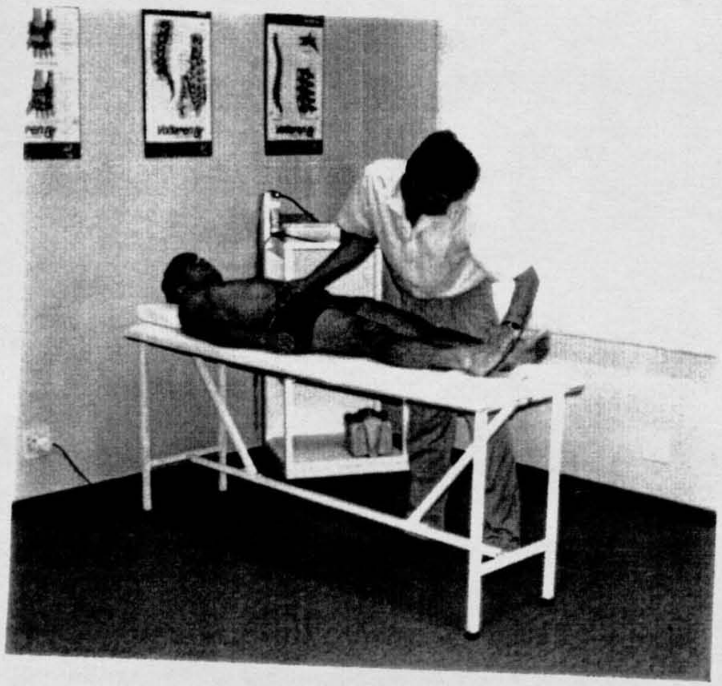


FIGURE 12 : LEG LENGTH MEASUREMENTS :
ANTERIOR SUPRA ILIAC

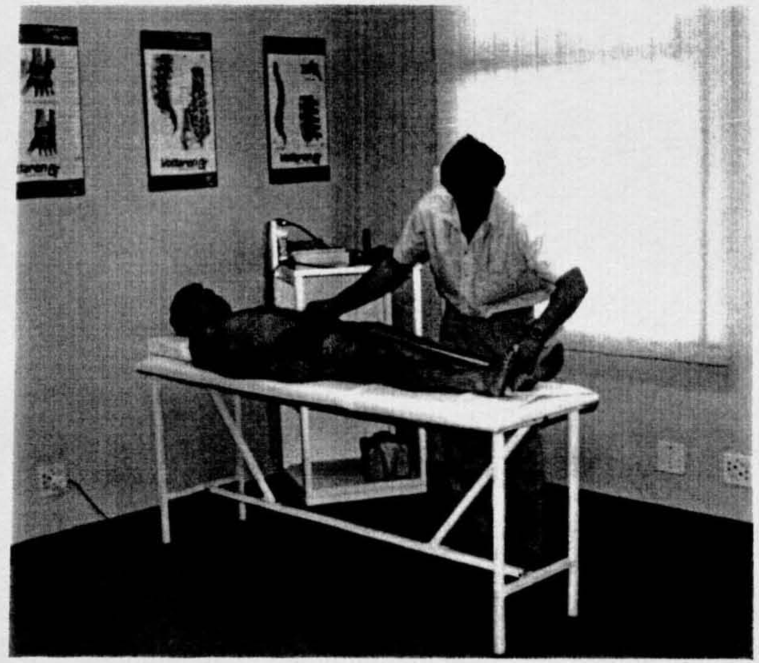


FIGURE 13 : LEG LENGTH MEASUREMENTS :
UMBILICUS

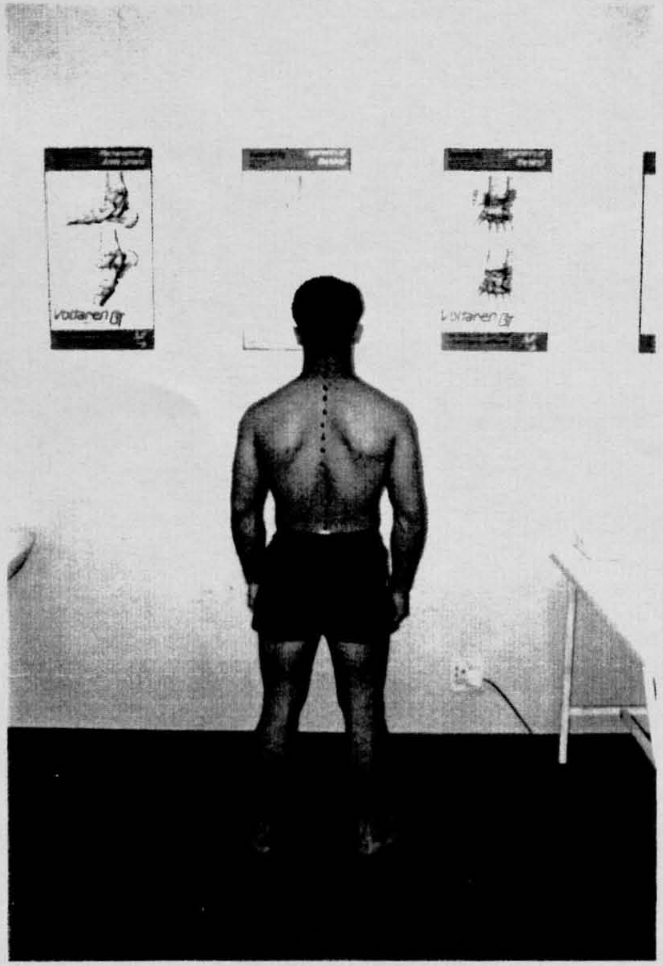


FIGURE 14 A : FORWARD BENDING TEST

FIGURE 14 B : FORWARD BENDING TEST

The measurement was taken with the anthropometer. The subjects stood barefoot on the floor, their heels together, their legs and torso stretched upwards to their fullest extent and their back to the wall with the head in the frankfort plane. The shoulders were relaxed and the arms stretched straight downwards. It is vitally important to ensure that the anthropometer does not deviate from the perpendicular when the readings are taken. (Fig 15) (Calliet, 1985).

3.2.5 Seated Height

When measuring the seated height the subject sits over the end of a hard surface with the knees pushed back against the surface. The subject's feet are rested on a stool or chair so that the hips and knees are flexed at 90 °.

The subject is instructed to sit tall and keep the head in the frankfort plane. The seated height is measured from the top of the head down to the plint top. The anthropometer must not deviate from the perpendicular (Fig 16).

3.2.6 Landmarks

The following landmarks were measured, bilaterally from the floor and noted : acromion, subscapular and anterior supra-iliac crest (Fig 17, 18 & 19).

