THE EFFECT OF COMPLIANCE TO A RIGO SYSTEM CHENEAU BRACE AND A SPECIFIC EXERCISE PROGRAMME ON IDIOPATHIC SCOLIOSIS CURVATURE.

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A thesis submitted to the Faculty of Health Sciences, University of the Witwatersrand, Johannesburg, in the fulfilment of the requirements for the degree of Doctor of Philosophy.

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DECLARATION

I, Louise Ann Rivett declare that this thesis is my own work, except for the help given by the persons listed in the acknowledgements. It is being submitted for the degree of Doctor of Philosophy at the University of the Witwatersrand, Johannesburg. This thesis has not been submitted before for any degree or examination at this or any other University.

Signature

Louise Ann Rivett

Signed day of month, 2012
In Johannesburg

Date

DEDICATION

In memory of my late mom, Monica Rivett (1932-1994), without whom I would not have my degree or be as successful as I am today. Also in tribute to all those that have scoliosis, an undeserved challenge for patients and a disease that still requires a large amount of research by the medical fraternity.

PUBLICATIONS AND PRESENTATIONS IN SUPPORT OF THIS THESIS

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ABSTRACT

Scoliosis is a three dimensional deformity in which the spine deviates from the normal sagittal and coronal position in upright posture and becomes fixed in an unbalanced posture. The aetiology is poorly understood, however the spinal deformity is a problematic developmental process, the outcome of which can be altered with appropriate intervention. There is some evidence in the literature that scoliosis is reversible. Asymmetric loading is the driving force for development and progression of curvatures. Progression of curvatures is related to growth potential, magnitude of the curve and bone age. Curves that are not managed result in signs and symptoms of pain, deformity, pulmonary dysfunction and psychological distress. For many cases that end up in surgery, spinal fusion fails to address the significant clinical symptoms of spinal deformity. The complications of surgery are high. There is controversy as to whether conservative management of wearing a brace and exercises are effective in stabilising the curve. Past studies have shown that exercises alone do not improve the curve. Studies have also shown that a brace only prevents progression of the curve and the efficiency of the brace is not clear. Guidelines for brace wearing have not been given in the literature. High correction bracing has however been shown to have favourable outcomes when patients are compliant.

The aim of this study was therefore to determine the effect of compliance to the RSC brace and a specific exercise programme on idiopathic scoliosis curvature. Further objectives were to determine factors affecting compliance to the treatment protocol. The quality of life and psychological traits of compliant subjects and non compliant subjects during the study were established and compared.

To achieve these objectives a pre test /post test study design was used with a post study comparison between subjects who complied with the management and those who did not comply. Fifty one subjects, girls aged 12-16 years were drawn from a private physiotherapy practice in Randburg, South Africa referred by different orthopaedic surgeons. Cobb angles were between 20-50 degrees and

subjects had no prior treatment. Subjects were divided into two groups after the brace and exercise interventions were complete and when weaning out of the brace had begun. Subjects were allocated to the two groups according to their compliance. The compliant group was defined as those subjects who wore the brace 20 or more hours a day and exercised three or more times per week. The non-compliant group were those subjects who wore the brace less than 20 hours a day and exercised less than three times per week. The study was terminated the day the subjects started weaning out of the brace. The two study groups were compared with respect to the Cobb angle, kyphotic and lordotic angle, apical vertebral rotation, scoliometer measures, peak flow, quality of life and personality traits.

The subjects in both groups were well matched at baseline. The compliant group, who wore the brace 21.5 hours per day and exercised four times a week, significantly improved in all measures compared to non compliant subjects, who wore the brace 12 hours per day, exercised 1.7 times a week and significantly deteriorated. The non compliant group followed the natural history of progression of IS curvatures. The major Cobb angles in the compliant group improved 10.19° (±5.5) and deteriorated 5.52°(±4.3) in the non compliant group. Compliant subjects had a significantly better quality of life than the non compliant subjects. Vitality, physical functioning, self esteem, bodily pain, school activity and general health perception, emotional function were significantly better in the compliant group compared to the non compliant group. The compliant group were significantly more emotionally mature, stable and realistic than the non compliant group.

In conclusion good compliance to a conservative treatment programme of the RSC brace and a specific regime of exercises resulted in a significant improvement in curvatures, poor compliance resulted in progression/deterioration. A poorer quality of life in the non compliant group possibly was caused by personality traits of the group, being more emotionally immature and unstable. Possibly different personality traits have different psychosocial coping mechanisms and when put in a stressful situation, result in different levels of compliance. A personality trait questionnaire is recommended on subjects initially, to predict compliance and then to include psychological support if required. This conservative treatment programme can be offered to patients all over South Africa and Africa. The patients only have to visit the physiotherapist and brace technician once a month and in some cases every three months. Further studies are required on the long term effects of this conservative treatment programme. Scoliosis is a complex condition of the developing child, and their psychosocial coping mechanisms need further research to improve compliance.

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TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

ABBREVIATIONS USED

AIS: Adolescent Idiopathic Scoliosis

ATR: Angle of Trunk Rotation

BrQ: Brace Questionnaire

BSSQbrace: Bad Sobernheim Stress Questionnaire

cm: Centimeters

CNS: Central Nervous System

CT: Computed Topography

DoboMed: The Dobosiewicz Method

EU: European Union

FVC: Forced Vital Capacity

HRQoL: Health Related Quality of Life

HSPQ: High School Personality Questionnaire

IS: Idiopathic Scoliosis

l/min: Litres per minute

MRI: Magnetic Resonance Imaging

16 PF: Sixteen Personality Factor Questionnaire

PHV: Peak Height Velocity

PSIS: Posterior Superior Iliac Spine

QoL: Quality of Life

RCT: Randomised Controlled Trial

RSC Brace: Rigo System Cheneau Brace

SEAS: Scientific Exercises Approach to Scoliosis

SIJ: Sacro-Iliac Joint

SIR: Scoliosis Intensive Rehabilitation Program

SNS: Sympathetic Nervous System

SOSORT: Society on Scoliosis Orthopaedic and Rehabilitation Treatment

SRS: Scoliosis Research Society

TLC: Total Lung Capacity

VC: Vital Capacity

WHO: World Health Organisation

Chapter 1

INTRODUCTION

1.1 An Overview of Idiopathic Scoliosis

Idiopathic Scoliosis (IS) is a lateral curvature of the spine in an otherwise healthy child for which the cause is unknown (Lonstein and Carlson, 1984). Scoliosis is a three dimensional deformity in which the spine deviates from the normal sagittal and coronal position in upright posture and becomes fixed in an unbalanced posture (Hawes, 2003; Negrini et al, 2005; Weiss et al, 2006). Scoliosis comes from the Greek word 'skolios' meaning crooked (Moen and Nachemson, 1999). Idiopathic scoliosis is defined as a curvature greater than a 10 degree Cobb angle (Weinstein, 1999). Idiopathic Scoliosis will develop in 2-3 percent of children (Weinstein, 1999; Schommer, 2002. A widely used classification of IS divides the condition into three groups, depending on when the scoliosis first presented; infantile, below 3 years; juvenile, age 3-10 years; and adolescent, age 10 years until the end of growth. Adult scoliosis is 20 years and above (James, 1954). Eighty per cent or more of Idiopathic Scoliosis is of the adolescent variety, namely Adolescent Idiopathic Scoliosis (AIS) (Risenborough and Wynne Davies, 1973).