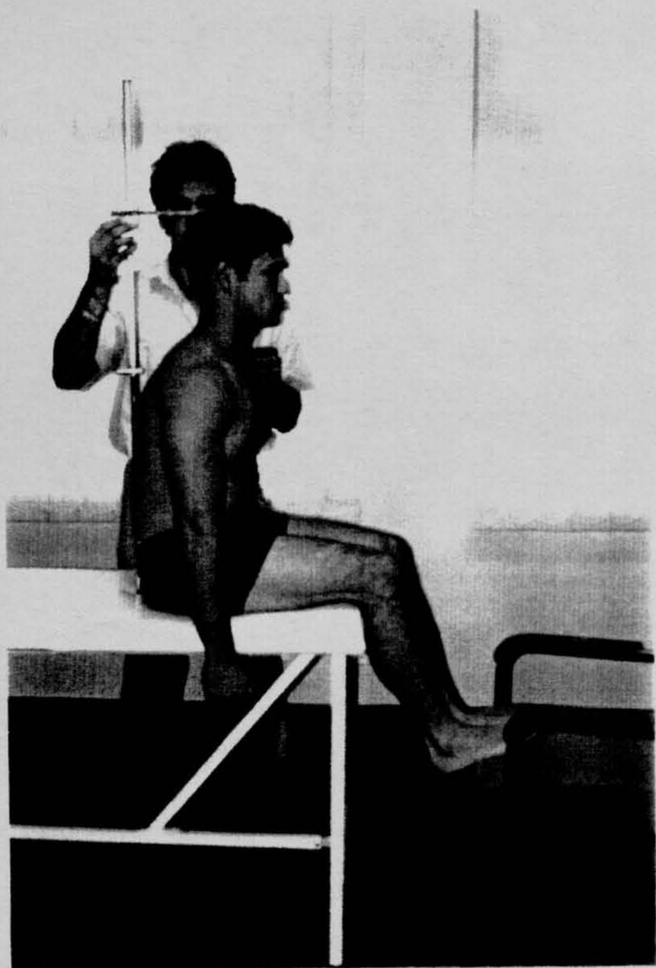


FIGURE 16 : SEATED HEIGHT

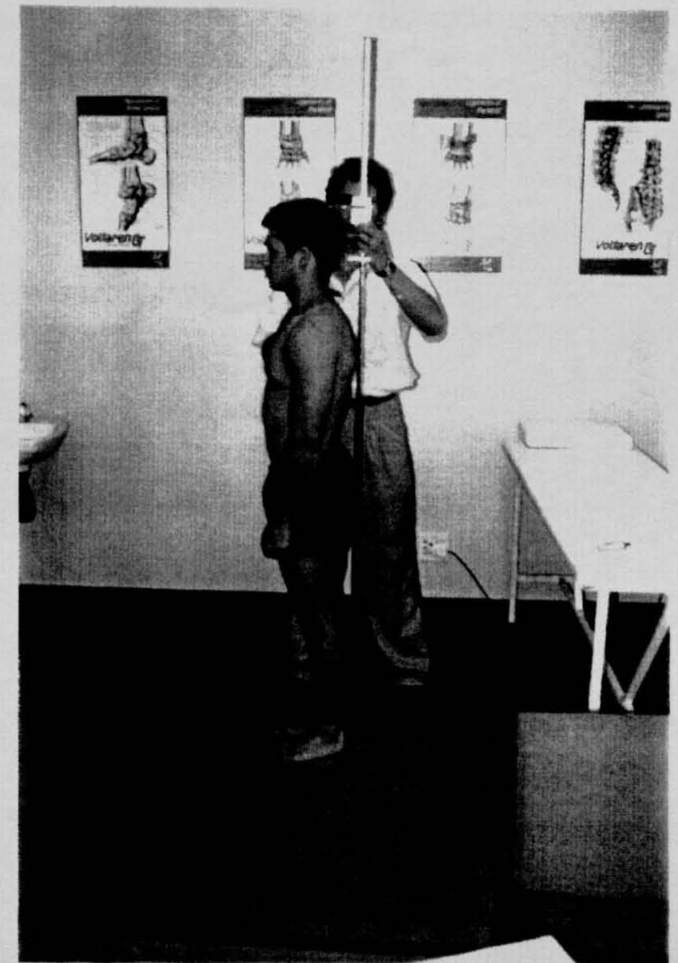


FIGURE 15 : STANDING HEIGHT

FIGURE 18 : SUBSCAPULAR HEIGHT

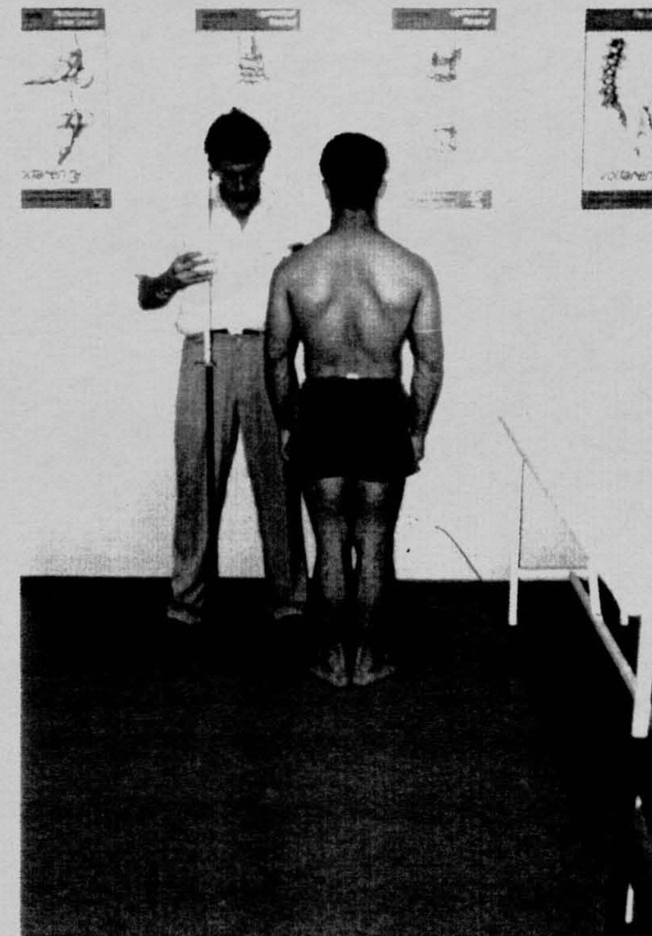


FIGURE 17 : ACROMIAN HEIGHT

The subject stood erect with his/her feet together. These measurements were noted prior to doing the flexibility tests.

3.2.7 Range of Motion

1. **Flexion :** The subject stood erect, feet together with both hands and arms extended downwards in front of the thighs. From this position the subject flexed maximally in the hips without bending the knees. If the subject failed to touch the ground the distance from the finger tips to the ground was measured. This was recorded as a negative value. If the subject touched the ground a 100 % value was given (Fig 20) (Calliet, 1988).

2. **Extension :** The subject lay prone on the plint with the arms extended at the side. From this position the subject maximally extended the back. The distance from the chin to the plint was measured (Fig 21) (Calliet, 1985).

3. **Lateral Flexion :** The subject stood erect, feet together and arms and hands extended at the side. The distance from the finger tips to the ground was measured, both left and right. The subject then flexed maximally in the saggital plane

to the right and then to the left. At maximum flexion the distance from the finger tips to the ground was measured. This distance was subtracted from the initial measurement. The greater the difference between the two readings, initial and flexed, the greater the flexibility. (Fig 22) (Calliet, 1985).

4. **Torsal Rotation :** Standing, facing forward with feet together, the subject rotated maximally without moving the feet or knees. The angle of rotation was measured subjectively. No objective method of evaluation is available. Ninety degrees rotation was noted when shoulder was rotated perpendicular to the neutral position. (Fig 23) (Calliet, 1985).

3.3 PROGRAM

The training program that was used can be used with scoliosis subjects who have a deviation either to the right or left. The program commenced with a warm-up cycling session on a bicycle ergometer, followed by specific stretching or mobilizing exercises and culminated with specific strengthening exercises. Each subjects' program was written on a program card with the re-evaluation date stipulated at the foot of the card (Appendix C). the exercises were as follows :

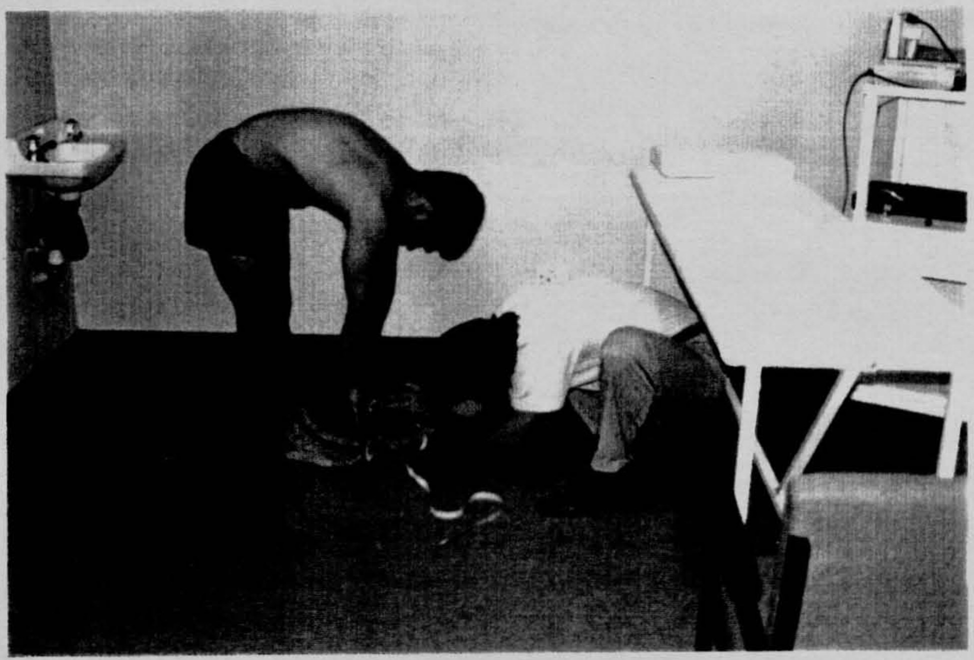


FIGURE 20 : RANGE OF MOTION : FLEXION

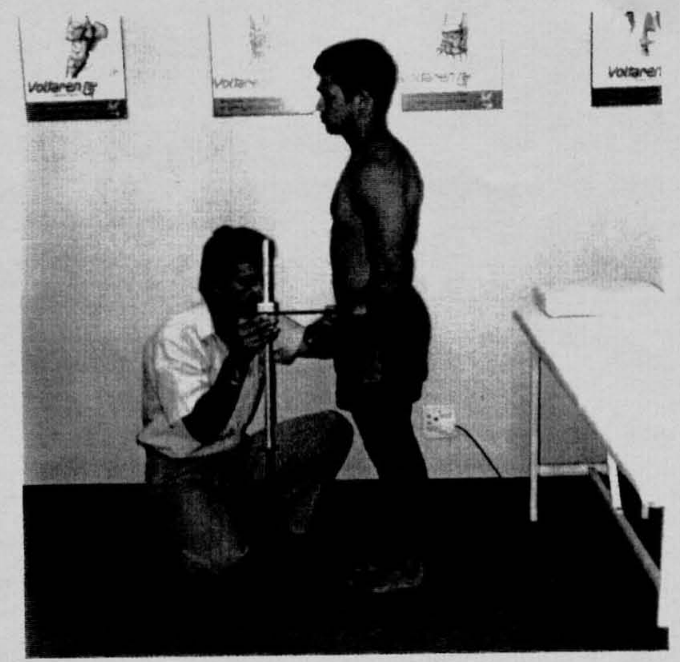


FIGURE 19 : ANTERIOR SUPRA – ILIAC CREST HEIGHT

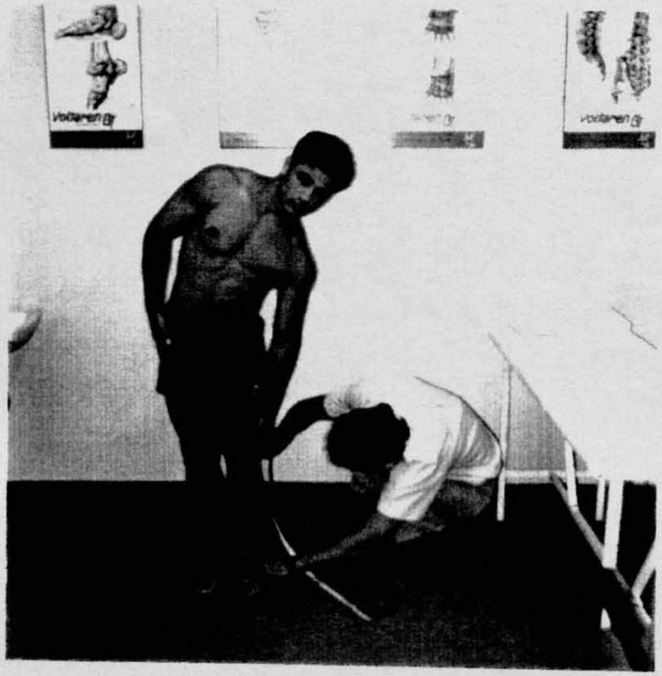


FIGURE 22 : RANGE OF MOTION : LATERAL FLEXION

FIGURE 21 : RANGE OF MOTION : EXTENSION

3.3.1 Cycling

This was done for five minutes to allow the subject to relax and focus on the program (Fig 24).

3.3.2 Mobilizing Exercises

Flexibility is joint and activity specific. Adequate flexibility is vital for the prevention of injuries and soreness. Because many cases of scoliosis are a result of reduced flexibility on one side of the vertebrae, this aspect forms an important part of the rehabilitation program (Porter, 1986; Fuller et al, 1991).

The exercises used in this study were devised specifically for the program. The flexibility exercises used were as follows :

(i) **Hamstring stretch :** The subject sits length ways on an exercise bench with one leg extended flat on the bench and the other leg off the bench. In performing the exercise the subject must sit tall whilst holding the chin up. In this position, with the back held straight and the knee fully extended, and the foot dorsiflexed, the subject lowers the torso forward-downward so as to stretch the hamstring muscles; gluteus muscle. This position is held for forty five seconds and repeated three times on each leg. (Fig 25).

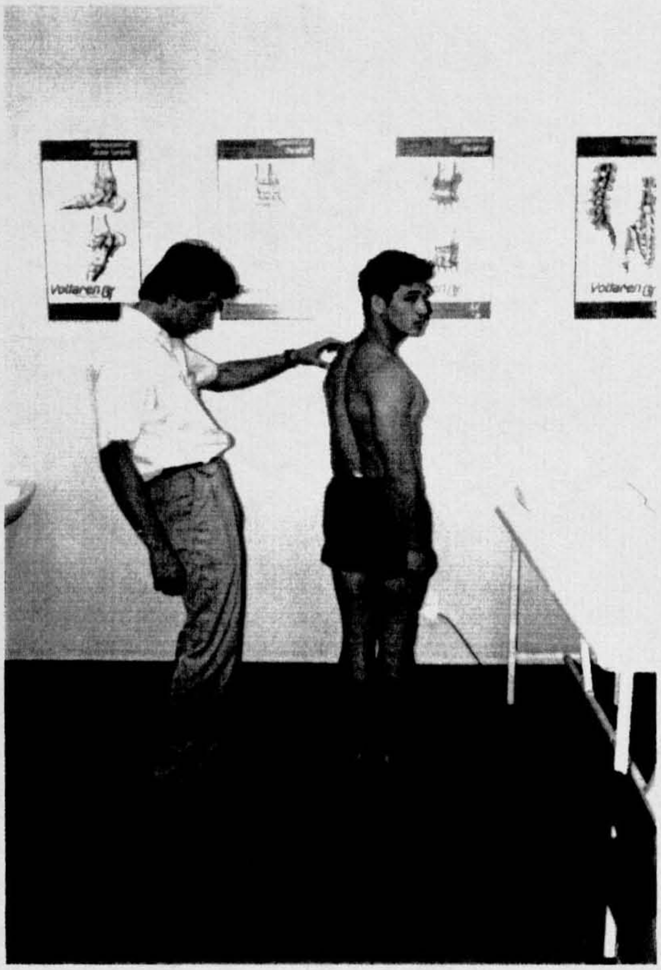


FIGURE 23 : TORSAL ROTATION

(ii) **Side stretch :** The side stretch is done to the convex side of the major curve. The subject stands erect with the feet shoulder width apart and arms extended downwards at the side. The subject then flexes fully to the lateral sides, then holding this position for sixty seconds. This is repeated five times (Fig 26).

(iii) **Side stretch on knee - one leg straight :** Presuming that the major curve is convex to the right the subject kneels on the mat with the weight on the left knee with the right leg extended to the side - the convex side. The left arm is then fully abducted to the side of the head. With the right hand gliding on the right thigh the subject flexes laterally to the right, holding this position for forty five seconds. The exercise is repeated three time (Schrecker, 1979) (Fig 27).

(iv) **Seated torso twist stretch :** Scissor-sitting on a gymnastic mat. The subject, keeping the spine erect, twists the torso maximally to the side of the convex curve. This movement is repeated three times, holding each for thirty seconds. (Fig 28).

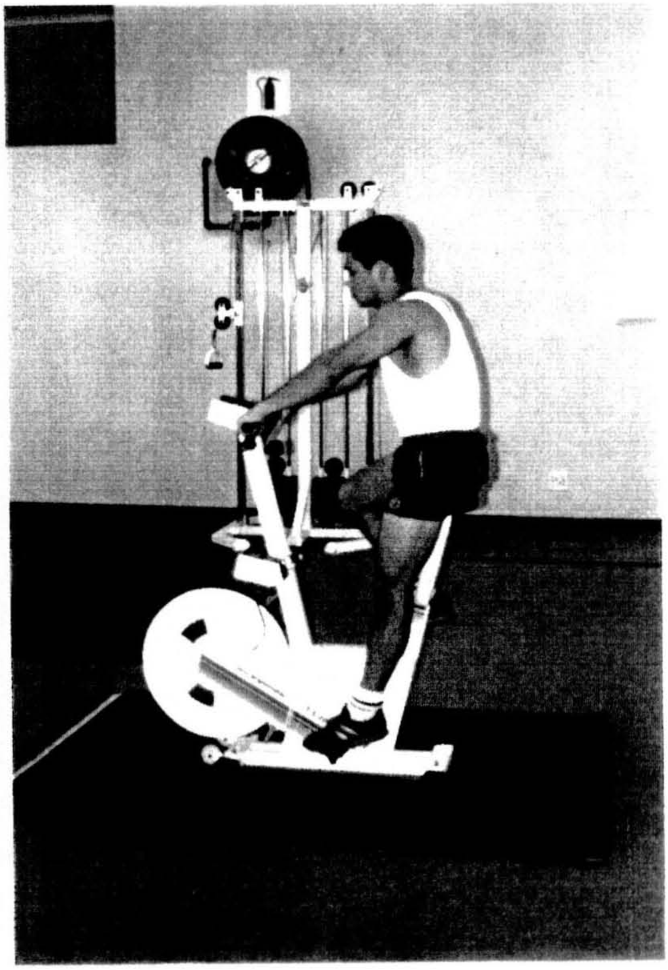


FIGURE 24 : CYCLING

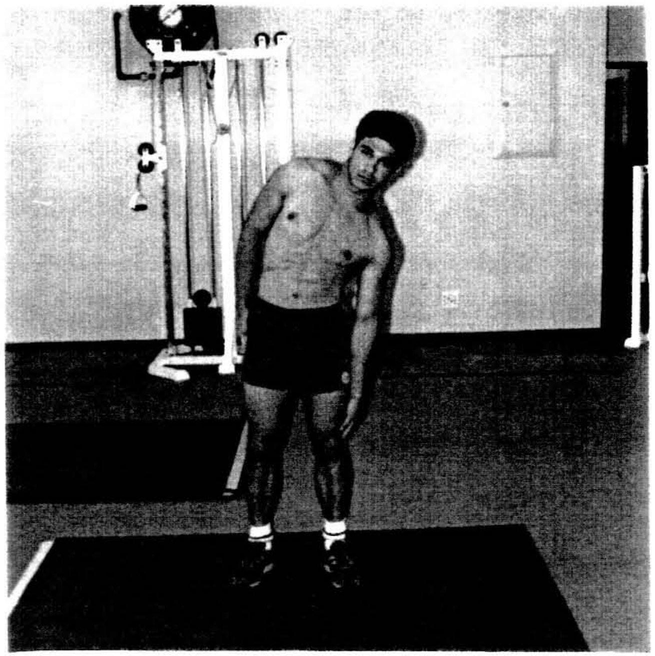


FIGURE 26 : SIDE STRETCH

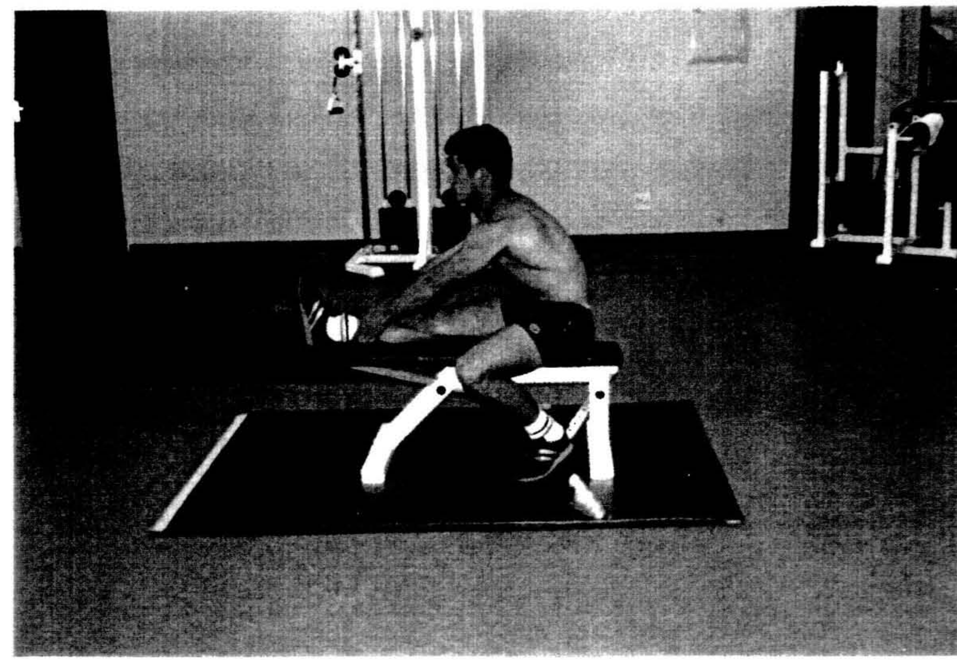


FIGURE 25 : HAMSTRING STRETCH

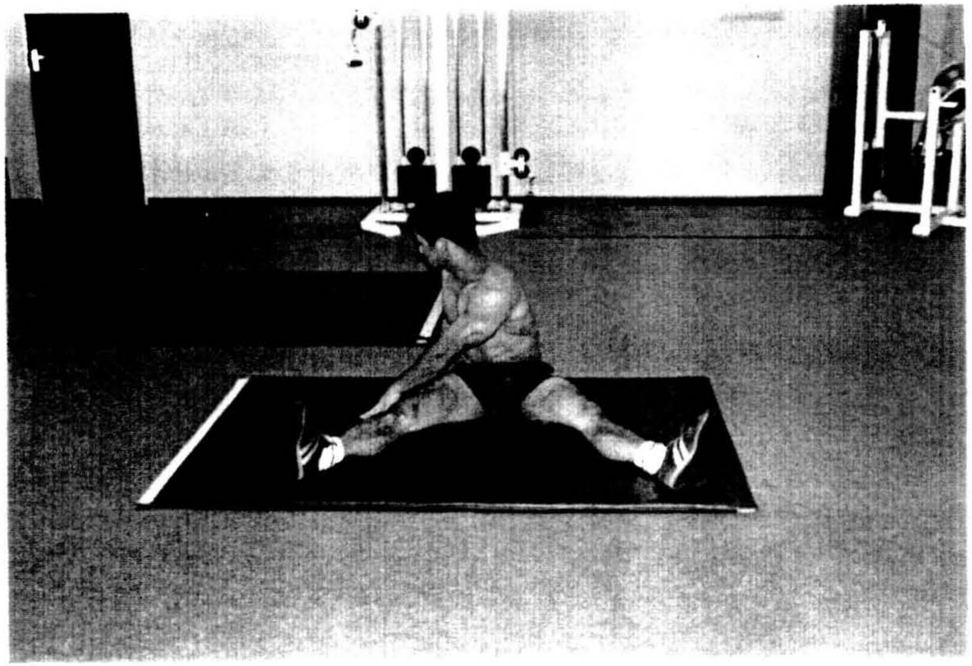


FIGURE 28 : SEATED TORSO TWIST STRETCH

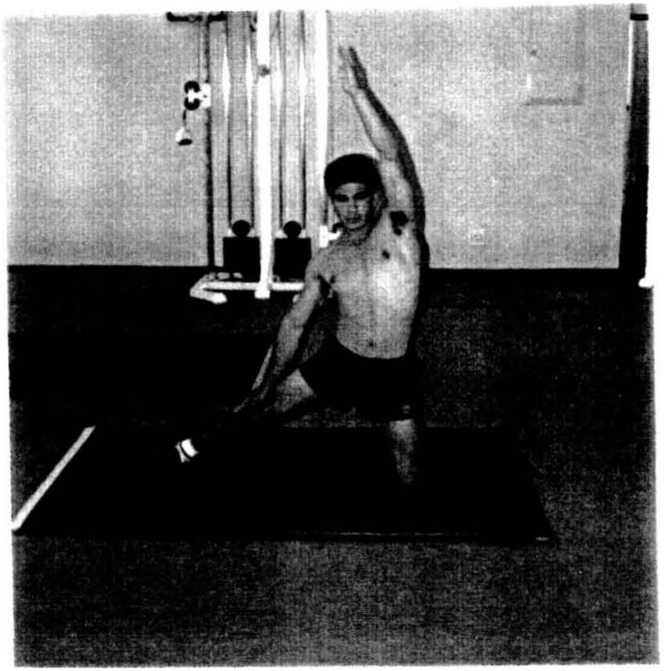


FIGURE 27 : SIDE STRETCH ON KNEE – ONE LEG STRAIGHT

(v) **Cat and Camel :** On all fours the subject span bends by arching the back so as to stretch the abdominal muscles. From this position the abdominal muscles are contracted and the back is forced upwards into a stretch. In this movement the thoracic portion of the spine is stretched. Two sets of fifteen repetitions are done, holding each movement for three seconds (Fig 29).