Idiopathic Scoliosis is a biphasic process. It first appears and then it can progress, regress or remain stable according to Rigo (2005). Signs and symptoms of Idiopathic Scoliosis (Hawes, 2003; Weiss, 2003) include:

- pain
- a three dimensional torso deformity
- psychological distress
- pulmonary dysfunction- decreased chest wall compliance
  - decreased vital capacity
  - shortness of breath
  - reduced exercise capacity
  - recurrent respiratory infections

The magnitude of scoliosis is measured using the Cobb angle (Cobb, 1948). The Cobb angle is defined as the degree of tilt between two vertebrae, the caudal and cranial end vertebrae, that are the most tilted (Newton and Wenger, 2001). The angle is used to assess whether the curvature has stabilised or is getting worse (Lonstein, 1995). Progression of curvatures according to Lonstein and Carlson (1984) is related to: growth potential; magnitude of curve itself; bone age (Risser Sign); gender; spine slenderness; eccentric loading ie. gravity; gait; torsion-lordosant forces (Burwell, 2003).

$$\text{Lonstein Progression Factor} = \text{Cobb angle} - 3 \times \frac{\text{Risser sign}}{\text{chronological age}}$$

(Lonstein and Carlson, 1984)

In girls the highest risk of progression is before the onset of menarche. ie. equal or greater than 12 years of age (Weinstein 1999; Masso et al, 2002). Males have approximately one tenth the risk of progression of females. Different curve patterns have different prognoses (Peterson and Nachemson, 1995). There are 15 different curvature patterns according to the Rigo classification (Rigo, 2005) and therefor all have different biomechanical properties which result in different prognoses. For example thoracic curves in general have a worse prognosis than others (Bleck, 1991); and double curves nearly always progress (McMaster, 1985). Research by Harrington (1976), showed that postural imbalance alone can induce severe scoliosis, which can be resolved when the imbalance is removed before growth is complete (Harrington, 1976). The implication of this is that "scoliosis is reversible" even when it is accompanied by deterioration of structures of the spinal column. Harrington's work suggests a combined programme of early detection and early curve correction. If asymmetric loading is removed before growth is complete, and before too much time has passed, spinal deformity can be eliminated (Harrington, 1976; Mehta, 1984).

Curves not managed can result in the signs and symptoms already mentioned and progression of the curve in some cases to the point of being dangerous, namely, when lung function is restricted leading to later heart failure. Risk of curvature progression is essential to the appropriate design of idiopathic scoliosis treatment (Weinstein, 1999). Progression is defined as an increase of greater than five degrees in the Cobb angle (Cobb, 1948; Weiss et al, 2003). When curvatures progress to 25 degrees bracing has been used to stabilise the progression of the curvature. The efficiency of bracing continues to be questioned and is controversial (Asher and Burton, 2006; Lou et al, 2008).

Spinal fusion surgery is recommended for skeletally immature patients when curves progress to 40 – 45 degrees and mature patients with curves >50 degrees (Newton and Wenger, 2001; Weiss et al, 2003B). Curves of this size cause pulmonary dysfunction and pain and in some cases can cause heart failure (Hitosugi et al, 2000).

Opinions vary about the efficiency of conservative treatment of scoliosis (Weiss, 2003). In Europe bracing is considered to be successful in preventing progression of the curve, altering the natural history of scoliosis and reducing the numbers of patients requiring surgery (Weiss, 2003; Weiss et al, 2003B). However in some areas of the USA and Great Britain bracing and exercise is considered to be an inconvenience to lifestyle, it is time consuming and it is considered easier to let the curve progress, until surgery is required. In these countries there is very little research done to test the efficiency of physiotherapy in the early stages of idiopathic scoliosis. The thought is that small curves often remain stable or may improve (Weinstein, 1999).

High correction bracing has been shown to have favourable outcomes when the patient is compliant (Emans et al, 1986; Fernandez-Feliberti et al, 1995; Weiss, 2003; Weiss et al, 2003). Wearing the brace for 23 hours a day is significantly more successful than wearing the brace for eight and 16 hours per day (Rowe et al, 1997). Compliance and primary correction effect are the two most important variables associated with good brace outcomes (Weiss, 2003; Weiss and Rigo, 2008B).

In Germany a conservative method of treatment including intensive in-patient rehabilitation is recommended for curves with Cobb angles of 20–30 degrees.

Smaller curves 15 – 20 degrees are treated by out-patient physiotherapy/ exercises (Weiss, 2003). In-patient rehabilitation includes an intensive Schroth programme of exercises, bracing and physiotherapy. The effects of conservative treatment are: improved postural balance; decreased pain; improvement in the cosmetic signs of deformity (Rigo, 1999), and increased chest expansion, increased vital capacity, improvement in psychological distress, and a reduced rate of curve progression (Rigo, 2003; Weiss et al, 2003).

Treatment of scoliosis with the Cheneau brace is currently the most practised conservative method of treatment in Germany, Austria, Spain, Poland, France and Italy (Weiss, 2003). After working with the Cheneau brace for 15 years Dr Rigo has designed a brace that addressed a wider range of curves, as there were too many failures with the previous brace. The Rigo System Cheneau (RSC) brace corrects frontal and sagittal alignment in a three dimensional way. Correction is achieved through distortion correction forces. Breathing mechanics produce the necessary internal active forces to push out the sunken areas of the trunk as well as the sunken spine (Rigo, 2005).

Conservative treatment has remained controversial for many years (Weiss et al, 2003B). The reasons for this are: a lack of standardisation of protocols and data analysis, as well as a lack of reliable information about the natural history of untreated scoliosis (Dickinson and Weinstein, 1999). There are still many unknowns about brace treatment, which are required to determine the effectiveness of brace treatment (Lou et al, 2008). The full recipe for a successful result in a brace is not known. If scoliosis is indeed idiopathic then underlying causes of scoliosis must be ruled out (Shindle et al, 2006). In addition there have not been any systematic long term clinical studies done. There are differences of opinions as to whether exercise is a useful intervention for IS (Maruyama et al, 2002; Hawes 2003; Negrini et al, 2008B).

In earlier years, 1941 onwards, most patients chose to have surgery for cosmetic reasons (Lonstein, 1995), because of the rib hump. Spinal surgery does not eliminate the curve but reduces it to a smaller magnitude and freezes it there. The amount of correction depends on the surgical method used and is usually about fifty percent (Bleck, 1991). Surgically induced improvement in the Cobb angle does not result in a matching increase in respiratory function and pulmonary function may in fact decline after surgery (Goldberg et al, 2002). One of the complications of spinal surgery is the reduction of spinal and skeletal mobility. Pulmonary dysfunction in scoliosis is not believed to be a direct consequence of spinal curvature but is due to a secondary loss of skeletal mobility. Surgery further reduces this. Later studies have shown that surgery does not improve the signs and symptoms of scoliosis (Hawes, 2006; Weiss and Goodall, 2008C; Weiss, 2010). The rib hump does not improve after surgery and can worsen after surgery (Pratt et al, 2001; Weiss and Goodall, 2008C).