(vi) **Horizontal shoulder adduction :** Standing, the subject adducts the shoulder maximally horizontally on the concave side of the spine. The hand of the non adducted arm is cupped under the elbow to ensure maximal flexion. This is repeated twice for forty five seconds (Fig 30).

3.3.3. Strengthening exercises

Exercise is essential for restoring function to weakened and atrophied muscles. Strengthening of weakened spinal muscles accompanied with stretching exercises is essential for the rehabilitation of scoliosis (Kendall and MacCreary, 1983).

(i) **Scissor-side-lying :** Side lying with the legs in scissors position, the upper leg being placed forwards. The arms are extended above the head. The subject now raises the arms and trunk to the

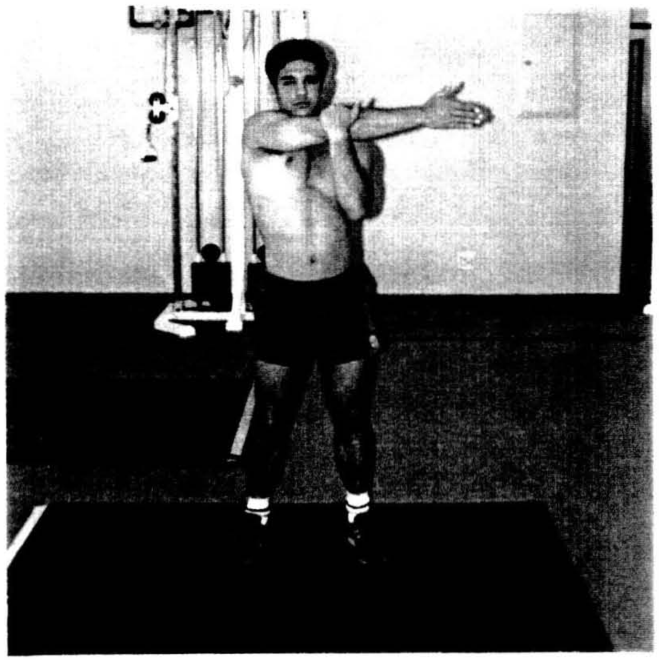


FIGURE 30 : HORIZONTAL SHOULDER FLEXION

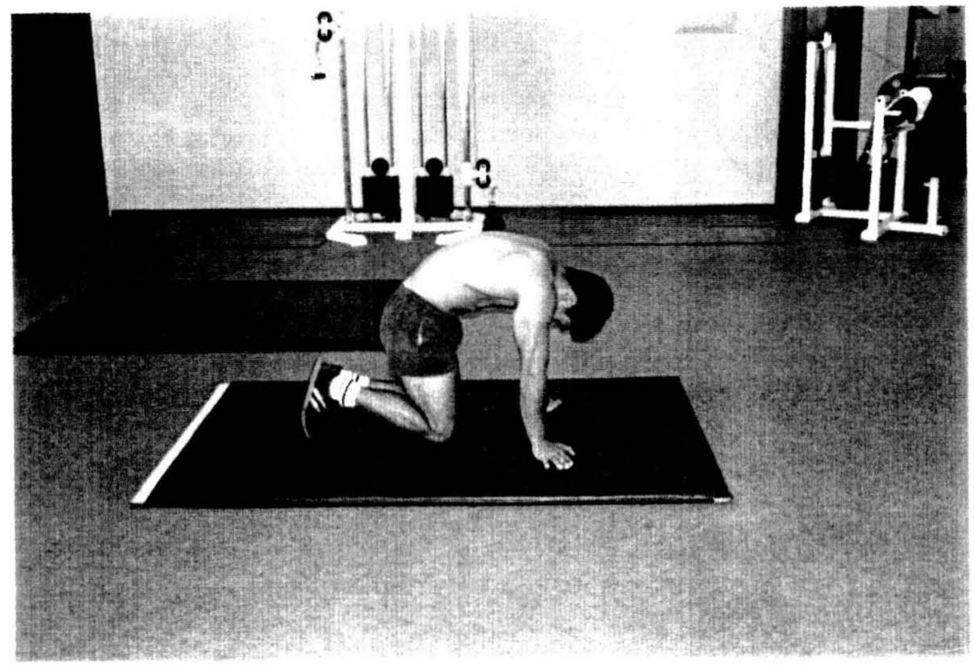


FIGURE 29 : CAT AND CAMEL STRETCH

convex side of the curve, and holds for two to three seconds. Two sets of twelve repetitions were done for the first four weeks where after three sets of twelve were done for the second four weeks (Schrecker, 1979). (Fig 31).

(ii) **Horizontal shoulder abduction (cable) :** The cable pulley is set to shoulder height. The subject, when holding the grip, must stand so as to have the arm on the convex side of the major curve fully horizontally adducted. Keeping the elbow locked straight and the shoulder square, the shoulder is then fully, horizontally abducted and held for three seconds. The movement is done slowly and deliberately. Two sets of twelve repetitions are done for the first three to four weeks, where after each subjects' program is specifically adjusted. A resistance which allowed the individual to only complete twelve repetitions was used. (Fig 32A/B).

(iii) **One arm dumbbell rowing :** The subject kneels with the left leg on an exercise bench, presuming that the scoliosis is to the right, and supports with the left arm. The right leg extended at the knee and supported on the ground at a hip angle of forty five degrees. With a hand weight in the right hand the subject lifts the weight from downward extended position in front of the shoulder to a flexed

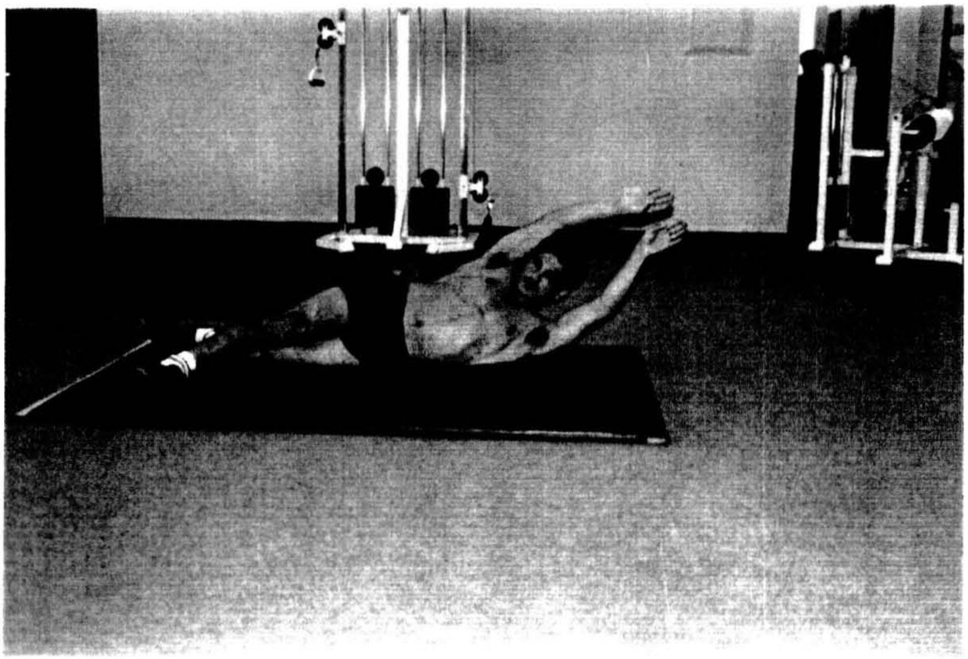


FIGURE 31 : SCISSOR - SIDE-LYING

position alongside the hip. With this movement the rhomboid complex adducts the scapula. The trapezius is also worked. The arm then returns to its original position. One set with a weight heavy enough to perform fifteen repetitions was done, holding the weight in the up position for two seconds (Fig 33A/B)

(iv) **Lateral flexing in the standing position :**

Presuming again that the spine is convex to the right, the subject stands with the feet shoulder width apart and a weight in the left hand. The movement executed is as for the side stretch with the subject flexing maximally, in the saggital plane to the right. This position is held for three seconds before returning to the starting erect position. Four sets of fifteen repetitions are done for the first four weeks, there-after each individuals' program is specifically adjusted. A weight which permits only fifteen repetitions is used. (Fig 34).

(v) **Reverse Peck Deck :** The subject sits in a reversed manner on the peck deck machine, facing the back support. The elbow, on the convex side of the major curve, is placed on the arm padding with the shoulder and elbow at ninety degrees. Supporting on the apparatus with the free arm the subject fully