The complications of spinal surgery are high (Weiss and Goodall, 2008C). These include: neurological deficit due to damage to the spinal cord; death; severe blood loss; tearing of membranes covering spinal cord; artery laceration during harvesting of bone graft; urinary infections due to catheterisation; acute pancreatitis; painful obstructive bowel dysfunction due to immobilisation; wound infections; neck and back pain; infections associated with hardware inserted; broken rods right after surgery or many years later; crankshaft phenomenon, where the spine keeps growing rotating around the fusion; decompensation, where if one curve is fused others should compensate and this does not happen and they loose the ability to stand up straight; increased torso deformity; increased sagittal kyphosis; as well as strain on unfused vertebrae. An outcome of spinal surgery can be loss of spinal mobility over the entire spine (Hawes, 2002).

1.2 Problem Statement

The cause of spinal deformity is a problematic developmental process, the outcome of which can be altered with appropriate intervention. There is some evidence in the literature that scoliosis is reversible. For many cases that end up in surgery, spinal fusion fails to address the significant clinical symptoms of spinal deformity. There is a lack of agreement about the potential for proactive therapeutic intervention to stabilise the curve. Past studies have shown that exercises alone do not improve the curve. Studies have also shown that a brace only prevents progression of the curve and the efficiency of the brace is not clear. No guidelines for practice have been given in the literature as to how many hours to wear the brace and what exercises to do. No studies show what specific exercises and a brace would improve scoliosis. The effectiveness of the brace is determined by the compliance of the child to wearing the brace.

1.3 Significance of the Study

This study may show how compliance to a specific exercise programme and wearing the brace affects conservative treatment. The study may also show whether the curve can be improved conservatively. This study may indicate the number of hours a brace needs to be worn to improve the Cobb angle and the type of specific exercises that need to be done to be successful with treatment. The ideal time to start weaning out of a brace could be indicated. This study could show how a conservative treatment programme can be done, with patients only having to see the physiotherapist and brace technician once a month and in some cases every three months. The frequency of physiotherapy visits is less than that described in international literature on other physiotherapy methods and the reduced frequency is relevant in developing countries. Therefor the programme has the potential to be offered to patients all over South Africa and Africa.

1.4 Research Question

What is the effect of compliance with the RSC brace and a specific exercise programme on idiopathic scoliosis curvature?

1.5 Aim

To determine the effect of compliance with the RSC brace and a specific exercise programme on idiopathic scoliosis curvature.

1.6 Objectives

- To compare: the effect of the RSC brace and specific exercises on idiopathic scoliosis curvature between girls who wear the brace for 20-23 hours per day and do specific exercises at least three times per week and those who wear the brace for less than 20 hours per day and exercise less than three times per week
- To establish the change in the scoliosis curves during the course of management up to the point of weaning from the brace.
- To determine the factors that affect compliance to the treatment protocol.
- To establish and compare the quality of life of compliant subjects and non compliant subjects during the study .
- To compare the psychological traits of compliant and non compliant subjects during the study.

Chapter 2

LITERATURE REVIEW

2.1 Introduction

In this chapter the epidemiology and the causes of IS will be presented. The development and the progression of scoliosis is presented and the signs and symptoms of IS are discussed. Two treatment options, that is, conservative treatment and surgery will be presented. The aims and guidelines of conservative treatment as described in the literature are given. Different conservative treatment methods available internationally and locally are presented. These methods are with particular reference to different types of exercises (done internationally) and braces (local and international). Spinal fusion surgery is then discussed, including its effects and complications.

Papers for this review were obtained using Pubmed, Pedro, Google, Cochrane Collaboration search engines and cited references. Papers were also sourced from scoliosis conferences, courses and websites.

2.2 Epidemiology

There are no screening programmes for babies and young children and therefor the prevalence of infantile and juvenile IS is not known (Hawes, 2002). School programmes which screen preadolescent children provide the only database indicating the prevalence of IS. The preadolescent age range, 8-14 years, is screened because spinal deformity increases dramatically and becomes evident during growth spurts with rapid height increases. The prevalence of AIS, when defined as a curvature greater than 10 degrees (Cobb angle), is 2-3 percent (Weinstein, 1999). Adolescent IS occurs more in girls than in boys, with progression more frequent and severe in girls (Weinstein, 1999). Overall ratios of girls to boys of 5:1 up to 11:1 have been reported (Reamy and Slakey, 2001;

Ueno et al, 2011). The prevalence of large AIS curvatures is less than small curvatures, as not all curvatures progress. The prevalence of curvatures greater than 20 degrees is between 0,3 and 0,5 percent. Curves greater than 40 degrees affect less than 0,1 percent of the population (Hawes, 2002). The more severe the curve at the time of diagnosis and the younger the child, the more likely the significant increase in the magnitude of the curve (Lonstein and Carlson, 1984; Masso et al, 2002). Juvenile IS is more likely to progress, is less likely to respond to bracing and more likely to require surgical treatment than AIS (Masso et al, 2002). Smaller curvatures do not always progress. Infantile IS resolves spontaneously in 52-92 percent of patients (McMaster, 1983). Infantile IS is a preventable deformity and the position in which the infant is lain down may be a causative factor. Infantile scoliosis has been reduced in Europe since the adoption of the prone sleeping position in babies (McMaster, 1985). A study on 672 scoliosis subjects between 1968 to 1982, showed that most infantile curves (those that present in the first 6 months of life) occur in males (McMaster, 1983). The reason this should occur is not explained. Most common juvenile curves present in females (McMaster, 1983). There was no explanation in the study for this difference in presentation.

An overall prevalence rate of 9,2 percent of IS has been reported, however only 0,23 percent require treatment (Nissinen et al, 1993). The differences that have been found between different populations are thought to be genetic, however there is no proof at present (Robin, 1990). Environmental factors may also be involved in the varied prevalence rates between populations (Grivas et al, 2005). Late age menarche, a reliable prognostic factor for IS, is related to higher prevalence of AIS in latitudes north of 30 degrees (Grivas et al, 2006) The prevalence of AIS decreases in latitudes close to the equator. In northern countries delay in age of menarche, associated with AIS, is possibly due to preservation of high levels of melatonin secretion during the pre- menarcheal period in scoliotic girls due to light insufficiency. In the northern latitudes, there are less light hours and sunlight influences melatonin secretion. Melatonin production is stimulated by darkness. Melatonin acts on the gonads indirectly, reducing the secretion of gonadotropines, thus delaying skeletal maturity and age at menarche.

This leads to a relatively prolonged period of spinal vulnerability and the potential for curve progression (Grivas et al, 2006). This will be explained further in 2.3 below.