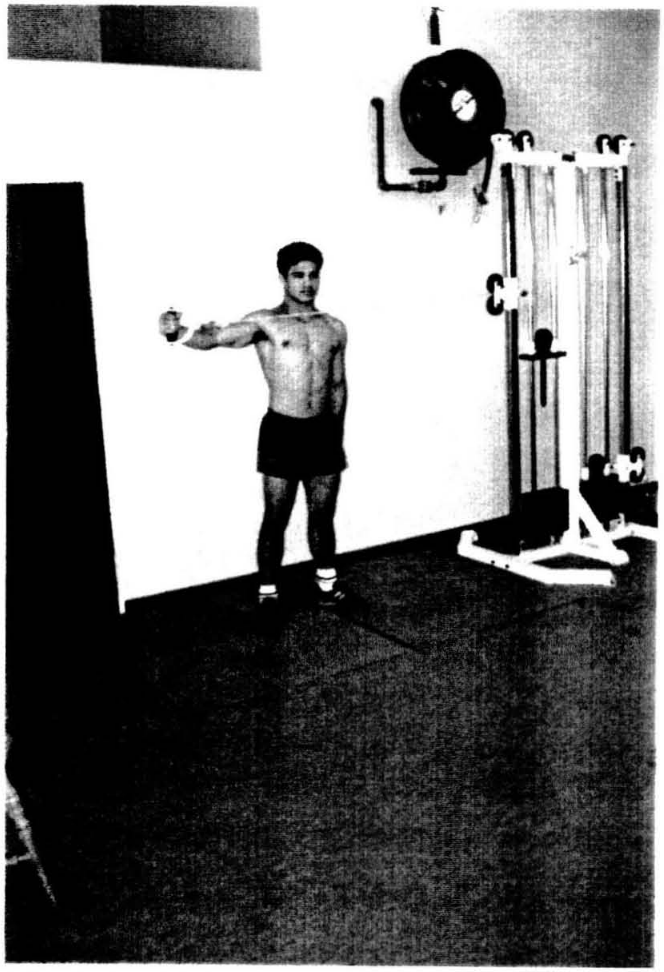


FIGURE 32 B : HORIZONTAL SHOULDER EXTENSION – CABLE

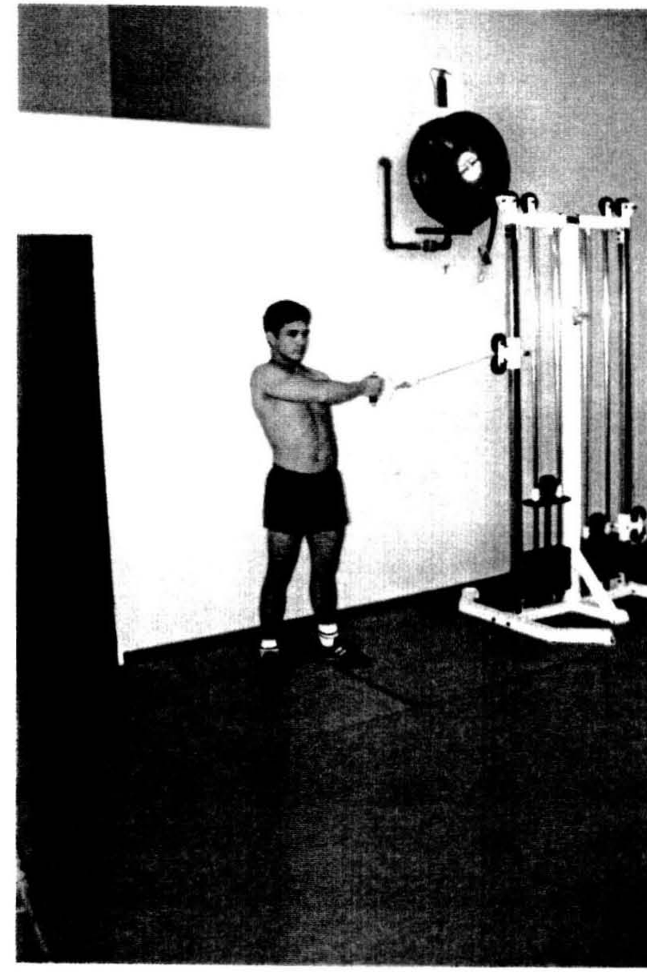


FIGURE 32 A : HORIZONTAL SHOULDER EXTENSION – CABLE

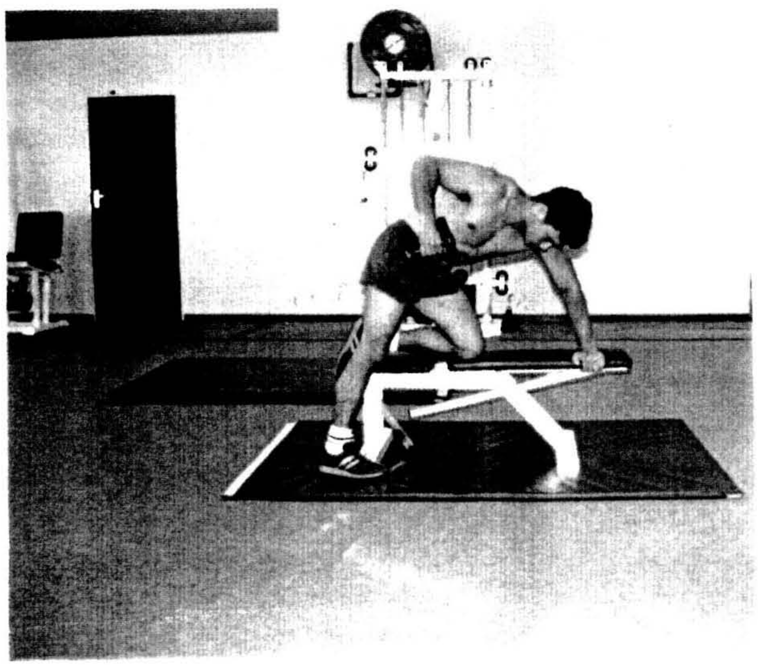


FIGURE 33 B : ONE ARM DUMBBELL ROWING

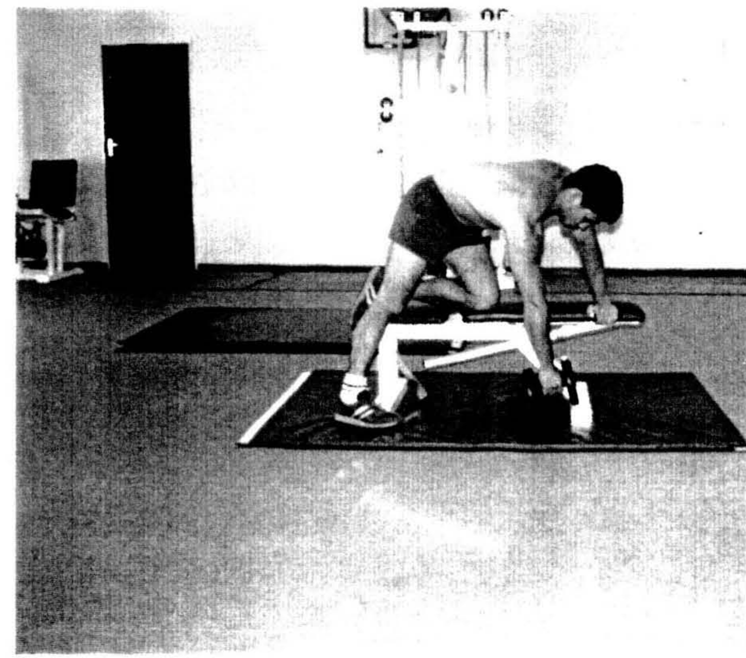


FIGURE 33 A : ONE ARM DUMBBELL ROWING

abducts the shoulder horizontally so as to maximally adduct the scapula. Two set of ten repetitions are done, holding each repetitions for two seconds.(Fig 35 A & B).

(vi) **Stomach crunches** : Supine lying on a gymnastic mat with the knees flexed ninety degrees over an exercise bench. The hips were also ninety degrees flexed. The subject crosses arms over the chest. Using only the abdominal muscles, keeping the lower back flat on the ground, the head and shoulders are lifted and curled inwards toward the hips. This position is held for two seconds. Two sets of maximum repetitions are done (Fig 36 A - B).

During the initial sessions the subjects found the exercises to be tough. Groups of no larger that five, were personally supervised during each session. On the day of the sixth, twelfth and eighteenth sessions the subjects first underwent a re-evaluation, except for the x-rays and the cybex, before their programmes were adapted for the following two weeks. During the initial session the exercise frequency, repetitions and intensity was determined for each subject depending on the progress made. After the second week the total sets per exercise were increased by one set. The sets and repetitions remained the same for the remainder of the rehabilitation

Each exercise repetition was preformed slowly, with a two second hold at full contraction in each repetition, except for the stretching where the hold varies from thirty to sixty seconds. A forty second rest between sets was permitted. The resistance used increased with an increase in the strength of the subject. The resistance should only allow the twelve or fifteen repetitions for each exercise. Throughout the rehabilitation period quality performance of the exercise was emphasized.

3.4 STATISTICAL ANALYSIS

The statistical methods and tables used in the study were derived from Runyon and Harber (1980) and Neter et al, (1978).

The following statistical analysis were applied :
A test for homogeneity between group one, the test group, (UI) and group two the control group U2 at day zero and day 24 was done using the t-test.

Hypotheses : Ho : Ud = 0 (indicates no differences).

H1 : Ud = 0 (indicates differences).

The paired t-test for two dependant test groups was used to test the differences between day zero and day 24 for the two groups.
The following hypothesis was tested :

Ho : Ud = 0 indicating no differences.

D = day zero measurement minus day 24 measurement.

If P < = 0,05 the differences is meaningful, and
If P > 0,05 the differences is not meaningful.

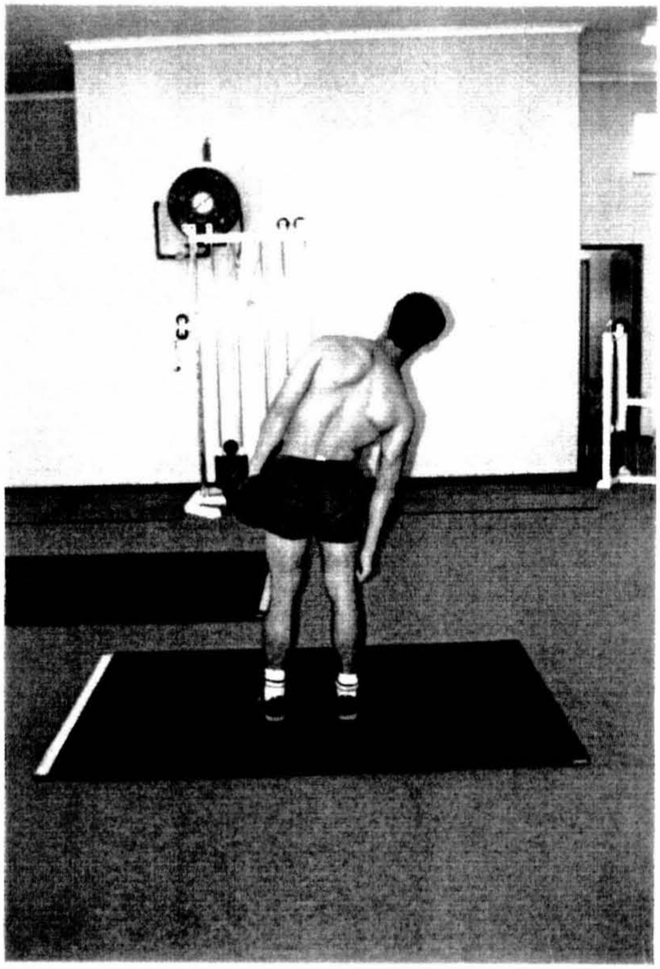


FIGURE 34 : LATERAL FLEXING IN
STANDING POSITION

FIGURE 35 B : REVERSE PECK DECK

FIGURE 35 A : REVERSE PECK DECK

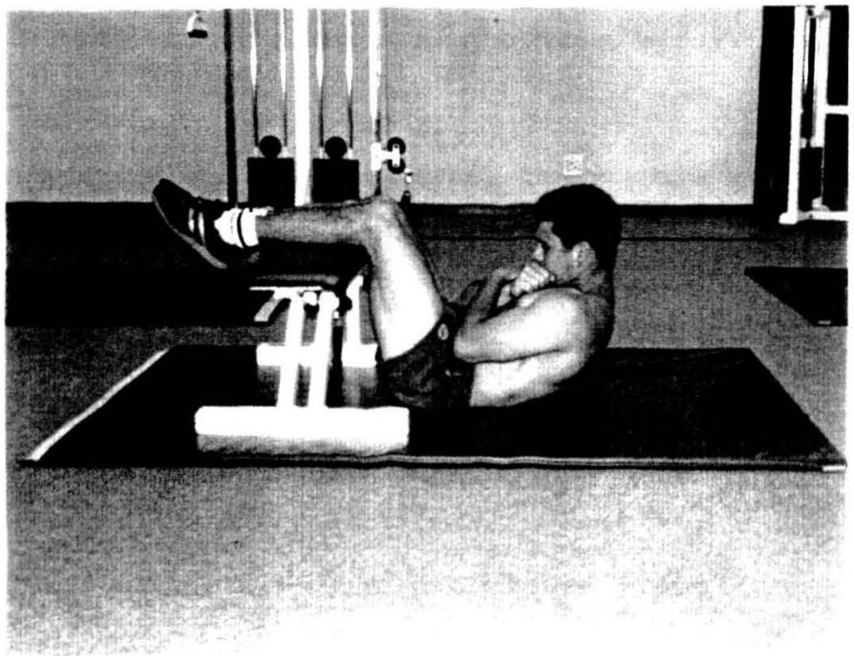


FIGURE 36 B : STOMACH CRUNCHES

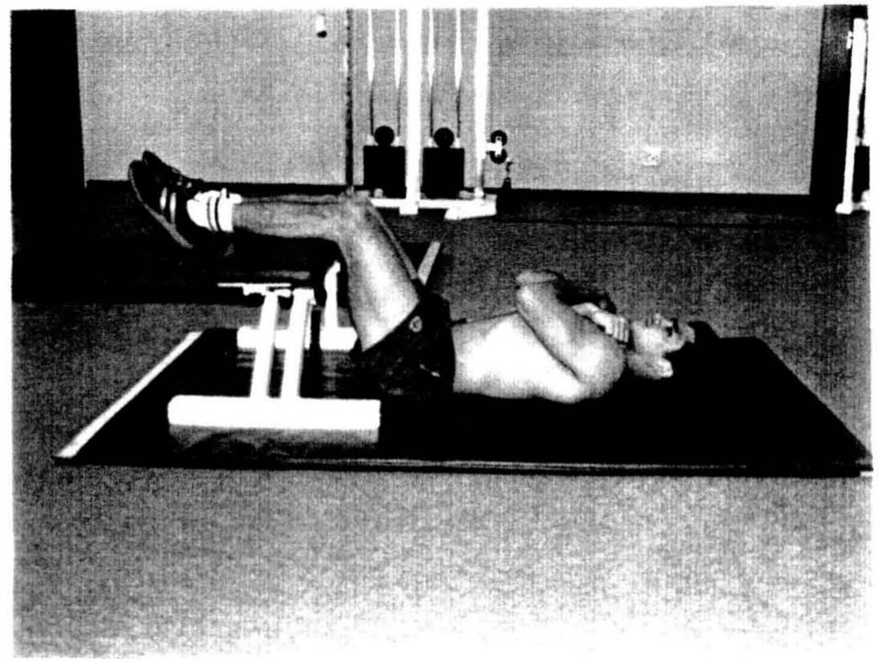


FIGURE 36 A : STOMACH CRUNCHES

CHAPTER 4

RESULTS

The t-test for the two independent groups, at day zero, proved to be homogeneous as the probability of exceedence for group one and group two were greater than 0.05 ($p > 0,05$). There was a 5 % probability of exceedence ($p > 0.05$); in other words a surety of 95 %. This was true for all the variables. The umbilicus leg lengths for group one were 94.71 cm with a standard deviation of 9.37 cm for the right leg and 94.86 cm with a standard deviation of 9.65 cm for the left leg ($n = 31$). For group two the umbilicus leg lengths for the right leg were 93.19 cm with a standard deviation of 8.90 cm and 93.17 cm for the left leg with a standard deviation of 9.34 cm ($n = 27$). The mean size of the major scoliotic curve for group one was 11.55 degrees and for group two 10.26 degrees.

Standing height and seated height were measured for all subjects of both groups. The standing height, for group one was 172.03 cm with a standard deviation of 10.42 cm and for group two 174.23 cm with a standard deviation of 10.10 cm. Seated height was measured at 82.19 cm with a standard deviation of 10.92 cm and 83.57 cm with a standard deviation of 8.83 cm for groups one and two respectively. Lateral flexion to the convex side of the curve was 15.83 cm for group one and 16.92 cm for group two.

The data are summarized in Tables 6 & 7.

TABLE 6

T-Test for parameters for Group one : Day zero (n =31)

Description	Mean	Std Dev	T	Prob >/T
Umbilicus R(cm)	94.713	9.372	0.636	0.5272
Umbilicus L(cm)	94.861	9.654	0.6756	0.5021
Curve(deg)	11.548	5.440	1.1340	0.2624
Standing Height(cm)	172.417	10.417	-0.8132	0.4196
Sit Height(cm)	82.187	10.920	-0.5344	0.5952
Flexion(cm)	15.832	4.011	-1.2501	0.2169

TABLE 7

T-Test for parameters for Group two : Day zero (n = 27)

Description	Mean	Std Dev	T	Prob >/T
Umbilicus R(cm)	93.185	8.895	0.6340	0.5282
Umbilicus L(cm)	93.174	9.340	0.6740	0.5031
Curve(deg)	10.259	3.020	1.0927	0.2794
Standing Height(cm)	174.226	10.099	-0.8114	0.4206
Sit Height(cm)	83.574	8.833	-0.5266	0.6005
Flexion(cm)	16.992	2.552	-1.2135	0.2300

From the above Tables 6 and 7 it is evident that no differences are apparent between the two groups for all the variables ($p > 0.05$). The null hypothesis can be accepted : Ho : U1 = U2; the groups are homogeneous; with a 95 % accuracy. Furthermore the differences between day zero and day 24 for the two groups were tested with the two-tailed t-test. Seeing that a measurement of each variable was taken on day zero and then on day 24, it can be concluded that the measurements are dependant observations. The hypothesis Ho : Ud = 0 (no difference; where d is the measurement on day zero minus the measurement on day 24) against the alternative;

H1 : Ud = 0 (difference between the two groups).

Due to the fact that the p value for group one was smaller than 0.05, the null hypothesis can be discarded. The assumption that a meaningful difference at day zero and day 24 is evident can be made on a 5 % probability of exceedence (Table 8). However, variable D4 does not indicate a meaningful difference (p > 0.05).

TABLE 8

Paired T-Test for Group one (n = 31)

Variable	Differences in	Mean diff	Std Dev	T	Prob >/T
D1	Umbilicus R	-0.519	0.783	-3.691	0.0009*
D2	Umbilicus L	-0.317	0.538	-3.839	0.0006*
D3	Curve	-121.771	173.277	12.115	0.0001*
D4	Standing	88.119	6.404	-0.160	0.8739
D5	Sit Height	-1.726	1.640	-5.858	0.0001*
D6	Flexion	-3.571	2.678	-7.424	0.0001*

* p < 0.05

With group two there is only meaningful differences at D3, D4 and D6. The rest are not meaningful for the two-tailed tests Ho : Ud = 0 against H1 : Ud = 0 (Table 9).

TABLE 9

Paired T-Test for Group two (n = 27)

Vari-able	Difference in	Mean diff	Std Dev	T	Prob >/T
D1	Umbilicus R	-0.059	0.245	-1.255	0.2206
D2	Umbilicus L	-0.085	0.085	-1.531	0.1379
D3	Curve	-107.152	108.720	-2.174	0.0116*
D4	Standing	93.319	15.977	-3.647	0.0012*
D5	Sit Height	-2.667	14.419	-0.961	0.3454
D6	Flexion	-0.304	0.610	-2.585	0.0157*

* p < 0.05

When considering variable D3, the following conclusion can be made:

Due to the fact that for group one T = 12.115 (prob >/ T = 0.0001) we can reject that there has been an improvement in curve size. We can therefore conclude for group two, that the reading at day zero has a meaningful difference T = -2.714 (prob >/ T = 0.0116), therefore we reject Ho = Ud = 0. There is a meaningful difference between the reading at day zero and the reading at day 24 for group two, due to an increase in curve size.

At day 24 the same T-test was done as for day zero. The purpose was to determine if there were any meaningful differences between the variables of the two groups. There were meaningful differences with variables V11 and V14 for group one and group two, thus they are not homogeneous. The remainder of the data is homogeneous (p > 0.05) (Table 10).

TABLE 10

<u>T-Test for variable between groups one and two at day 24</u>

Variables	Description	Group One Prob >/T/	Group Two Prob >/ T
V9	Umbilicus R	0.4135	0.4158
V10	Umbilicus L	0.4317	0.4322
V11	Curve	0.0001	0.0000*
V12	Standing Height	0.5621	0.5744
V13	Seated Height	0.4385	0.4251
V14	Flexion	0.032	0.0040*

* p < 0.05

CHAPTER 5

DISCUSSION AND CONCLUSION

"Idiopathic Scoliosis is the most common form of spinal curvature seen by orthopaedic surgeons. However, it is the form that is the least well understood". (Bradford and Hensinger 1984, p 233). In the light of this statement, the purpose of this study was to determine whether corrective exercise had any positive effect on idiopathic scoliosis. An exercise programme was devised specifically for this study and the subjects involved were diagnosed by orthopaedic surgeons.

5.1 Umbilicus Leg Length

The umbilicus leg length was used as part of the subjects evaluation as an indirect means of monitoring changes in lumbar scoliotic curves (Calliet, 1975; Fisk, 1987). The spine tends to compensate for any inclination in the pelvic girdle, as a result of leg length discrepancies, or may cause a tilt in the hips as a result of the scoliotic curve (Porter, 1986; Fisk, 1987). Muscle contracture can result in postural scoliosis. When musculo-aponeurotic contracture become irreversible they initiate postural scoliosis. The hip then assumes a flexed, abducted position. Correction of the underlying problem allows the spine to straighten. If that correction is carried out too late spinal deformity can persist (Stranara, 1988).

The mean values for the right umbilicus leg length and left umbilicus leg length are depicted in table 6. It is evident that for both groups the umbilicus leg lengths were not the same bilaterally, indicating an inclination in the hips. Although these values are the mean for the two groups, not all the subjects had lumbar scoliosis which could effect the hips.

There was, however, bilateral improvement in group one. For group two there was no significant changes for either right and left umbilicus leg length due to the fact that they did not take part in any physical activity. However, when the two groups were compared at session 24, it is noted that they are homogeneous (Table 10). This indicated that umbilicus leg length cannot be used as an accurate indicator of scoliosis improvement or deterioration. This is not to say that the variable should be deleted from the evaluation process of a scoliosis patient. Leg length discrepancies, both umbilicus and anterior supra iliac, can be used as indicators for the severity of the case and the appropriate treatment (Bradford et al, 1987; Fisk, 1987; Stranara, 1988).

5.2 Spinal Curve (°)

The curves measured were done on posterior-anterior radiographs of the subjects using the Cobb method (De Smet, 1985; 1990; Kojima and Kurokawa, 1992). For those subjects who suffered from a double scoliosis, only the major curve was treated.