2.3 The Cause of Idiopathic Scoliosis

2.3.1 Diagnosis of Idiopathic Scoliosis

The diagnosis of IS is based on a medical history, physical examination and an X-ray in a standing position, which confirms a lateral curvature of the spine. There should be no obvious sign of congenital deformities of the spinal bones or body parts. History of metabolic disease, trauma, brain injury, polio or exposure to radiation should be ruled out (Hawes, 2002). A single X-ray is considered sufficient, as Computed Topography (CT) and Magnetic Resonance Imaging (MRI) scans do not consistantly reveal underlying pathologies found in other forms of scoliosis (Ramirez et al, 1997). However a CT or MRI scan can however, reveal the cause of the curvature and take the patient out of the 'idiopathic' category. A CT or MRI scan can reveal a hemivertebra or a tumour, which may not be seen on X-ray. Idiopathic Scoliosis however, shows no underlying pathology on X-ray, CT or MRI scan.

2.3.2 The Aetiology of Idiopathic Scoliosis

The aetiology, of IS is not known (Hawes, 2002; Sponseller, 2003). "Ideo" means 'one's own' and "pathic" is the Greek word for disease. There has been little progress in determining the aetiology of IS, despite intensive research for more than 100 years because it is almost impossible to separate the cause of IS from the effects of IS (Bagnall, 2008; Kouwenhoven and Castelein, 2008). At present patients with IS cannot be identified prior to the initial development of the spinal curve. Bagnall (2008) has suggested that a bipedal stance appears to be necessary for the development of scoliosis (Bagnall, 2008). Idiopathic Scoliosis contributes 70-90 percent to all known causes of scoliosis (Weiss, 2006; Soultanis et al, 2007), however there are at least 70 other known causes of scoliosis (Leathermann and Dickson, 1988), which are not idiopathic, some of which are listed below. Idiopathic Scoliosis is different in that there is no underlying pathology. Causes of scoliosis (not idiopathic) include:

Congenital :

- Malformed vertebrae, hemivertebrae
- Missing vertebrae
- Leg length discrepancy
- Cerebral palsy
- Neurological

Genetic diseases :

- Neurological
- Musculoskeletal
- Connective tissue defects

Infectious disease :

- Polio
- Tuberculosis

Postural Defects :

- Leg length discrepancy

Metabolic disease:

- Rickets
- Osteoporosis
- Arthritis

Pain

Psychological distress

Spinal infection

Tumours:

- Benign or malignant

Trauma:

- Radiation
- Surgery
- Injury
- Burns
- Spasm

The spine curves and rotates in different directions in response to environmental stimuli. Such curvatures are transient and reversible and occur numerous times during the day. This response depends on coordination between signal perception in the brain and signals to muscles and nerves which carry out the response. Therefor injury, infectious disease and genetic defects can interfere with normal posture and result in spinal curvature, or scoliosis, which is not idiopathic (Leathermann and Dickson, 1988). Different disorders have curves with different characteristics, different problems and complications. Understanding the pathology is an essential part of the evaluation of scoliosis (Soultanis et al, 2007).

Idiopathic Scoliosis is commonly considered to be a complex genetic trait disorder (Hawes, 2002; Asher and Burton, 2006). However there is no evidence presently that supports spinal deformity as being purely genetic (Burwell et al, 2011). Out of 114 subjects with scoliosis, 27 percent had relatives with a detectable curvature as shown by Wynne-Davies (1968). The remaining subjects did not have relatives with scoliosis, implying that IS is not always hereditary, but that inherited factors do play a role in some families. Studies to identify genes responsible for familial IS are underway (Miller, 2002), however a genetic disposition has not yet been shown to be responsible for hereditary IS. Current studies looking at causes of inherited IS, involve correlations between bone density, hormone secretion, familial posture, muscle texture and CNS function (Hawes, 2002). However it is difficult to establish the primary cause and secondary effect, as presently it is not known if the scoliosis is the original condition and the bone density, posture, muscle texture is an effect of the scoliosis or vice versa. Several investigators have shown that IS patients have problems with balance and have postulated a CNS disturbance, which could be the cause of the scoliosis (Gauchard et al, 2001).

Some studies propose connective tissue abnormalities, muscle and platelet defects, neuromuscular mechanisms, biomechanical defects and defects in growth and hormone systems as the cause of AIS (Shindle et al, 2006, Burwell et al, 2008A). The autonomic nervous system via its hypothalamic neuroendocrine control of puberty, skeletal growth and menarche contribute to the pathogenesis of AIS (Burwell et al, 2008A). In AIS there is a dysfunction of the sympathetic nervous system (SNS). There is an increase in SNS activity in AIS girls, due to a decrease in circulating leptin levels, the leptin-SNS concept (Burwell et al, 2008A). Leptin is a hormone with regulatory functions for growth and reproduction, including initiation of puberty in girls. In girls with AIS the autonomic nervous system (ANS) activity is found to be higher than in controls, which results in neuroendocrine mechanisms contributing to increased peak height velocity at an earlier age, general skeletal overgrowth, earlier skeletal maturation, extra-spinal skeletal length asymmetries (ribs, ilia), generalised osteopenia and lower body mass index (Burwell et al, 2008A).

The NOTOM escalator model, compliments the leptin-SNS concept (Burwell et al, 2008B). This model shows normal neuro-osseous timing of maturation (NOTOM) in a child during growth and maturation. There is a dynamic balance of postural equilibrium constantly renewed between two processes, linked through sensory and motor outputs. The two processes are: 1) the osseous escalator (which is increasing skeletal size and mass) and 2) the neural escalator (including CNS). The neural escalator is constantly calibrated as the body adjusts to biochemical and kinematic changes resulting from skeletal enlargement, enabling the body to coordinate motor actions. In AIS, progression results from the abnormality of the two processes (neural and osseous) in time and/or space. This asynchrony and/ or asymmetry causes failure of neural systems to control asymmetric growth of rapidly enlarging, moving adolescent spines. This asymmetric growth of the spine is explained by the dysfunction of the hypothalamus in the leptin- SNS concept. Adolescent IS may therefor result from disharmony between the somatic and autonomic nervous systems, that is a postural maturational delay (in the somatic nervous system) and hypothalmic dysfunction (in the autonomic nervous system). The disharmony occurring in the spine and the trunk of girls, compounded by biomechanical growth modulation, results in back shape asymmetry or scoliosis (Burwell et al, 2008A).

2.3.3 Non Structural versus Structural Scoliosis

A 'non structural' or functional scoliosis can be diagnosed when the patient (in standing) shows a curvature on X-ray, however the curve disappears when an X-ray is taken with the patient lying down or bending sideways. Examples are:

1) A curvature which is corrected using a shoe lift to balance out a leg length discrepancy (Hawes, 2002).

2) A curve that develops in response to slouching, muscle spasm or injury (a disc injury). The curve can disappear with treatment. In non structural scoliosis spinal segments have normal flexibility and resume their natural configuration when the body is relaxed (Hawes, 2002).

A 'structural' scoliosis is associated with loss of flexibility in one or more segments of the curved spinal column (Leathermann and Dickson, 1988). Structural scoliosis can be idiopathic, or of unknown cause. In structural IS the vertebrae are 'stuck' in a rotated position, the rib hump is rigid, the normal alignment of the thorax is skewed, discs between vertebrae become compressed and or wedged (Stokes et al, 2006). Curves are always present on X-ray while lying supine, however the magnitude of the curve might be reduced while in supine. Cobb angles can vary in magnitude between X-rays taken in the morning with those taken in the afternoon (Beauchamp et al, 1993). Cobb angles can increase during the day because gravity causes disc shrinkage and body height can decrease by one percent during the day (Zetterberg et al, 1983).

Structural idiopathic scoliosis has more potential for progression than non structural because of the abnormality of the vertebral column or its supporting mechanisms (Leathermann and Dickson, 1988). In structural scoliosis, spinal curvatures increase during growth because they lead to asymmetric loading of the vertebrae, which in turn causes asymmetric growth and wedging of the vertebrae (Stokes et al, 2006). Postural imbalance is known to cause scoliosis (Harrington, 1976). A non structural scoliosis with postural imbalance can precede and develop into structural scoliosis, with vertebral wedging, over a period of time (Hipps, 1963; Goldberg, 1978). Most structural spinal curvatures start out as non-structural curvatures (Harrington, 1976).

All components of vertebral deformity in structural scoliosis can be reversed when normal posture and movement is restored before growth is complete (Harrington, 1976). Harrington (1976) induced postural imbalance by restricting movement in healthy mice. The postural imbalance alone caused a structural scoliosis with vertebral rotation, as well as wedging of the vertebra and discs. The curvatures resolved when the postural imbalance was removed. Although these are animal studies, Harrington's work is important as it lead to further studies and is frequently cited. This reversal of curvatures has been reinforced by other animal studies (Mente et al, 1999; Braun et al, 2001). Harrington also presented a case study of a girl, aged 2.5 years of age, who had surgery to remove a congenital defect. She had a severe 75 degree curvature, which by protecting her spine from gravity was resolved by the age of 15 years (Asher, 1984). This study shows that curves can be reversed.

Reversibility of curvatures is also described by Mehta (1978), who showed that children can develop scoliosis in response to pain. A comprehensive review of the literature, by Hawes and O'Brien (2006), found that if spinal curvatures can be diagnosed in the early stages before pathological deformity of the elements, curvatures can be reduced. A small but sustained postural imbalance of forces along the spine can cause a scoliotic curve. An imbalance can be due to a genetic defect, pain, injury, or surgery. Irrespective of the trigger, idiopathic or not, the sustained postural imbalances over time result in asymmetrical loading relative to the spinal axis and then the dynamics of growth within the vertebrae are altered causing scoliosis. Evolution of a spinal curvature into a spinal deformity can be reversed by reversing the state of continuous asymmetric loading. This conclusion was made from the review cited above of over 10000 papers, which summarize what is known about the pathological processes by which spinal curvatures develop into spinal deformities. The review was very comprehensive, of all English papers and texts published on scoliosis. The quality of the studies was not established in the review.

Asymmetric muscle forces acting on each rib cause rib-vertebra angle asymmetries and are aetiological for idiopathic scoliosis (Burwell et al, 1991; Grivas et al, 1992). Lower rib-vertebra angles have been found in children with scoliosis (Grivas et al, 2002). The rib cage deforms early and scoliotic children have an underdeveloped thoracic cage compared to non-scoliotic counterparts.

Wearing a school backpack weighing 8-12kg results in changes in posture and an increase in lumbar lordosis (Negrini and Negrini, 2007). The increase in lordosis does not recover to its baseline values once the load, symmetrical or asymmetrical, is removed. Sustained postural imbalances over time result in asymmetrical loading which can lead to IS (Hawes and O'Brien, 2006). The increase in lordosis can result in pain, which later results in pain in adulthood (Negrini and Negrini, 2007). Patients with scoliosis often present with an increased lordosis.

There are asymmetries of hip rotation in scoliosis patients (Kotwicki et al, 2008). There is no limitation of range of movement, but there is movement of one hip towards internal rotation and the other hip towards external rotation during gait.

The implication of this is a ‘torsional offset’ of activation of muscle patterns around the spine in girls with structural idiopathic scoliosis during gait. This relates to the small postural imbalances of forces along the spine (Hawes and O'Brien, 2006).

2.3.4 Scoliosis Related to Sport (Non Idiopathic)

Sports associated scoliosis can be seen in people who engage intensively in repetitive motion activities for example: rowing, skiing, cycling, gymnastics, tennis, javelin throwing and ballet (Bleck, 1991). The reason for this is that postural imbalance occurs, because of the repetitive asymmetrical activity involved (Mehta, 1978; Stokes, 2000). The postural imbalance is a component of structural scoliosis. Tanchev et al (2000) found a ten fold increase in the incidence of scoliosis among girls (mean age 13 years) who had trained intensively as gymnasts for more than five years. They concluded that the combination of generalised joint laxity, delayed maturity and an asymmetric spine, from significant physical loading and repeated asymmetric stress on a growing spine that occurs with rhythmic gymnastics, lead to scoliosis (Tanchev et al, 2000). Exercise such as gymnastics, and ballet can exacerbate existing spinal deformities (Stokes, 2000). The repetitive asymmetric loading on existing wedged vertebrae, leads to further asymmetric growth and additional wedging of the vertebrae. Therefor progression of the curvature occurs. (This ‘Vicious Cycle’ will be explained in detail in the next section).

In summary scoliosis is known to occur in response to genetic, environmental and metabolic insults and may take years before signs or symptoms actually show (Wynne-Davies, 1975; Hawes and O’Brien, 2006).

2.4 Development and Progression of Scoliosis

The bony axis of the human spine, which cannot tolerate a weight of more than 10kg without buckling, depends for stability on a balanced muscular system coordinated by the CNS (Stokes and Gardner-Morse, 2003). The effects of gravity on upright human posture are very powerful. Individuals are taller in the morning than in the evening, as a result of compressive forces bearing down all day.

The ‘Vicious Circle’ model, published by Roaf (1960), states that asymmetric loading is the primary driving force for the development and progression of spinal deformity. When a curvature develops during vertebral growth, compression of the vertebral plates results in unequal growth, and then progression of the curvature occurs (Roaf, 1960). The asymmetric loading on the growth plates inhibits their growth, however this occurs throughout a patient’s lifetime and not only during active growth (Stokes et al, 1996). Stokes (2000) then modified the name and developed the ‘Vicious Cycle’ concept, which states that an initial trigger (phase one) causes a spinal curvature (phase two), which increases during growth because it leads to asymmetric loading of the vertebrae, which in turn causes asymmetric growth and additional wedging of the vertebrae (phase three). Vertebral body growth plates are affected (Stokes et al, 2006). The more unbalanced the load, the more likely it will become increasingly imbalanced over time under the continuous effects of gravity. Progression of the curvature is phase four. The spine will then enter into the Vicious Cycle again at phase one. The Vicious Cycle model explains why curvatures that are stable through childhood progress quickly during the period of rapid growth in adolescence (DeToledo and Haddad, 1999). If asymmetric loading is reversed and balance is restored, equal loading of growth plates results in restored symmetry and reversal of curvatures (Harrington, 1976).