Other methods incorporated in the treatment of scoliosis vary from bracing to surgical techniques (Rothman and Simoene, 1982; White and Panjabi, 1990; Winter, 1992). Most of the literature states that exercise alone does not prevent the progress of a scoliotic spine, nor will exercises correct an existing scoliosis (Calliet, 1975; Dickson and Bradford, 1984; Bradford et al, 1987). None of the authors define the exercises used in scoliosis rehabilitation; on which they have founded their claims.

Stagnara (1988) suggested that muscles on the convexity of the constant curve act to prevent the upper spine from collapsing into the concavity. This was confirmed by Zetterberg (1982).

Koes et al, (1991) conducted a blind review of physiotherapy exercises used in the treatment of back pain, in an attempt to assess efficiency of exercise for back pain. On comparing exercise therapy with other means of conservative treatment they concluded that of the seven regimes compared, only two Manniche et al, 1988; Lindstorm et al, proved that exercise therapy was better than the other conservative treatment used. The other five studies indicated that other conservative treatment regimes were superior to exercise therapy. However, three of the five exercises had method scores lower than 40 (maximum 100). Method scores were graded according to exercise specificity, exercise practicality, the effectiveness of the exercises, the structure of the programme, and the success of the programme at completion and after a twelve month follow up period. It must be stated that additional physical treatment modalities such as massage, hot compression and short wave diathermy were allowed. Another facet of their work compared different types of exercise therapy. The study (Manniche et al, 1988) with the highest method score favoured an exercise scheme of three months intensive dynamic back extensor exercises. The same principle of intensive exercise over a three month period was incorporated in this study on scoliosis.

In the present study the subjects were allocated randomly to either the exercise or control group so as to reduce bias. From Table 6/7 it can be seen that the two groups were homogeneous at day zero when considering the curve size. Group one, the exercise group, followed the specific programme of 24 sessions over eight weeks and showed a substantial improvement in curve size ($p = 0.0001$) over the control group. The T-test at session 24 between the two groups showed no homogeneity for curve deviation, indicating that the group which followed the programme had improved whilst the control group had deteriorated. One important factor contributing to the improvement was that the subjects in group one were exercised at an extremely high intensity, whilst the subjects in group two did not follow the programme. This is also a reason given for the success in Manniche's et al (1988) study which stated that intensive back exercises were significantly better than mobilization, short wave diathermy, massage and hot compression. The subjects were evaluated bi-weekly which permitted an immediate and individualistic adaption of the programme used.

When comparing this study to those evaluated by Koes et al (1991), using their assessment criteria, a relatively high method score is obtained (52). This study does not concern itself with a follow up period, which carries a value of 10 (Koes et al, 1991). The method score for specificity was high as each exercise was designed, and largely achieved, to isolate the muscle groups during both stretching and strengthening. Most of the strengthening exercises scored low on the practicality scale due to the fact that they could only be performed with the aid of specific equipment. This made it impossible for the subjects to follow the programme at home. It is also impossible to determine the effectiveness of any specific exercise, conclusively. However, as a programme the exercises were effective. The programme was structured well with a warm up, stretching and strengthening phase. The success of the programme after 24 sessions rated well. Unfortunately, no medium or long term follow ups were done on any of the subjects.

It is evident that the programme incorporated in this study was effective in correcting, to a certain extent, the scoliotic spine. Monitoring of the spine curvature by means of the forward bending test is also an effective, indirect,

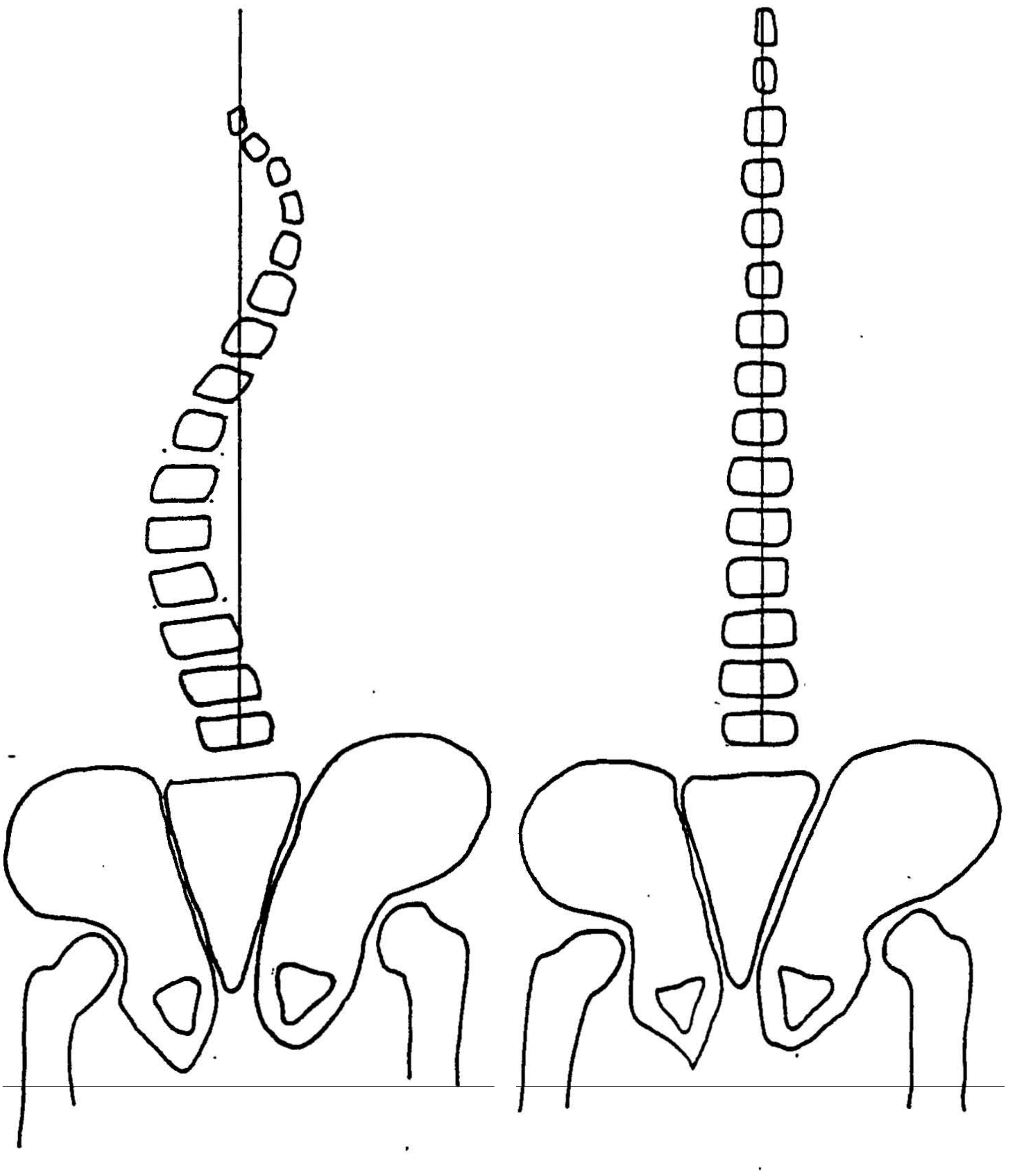


FIGURE 37 : SCOLIOTIC HEIGHT VERSUS NON OR CORRECTED SCOLIOTIC HEIGHT

means which to plot the changes in spinal curvature.

5.3 Standing and Seated Height

A comprehensive study was conducted by Loncar - Dusek et al, (1991) on growth velocities in idiopathic scoliosis subjects. They concluded that an increase in growth velocity is closely associated with the onset of idiopathic scoliosis in adolescent subjects. This substantiates the works done by Drummond and Roagala (1980) and Dickson (1984) that states that scoliotic adolescents are taller than non scoliotic adolescents. This prompted the monitoring of both standing and seated height.

From tables 6 & 7 it can be seen that the two groups were homogenous at the outset of the programme, but not at the completion of the programme (Table 10). Seated height in group one showed a statistically meaningful improvement between day zero and day 24. This is not the case in group two. For group two neither standing or seated height showed any significant difference (Table 9).

The reason why there was no significant difference in standing height between day zero and day 24 is that the observation period of eight weeks is too short for any substantial growth to take place.

The significant improvement in group one can be attributed to two factors:

Firstly, it can be attributed to the effect of the programme. The experimental period of eight weeks is too short for any substantial growth to occur. Therefore, any improvement in sitting height must be due to the exercise programme.

Secondly, the subjects' motivation when being re-evaluated could have been higher due to the positive physchological impact of the programme. If the subject does not sit 100 percent erect it will definitely negatively effect the true reading from one evaluation to the next. In reducing the lateral deviation in the spine the distance between C1 and S1 will increase since the pelvic girdle is fixed and any displacement must take place vertically upwards (Fig 37).

5.4 Lateral Flexion

Lateral flexion to the convex, or in most cases the dominant side, is negatively influenced by the lateral deviation of the spine (Fuller et al, 1991). In their study they measured lateral flexion and rotation. They concluded that non-scoliotics were a mean of 12.0 cm more flexible than the scoliotic group.

In this study, lateral flexion as well as rotation was measured. The rotation values were not statistically scrutinised as the monitoring thereof was too subjective. The lateral flexion to the convex side, for the control group, deteriorated with a corresponding increase in curve size. The group which was subjected to the exercise regime, group one, showed resounding improvement in flexibility. This flexibility improvement can be paired with the improvement in curve size.

These results support those of Fuller and associates (1991). It can be accepted that lateral flexion, and the change thereof, is an acceptable accurate means by which to indirectly monitor the scoliotic curve. As the curve size decreases, the lateral flexion increases.

5.5 Conclusion

Fuller et al, (1991) made a strong suggestion, at the conclusion of their study, that, multivariate research designs to explore new therapies are needed. They stated that, in their opinion, muscle imbalancements do cause scoliosis. This being true, they suggested that an aggressive physical therapy be employed to create an unbalanced pull on the vertebrae, from the convex side, in an attempt to reduce the curve progression.

In this study, the programme employed was individualistic and aggressive. It is evident that this contributed to the success of the study. Koes et al (1991), in their review of exercise regimes and their success,concluded that physiotherapy exercises, applied intensively, are successful. Those regimes that reported negative results of exercises had low method scores. They state, as did Fuller <u>et al</u>, (1991), that further research is needed in which more attention is given to the methods of the studies.

The variables incorporated in this study were intended as a means by which to indirectly and quickly monitor the progress of the curve, without major radiographic expenses, as well as to adjust and adapt the programmes. The only direct monitoring of the spine was done by means of radiographs. All the variables, except standing height, proved, within themselves, to be acceptable. However, when comparing the variables at day 24 only the degrees and lateral flexion proved to be statistically sound monitoring variables. Of the two variables, lateral flexion is an indirect monitoring variable. Unfortunately, rib hump, an indirect monitoring method, was not incorporated in this study. The rib hump measurement has been shown to be an acceptable, accurate and reliable method for monitoring curve size (Calliet, 1975; Stanara, 1988).

Due to the extreme pressures on our countries economy, as well as being a global problem, medical services which are a necessity are becoming an ever increasing luxury. Back pain in its entirety is a high financial and social problem (Porter, 1986). The modalities and regimes employed in treatment of, specifically scoliosis patients, are largely successful except those regimes which utilise exercise. (White and Anderson, 1991). This was a motivating factor in conducting this study. The programme used appears to be successful. Unfortunately, no follow-up of the patients was conducted. When considering the costs, comparing physiotherapy and biokinetic treatment to bracing or surgery, the patient should be offered the opportunity to engage in the physiotherapy and biokinetic treatment (Table 11).

It is not suggested that in cases where surgery is a necessity, exercise should take preference. Due to the fact that the purpose of this study was to evaluate a conservative method of scoliosis rehabilitation, it is suggested that during the period of observation of the curve the patient should engage in an intensively conducted exercise regime.

Loncar - Dusek et al, (1991) followed a group of adolescent individuals and monitored them for scoliosis. They concluded that of those who developed scoliosis during stages two and three of breast development for girls, 53.4 % of the subjects had an increase in curve size. The present study substantiates this trend with 59.26 % of the control group displaying deteriorated curves.

It is felt that if the subject engages in a specifically structured exercise regime this curve progression could be checked. It seems pointless and counter productive to allow the spine to deteriorate further (+/- 60 % chance) before implementing any form of treatment. Keim (1982) and Stagnara (1988) state that if there is no evidence of progression, exercise and follow-up alone is appropriate.

Bradford et al, (1987) and Stagnara (1988) state in their work that bracing has an 80 % success rate, with a curve progression of one to two centimetres after brace cessation. Bracing with physiotherapy and corrective exercises should, firstly, decrease the rehabilitation time, thereby reducing the brace wearing period, and ensure the maintenance of the improvement for a longer period, post brace. Winter (1992) treated 94 adolescent patients with thoracic curves (30 - 39 °) by Milwaukee bracing and exercises. A two year follow-up of the patients, after wearing of the brace indicated that only 14 % went onto surgery. The average pre-treatment curve was 33 ° with a post-treatment curve of 29 °. The curve at follow-up was 31 °.

From this study it would be strongly suggested that an intensive exercise regime, which is specifically adapted for the individual, be adopted, along with other conservative methods in certain cases. However, this should not be seen as a substitute for surgery, which, in drastic cases, is a necessity.

TABLE 11

Methods and costs of scoliosis rehabilitation

Methods	Modality	Costs
Surgical (orthopaedic, surgeon assistant, anaesthetist, radiographs, medication, treater, bed)	Internal fixation +	+/- R10 000.00
Bracing	C.T.L.S.O.	R1 760.00
Physiotherapy (pain treatment)	Mobilisation, ice, hot packs, ultra sound (excluding radiographs)	+/- R504.00 ┐ R 1 584.00
Biokinetics	Intensive corrective exercises, and maintenance programme (with radiographs)	R1 080.00 ┘

(Scales according to tariffs approved by South African Medical and Dental Council)

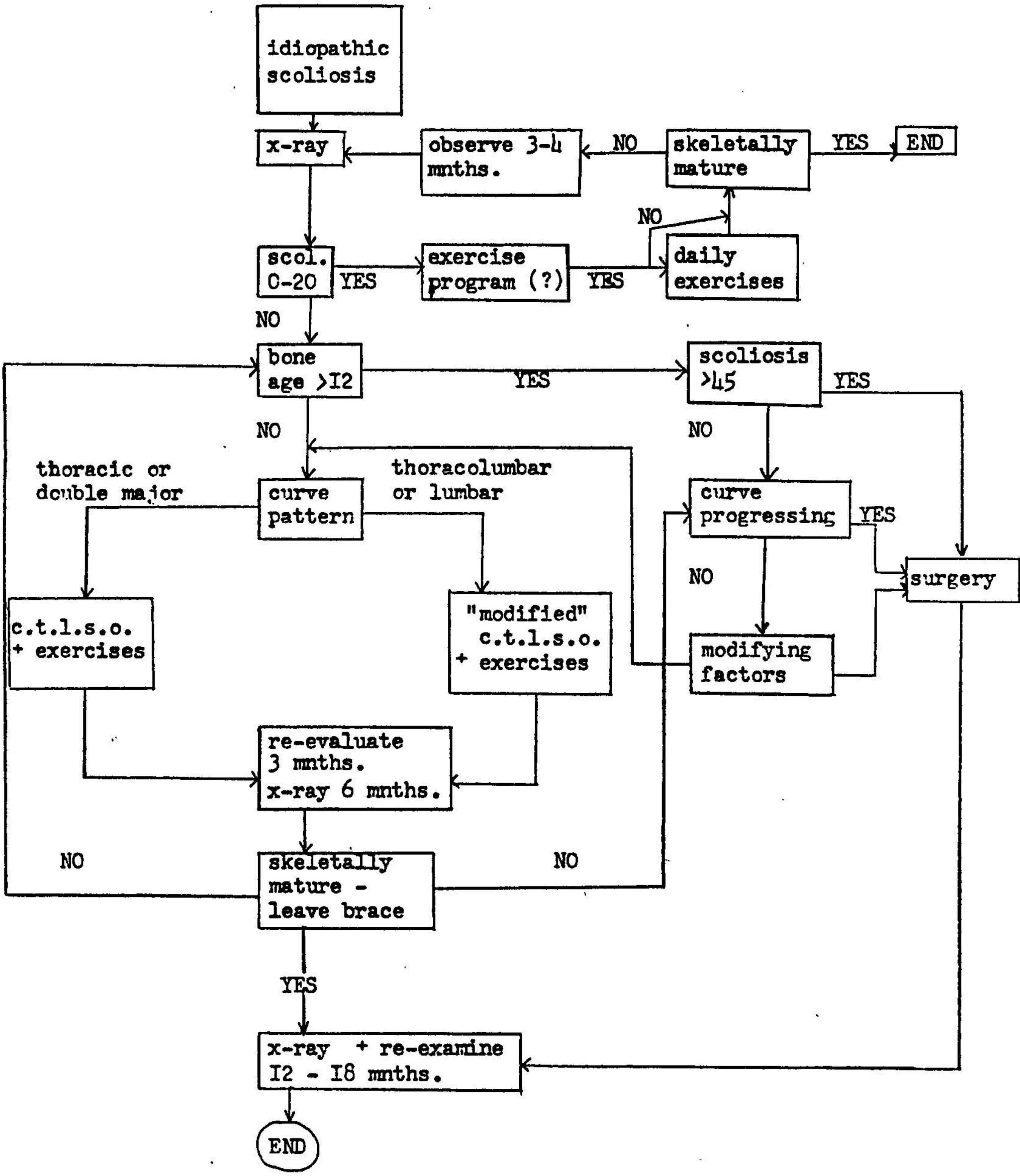


FIGURE 38: AN ALGORITHM HELPFUL IN DECISION MAKING FOR SCOLIOSIS PATIENTS.

(Adapted from Keim, 1982)

APPENDIX A

INFORMED CONSENT FOR RESEARCH EVALUATION

1. Explanation of the Evaluation

You will undergo a physical evaluation of the back. X-rays will be taken of your back to measure, accurately, convex and concave angles of your spine. A Cybex evaluation will be performed on the hip and back muscles.

2. Risks and Discomforts

Apart from the Cybex, no major discomfort will be experienced. Within the evaluation protocol and rehabilitation exercise programme there are no risks. Discomfort may be experienced post exercise due to the stress and strain on the debilitated muscles. This is expected from this type of protocol and rehabilitation.

3. Benefits to be expected

- The evaluation will allow us to ascertain exactly what and where your problem is.

- By means of the rehabilitation programme it will be attempted to rehabilitate your problem and alleviate daily pain and discomfort.

4. Injuries

Any questions about the procedures used in the evaluation or rehabilitation programme are encouraged. If you have any doubts or questions, please ask me at any time for further explanations.

5. Freedom of consent

Your decision to perform this evaluation and rehabilitation protocol is voluntary. You may deny consent or withdraw at any time if you so desire.

I have read this form and understand the risks, discomforts and benefits of the protocol.

I consent to participate in this test.

....

DATE SIGNATURE OF SUBJECT

....

SIGNATURE OF PARENT/
GUARDIAN

Questions :

Responses :

Signature : Guardian :

Participant :

Doctor :

Adapted from Blair *et al* : Guidelines for exercise *Testing and Prescription* : American College of Sports Medicine, 3rd edition, 1986.

APPENDIX B

PHYSICAL EVALUATION

Name : Age:

Tel : Sex:

Physician : Date:

Dominant side : Right: [ ] Left: [ ]

History : Pain (grade) :

Referred Pain :

Stiffness :

Numbness of Paraesthesia :

Other symptoms :

History of main problem :

Site :

Duration :

Frequency (days/weeks) :

Severity (x/10) :

Aggravating factors :

Past history of spinal injury :

SECTION B

Examination :

			Right	Left
a.	Leg Length :	umbilicus (cm)		
		iliac (cm)		
b.	Landmarks :	Acromial (cm)		
		Subscapular (cm)		
		Standing iliocristal (cm)		
c.	Height :	Standing (cm)		
		Seated (cm)		

d. Forward Bending Test (L/R) (vertebrae) (cm)

Scoliosis: Cervical:

Thoracic:

Lumbar :

e. Range of motion: (cm) **Right** **Left**

Flexion :

Extension :

Right rotation: normal/intermediate/abnormal

Left rotation: normal/intermediate/abnormal

Right lateral flexion: (begin - end) :

Left lateral flexion: (begin - end) :

f. Muscle Atrophy (where ?) :

Muscle Hypertrophy (where?) :

Muscle Balance :

SECTION C

	Right Leg (cm)	Left Leg (cm)
g. Sit and reach test :		
:		

	(L/R)	(Vertebrae)	(Degrees)
h. X-Rays report :			

		Right	Left
i. Cybex :	Average R.O.M.(deg):		
	Flexion (Nm) :		
	Extension (Nm):		
	Flexion/Extension (%):		

Summary:

Name .... Biokinetician ....

Diagnosis .... Doctor ....

Date															
	Exercise	Sets	Reps	WL	WL	WL	WL	WL	WL	WL	WL	WL	WL	WL	WL
1	Cycling	5 min													
2															
3	Stretching														
4	Hamstring	3	45 sec												
5	Stretching (L)/(R)	5	1 min												
6	Stretch on knee (L)/(R)	3	45 sec												
7	Scissor Torso Twist(L)/(R)	3	30 sec												
8	Cat and Camel	2	15	(hold	for 3	sec)									
9	Shoulder H. Flexion(L)/(R)	2	45 sec												
10															
11	Scissor sidelying (L)/(R)	2	12												
12	H. Shoulder ext (L)/(R)	2	12	(hold	for 3	sec)									
13	(L)/(R) Arm DB Rows	1	15	(hold	for 3	sec)									
14	DB in (L)/(R) hand														
15	- Side stretch to (R)/(L)	4	15												
16	Reversed PD (L)/(R)	2	10												
17	Stomach crunchies	2	max												

Follow for 2 weeks - [Re-evaluation date]

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