Progression of a curvature is defined as an increase in the magnitude of the Cobb angle of five degrees (Goldberg et al, 1988). Rapid growth rate is possibly the most important factor in affecting progression (Stokes, 2000). Genetic and developmental factors, including body shape, weight, posture, metabolism, musculature (Goldberg et al, 1997) and environmental factors, such as nutrition, psychological or physiological distress influence progression of the curve. Gender, spine slenderness, eccentric loading ie gravity, gait, torsion- lordosant forces (Burwell, 2003) and sporting activities can also influence progression of the curvatures. As discussed above sports involving repetitive asymmetric loading on wedged vertebrae, result in further asymmetric growth and wedging of the vertebrae and progression. Heavy school bags also result in changes in posture (Negrini and Negrini, 2007) and these sustained postural imbalances over time result in asymmetrical loading which can lead to further progression of IS (Hawes and O'Brien, 2006). Curvatures can however stabilise or improve spontaneously prior to skeletal maturity (Weiss et al, 2003).

Larger curves are at higher risk for significant progression. The more severe the curve at the time of diagnosis and the younger the child the more significant the increase in magnitude of the curve (Lonstein, 1988). Lonstein and Carlson (1984) reviewed 727 subjects with IS with initial curvatures of 5- 29 degrees. Subjects were monitored to the end of skeletal growth or until the curve progressed. Progression of the curve occurred in 169 (23 percent) of the subjects. In curvatures of 20-29 degrees diagnosed before the age of 11 years, the risk of progression was 100 percent. Of those diagnosed at 15 years, only 16 percent were progressive. Therefor they concluded that the younger the age the higher the risk of progression. They concluded that progression is related to: growth potential; the magnitude of the curve itself; bone age (Risser Sign) and chronological age. The Lonstein Progression Factor is thus:

$$\text{Lonstein Progression Factor} = \frac{\text{Cobb} < -\ 3 \times \text{Risser Sign}}{\text{Chronological Age}}$$

The Risser Sign is a valuable five-point grading system used for assessing skeletal maturity (Greiner, 2002). The Risser Sign is defined by the amount of calcification in the iliac apophysis and tracks progressive anterolateral to posteromedial ossification. Risser 1 signifies ≤ 25 percent ossification, whereas at Risser 5 the iliac apophysis has fused to the iliac crest after 100 percent ossification. Several studies have evaluated the reliability of the Risser Sign, with most supporting the methodology (Bull et al, 1999; Greiner, 2002; Rivett et al, 2009A; Risser, 2010).

The Lonstein Progression Factor formula is now used to establish the progression risk of curves by the International Society of Spinal Orthopaedic Rehabilitation Treatment committee (SOSORT) (Weiss et al, 2006). The formula is used in the SOSORT guidelines for conservative management of scoliosis and is essential to the appropriate design of IS treatment (Weiss et al, 2003). The progression factor dictates whether the patient should be braced or not, or should the treatment be exercise only. If the progression factor is high, the patients are braced, if the progression risk is very low, the patients will be given exercises and monitored (Weiss et al, 2006).

Different curve patterns have different prognoses (Peterson and Nachemson, 1995). There are 15 different curvature patterns according to the Rigo classification (Rigo, 2005). Curvatures can be in the thoracic and, or lumbar area, convex to the left or right. All curvatures have different biomechanical properties which result in different prognoses. eg. thoracic curves have a worse prognosis than others, because of the rigidity of the thoracic spine with the ribs (Bleck, 1991; Weinstein,1999); Double curves nearly always progress more than single curves (McMaster, 1985; Weinstein, 1999). The lumbar component of a double major curve is more likely to progress than the thoracic component (Weinstein and Ponseti, 1983). Females are at greatest risk before the onset of menstruation (equal or greater than 12 years of age) (Weinstein, 1999; Masso et al, 2002). Males have approximately one tenth the risk of progression of females. The reasons behind this are: females' muscle strength per lean body weight decreases from juvenile to adolescent years, whereas in males it increases (Sunnegardh et al, 1988); females have more directional asymmetry than males (Jantz and Brehme, 1993); the NOTOM Concept discussed earlier in 2.3.2. is based on the timing of adolescent growth spurts in relation to the timing of postural maturity. Girls enter the adolescent growth spurt in postural immaturity, boys enter the growth spurt during postural maturity.

Only one in ten curves progresses to the point that treatment with bracing is required. At 25 degrees bracing is used to stabilise progression (Weiss et al, 2003). Only 0,1 percent of IS curves progress to the point where surgery is required (Asher and Burton, 2006). Spinal fusion surgery is recommended for skeletally immature patients when curves progress to 40-45 degrees and for mature patients, with curvatures greater than 50 degrees (Weiss et al, 2003). It is important to balance the risk of curvature progression with complications of surgery in determining whether intervention would be beneficial (Weinstein et al, 2003). Physiotherapy based exercise intervention alone can reduce the incidence of progression (Weiss et al, 2003). Exercise and bracing can significantly reduce the number of patients requiring surgery (Weiss et al, 2003).

In skeletally mature patients, Edgar and Mehta (1988) reported that in 77 adult subjects, the average rate of progression was 1,3 degrees per year. Many studies show that most cases of IS continue to progress throughout life (Bjerkreim and Hassan, 1982; Weinstein and Ponseti, 1983; Weinstein, 1999). Some individuals show marked progression after skeletal maturity and others are stable (Collis and Ponseti, 1969). Progression is greater the more rigid the curvature (Lonstein and Winter, 1988; Hawes, 2003). On rare occasions curvatures can progress to greater than 100 degrees and cause death, however untreated AIS does not generally increase mortality rates (Asher and Burton, 2006). In a study by Pehrsson et al (1998), of 45 subjects over a period of 20 years, respiratory failure occurred only in subjects with predicted vital capacities of less than 45 percent and curves greater than 110 degrees.

2.5 Signs and Symptoms of IS

Patients can have ‘signs’ of spinal deformity that show on X-ray, but they are unaware of their presence and they have no symptoms (Hawes, 2002). The signs and symptoms include pain, pulmonary dysfunction, three dimensional torso deformity and psychological distress (Hawes, 2003; Weiss, 2003).

2.5.1 Pain

Whether or not scoliosis causes pain is controversial. Some people with scoliosis report pain and some do not have pain (Hawes, 2003). The prevalence of back pain is significantly higher in patients with scoliosis than in control populations (Weinstein et al, 2003). However, they state that back pain severity and duration may not be increased in patients with scoliosis. Pain in children and pain in adults are considered as separate issues as the amount of pain experienced in children with scoliosis is different to the amount of pain experienced in adults with scoliosis. The differences in pain experienced will be explained in the following paragraphs.

Most children with scoliosis do not complain of pain and visit the doctor because of an obvious deformity, and not because of pain (Lonstein, 1995). Painful scoliosis in children is not idiopathic (Ramirez et al, 1997) and the pain is indicative of an underlying problem. Example of these are tumour, spinal cyst, infection or muscle spasm. As backache is an uncommon complaint in AIS, and when it occurs in association with paravertebral muscle spasm and scoliosis, osteoid osteoma of the spine can be suspected (Sapkas et al, 2009). Sapkas et al (2009) therefor recommend an MRI for a painful adolescent scoliosis as X-rays may miss the lesion.

The absence of reported pain in children with scoliosis may be due to the complexity of evaluating pain in children (Vitale et al, 2001). During assessment of children, methods of establishing pain need to reflect the unique perspectives of children for example, replace " Do you have back pain?", with a 'pain drawing' to diagnose pain (Brown, 2001).

Unlike children, the majority of adult scoliosis patients suffer from pain (Weiss, 2003). A large study by Goldberg et al (1994) showed that 1178 young scoliosis adults reported significantly higher incidences of pain (23 percent) than a control group of 1217 subjects reporting a one percent incidence of pain. All subjects in the study were interviewed 10 years after diagnosis of scoliosis in adolescence. They concluded that back pain is responsible for a considerable amount of disability and handicap in later life. This is a credible study because of the large sample size, and a control group. Similar results were reported after a 44 year follow up (Weinstein et al, 2003). Chronic pain was three times higher in a scoliosis group than a control group. How scoliosis causes pain is not clear and not explained in the literature, however the magnitude of the pain is inversely proportional to curvature flexibility. The more flexible the curvature the less the pain; the more rigid the curve the more the pain (Deviren et al, 2002). Pain severity does not correlate with the curve size. Mild curvatures as small as 10 degrees may cause more pain than severe curves (Mayo et al, 1994). The reason for this is that the development of significant structural changes in the vertebra and the discs can be seen in patients with small curves. However in other small curvatures only disc compression occurs, without any structural changes (Xiong et al, 1994). Treating pain is of major importance in conservative treatment of IS (Weiss et al, 2006). Over the long term, patients with IS suffer difficulites with their sports activities compared with age-matched controls, because of the frequency of back pain and functional impairments (Parsch et al, 2002).

2.5.2 Pulmonary Dysfunction

Pulmonary dysfunction only occurs in patients with thoracic curvatures occurring above the attachment of the spine to the diaphragm (Hawes, 2002). Pulmonary limitations do not occur in patients with lumbar curvatures. The three dimensional deformity of the torso results in reduced spinal flexibility and reduced chest wall mobility, and compliance (Hawes, 2003; Weiss, 2003). Decreased chest wall compliance results in decreased chest excursion and therefor causes restrictive lung function, decrease in vital capacity (VC) and total lung volume. Respiratory muscle function is restricted by the biomechanical changes in the thorax (Durmala et al, 2008). The rib cage is reduced in volume, as a result of the deformity and the lower rib-vertebra rib angles, droopy ribs, found in almost all scoliotic children (Wojcik et al, 1976; Grivas et al, 2002A). The rib cage is narrower than non scoliotic counterparts (Tsiligiannis and Grivas, 2012). If the chest cannot develop normally during growth, there is insufficient space available for alveolar growth, with resultant extrinsic restrictive lung disease. The respiratory muscles lose their efficiency by deformation of their architectural arrangement and pattern of activation. Vital capacity is inversely proportional to curvature magnitude, the larger the curvature the more lung dysfunction and decreased vital capacity (Flagstad and Kollmann, 1928). Flagstad and Kollman (1928) were the first to document that in patients with Cobb angles of greater than 100 degrees, VC was reduced to less than 50 percent of predicted normal spine values. In curves of 60-90 degrees, the VC is reduced to 50-65 percent of normal values and in curves 25-50 degrees the VC is reduced to 70 percent of normal values (Flagstad and Kollmann, 1928). The reduction of VC is due to reduced mobility of the thorax and the diaphragm due to lateral curvature and rotation of the vertebra and chest wall (Bowen, 1995). The lung on the convex side of the curvature is compressed and distorted, whereas the lung on the concave side follows the curvature, and is larger and more active. The heart in severe curvatures is enlarged and displaced to the side opposite the convexity, namely the concave side. Increasingly rigid deformity of the spine compresses the rib cage, limits motion of the diaphragm and abdomen. Over time stiffening of the joints and ligaments of the chest wall, causes a 'frozen rib cage'. The patient has to work harder to breathe and breathing becomes rapid and shallow at rest or with activity. Inadequate ventilation of alveoli occurs and pulmonary pressure is increased. A reduced lung capacity reflects a frozen rib cage, not a defective lung (Bowen, 1995). In summary the larger the curve, the harder it is to breathe. If the curvature improves there is a corresponding increase in the ventilation, improved lung function and vital capacity (Block et al, 1970; Weiss, 2003).

Patients also present with reduced exercise capacity and recurrent respiratory infection (Weiss, 2010). In a RCT on 126 subjects, 86 with AIS, Dos Santos Aves and Avanzi (2009) found that in the six minute walk test, normal controls presented with significantly lower mean heart rate, higher oxygen saturation and walked longer distances than the AIS group (Dos Santos Alves and Avanzi, 2009). However, patients with severe deformities and a vital capacity less than 50 percent often report no problems or deficiencies, but when questioned they have tailored their lifestyle to accommodate their limitations, avoiding activities which require cardiovascular endurance (Bowen, 1995). A reduction in chest wall mobility and spinal mobility causing restrictive lung function in proportion to curvature size, which can lead to death by cardiac or respiratory failure in curvatures greater than 100 degrees (Asher and Burton, 2006; Weiss, 2010). Impaired respiratory function in scoliosis occurs gradually over time and patients adapt to reduced function and are unaware of their limitations and often appear 'symptomless' (Hawes, 2003; Weiss, 2010). Therefor in response to the onset of respiratory infection, cardiopulmonary failure can occur unexpectedly. The number of people who die as a direct or indirect result of scoliosis- related health problems is not known, as there are no overall population statistics for death due to spinal deformity (Hawes, 2002).

2.5.3 Psychological Distress

Mental health studies in IS have conflicting results (Asher and Burton, 2006). Some studies show that there are no mental health problems severe enough to require psychiatric treatment, and deformities are better tolerated by middle aged patients than teenagers. However there are many studies that show the relationship between spinal deformity and psychological problems (Edgar and Mehta, 1988; Hawes, 2001; Rumsey and Harcourt, 2004; Tones et al, 2006).

A 50 year follow up study on 117 late onset idiopathic scoliosis subjects compared with 62 volunteers in a control group, showed that 22 percent of the scoliotic group complained of shortness of breath during every day activities, compared with 15 percent of the control group complaining of shortness of breath. This was associated with a Cobb angle greater than 80 degrees. The authors of this study concluded that untreated late onset scoliosis causes little physical impairment other than back pain and cosmetic concerns. However cosmetic concerns, having psychological effects has been shown in many studies (Edgar and Mehta, 1988; Goldberg et al, 1994; Payne et al, 1997; Hawes, 2001). The adults in a 50 year follow up study were productive and functional at a high level at the 50 year follow up (Weinstein et al, 2003). This study had a long follow up period on idiopathic scoliosis only, which makes it a credible good study as the authors point out that previous studies included all types of scoliosis that lead to disability from back pain and cardiopulmonary compromise.

A small study of 26 Swedish women with severe IS, Cobb angles 65-150 degrees, ages 23-63 years, also showed positive correlations between psychological adjustment and vital capacity. They suffered from some degree of mental disturbance due to their disability. The mean VC was 52 percent of normal (Bengtsson et al, 1974). A reduced VC is associated with psychological distress. This study however is a very small study on only large curves and the results are therefor not generalisable. Psychological disturbances have been found in woman with Cobb angles greater than 40 degrees (Ascani et al, 1986).

Tones et al (2006) in a review of the literature showed that AIS patients may experience psychosocial difficulties during treatment for scoliosis. Recent studies on HRQL and psychosocial factors in scoliosis patients were reviewed since 2001. Psychosocial and body image disturbances were less marked in patients with good social or family functioning, as well as in patients who exercised regularly. Adolescents with scoliosis generally display more psychological problems than adults with scoliosis (Tones et al, 2006). The authors recommended interventions such as a support group, aimed at managing psychosocial or body image disturbances to help the negative impact of scoliosis on these facets of life. The diagnosis and treatment of AIS can have significant psychological consequences for affected individuals according to Reichel and Schanz (2003). Adolescence is a sensitive phase of a young person's development, and requires a special degree of adaptation in the event of a chronic illness (Reichel and Schanz, 2003). The diagnosis of AIS comes at a time when concerns with appearance and bodily functioning are at their height (Hawes, 2002). According to the body image literature, scoliosis threatens the stability of the patient body image via changes to bodily sensation, functioning and appearance (Rumsey and Harcourt, 2004). Deformity can promote a negative self image within the individual, who may also have difficulties with social interaction due to potential adverse reactions from others as a result of the visibility of their condition and the brace (Tones and Moss, 2007). Patients with scoliosis must face up to cosmetic impairments and subjectively significant defects. Cognitively the patient must come to terms with time consuming and sometimes uncomfortable treatment, for a condition that does not always have physical symptoms. Successful treatment to prevent the progression of curvatures, does not necessarily mean improvement in the state of health. Psychological problems are a consequence of feeling bad about having a cosmetic deformity (Bleck, 1991). Scoliosis is a risk factor for impairment of the quality of life of children and adolescents (Freidel et al, 2002A; Reichel and Schanz, 2003). The impact of scoliosis is particularly marked if brace wearing is indicated. Psychosocial impairment can be prevented with psychological group sessions and individual discussions (Tones et al, 2006). Parent-child relationships must also be considered when treating AIS as the parent's attitude towards the child's condition is related to the child's attitude towards his/her own condition, and these attitudes are related to psychological distress (Kahanowitz and Weiser, 1989).

Juvenile female scoliosis patients show a less positive point of view towards life and are more easily subject to depressive moods compared to the age-matched general population. Patients with scoliosis also report more physical complaints and have lower self-esteem (Freidel et al, 2002B). These results are independent of the seriousness of the impairment (ie. the size of the Cobb angle). Therefor patients with larger Cobb angles are not more depressed. Health related quality of life can be impaired in IS patients. The results of the above study are confirmed by a large study using The Adolescent Health Survey, a self- administered questionnaire, collected on 36741 school age adolescents, of whom 685 had scoliosis (Payne et al, 1997). Their results showed that scoliosis was an independent risk factor for suicidal thought, worry and concern over body development and peer interactions. Girls with scoliosis were 55 percent more likely to have suicidal thoughts and three times more likely to drink alcohol after school, than girls without scoliosis. Boys were 10 percent more inclined to have suicidal thoughts and 95 percent more prone to alcohol consumption, than those without scoliosis. Boys with scoliosis were 97 percent more likely to worry about their bodies' developing abnormally and 79 percent more concerned about peer relations.

2.5.4 Three Dimensional Torso Deformity

Scoliosis is a three-dimensional deformity of the spine and trunk, where the spine deviates from the normal sagittal and coronal positions (Negrini et al, 2005; Kotwicki et al, 2007). There are a number of signs that can be seen in a patient with curvature of the spine, affecting the aesthetic appearance of the patient (Hawes, 2002; Zaina et al, 2008). Signs can include the following: posteriorly the following may be seen, the head may be held to one side, instead of the head centered over the mid- sacrum; shoulder level asymmetry, one shoulder can be higher than the other; shoulder blade asymmetry, one shoulder blade can be winging or protracted more than the other; hemithorax asymmetry, where the rib cage is asymmetrical with a rib hump on one side. The rib hump is the rotation of the rib cage along with the rotation of the vertebra (Lonstein, 1995) and is the angle of trunk rotation (ATR). A curvature convex to the right will cause a rib hump to the right and a curve to the left will cause a rib hump to the left. The magnitude of the rib hump is often related to the size of the curvature, the larger curves generally have larger rib humps, however, a large curve can sometimes have a small rib hump. A large rib hump may be why patients seek treatment for their condition, as it affects their aesthetics. Other signs may include one arm being further away from the body than the other, and waistline asymmetry, with a side shift of the pelvis (Zaina et al, 2008). When observing the patient anteriorly, rib cage abnormalities, such as asymmetry may be seen. One side of the rib cage may also be uneven.

Sagittal plane assessment can show a loss of normal sagittal curvatures. There can be an increase in normal kyphosis (20-50 degrees) resulting in ‘roundback’ or hyperkyphosis (Zaina et al, 2008). There can be a decrease in thoracic kyphosis (less than 20 degrees), resulting in lordosis or thoracic hypokyphosis. Loss of lumbar lordosis can occur, resulting in a ‘flatback’ posture, of less than 25 degrees (Hawes, 2002).

2.6 Aims of Conservative Treatment of IS

The primary aim of scoliosis management is to stop curvature progression (Weiss et al, 2006). Other important aims are the improvement of pulmonary function, treatment of pain and improving the aesthetic appearance (Negrini et al, 2006). Curvature progression can be prevented by conservative management by bracing and exercises thus surgery can be avoided (Negrini et al, 2009). There is uniform consensus regarding the appropriate type of conservative treatment and standard features in the rehabilitation of scoliosis (Hawes, 2002; Weiss et al, 2006B). There are three modes of conservative treatment accepted by the Society on Scoliosis Orthopaedic and Rehabilitation Treatment (SOSORT) (Weiss et al, 2006; Negrini et al, 2009B):

1. Management based on physical therapy
2. Scoliosis Intensive Rehabilitation (SIR) in a clinic
3. Brace treatment (Weiss et al, 2006) which will be described in detail later.

1. Physiotherapy, indicated by SOSORT guidelines below and a SOSORT consensus meeting 2008, "requires therapists specifically trained and certified in scoliosis specific conservative intervention methods eg Schroth therapy, SEAS concept, Dobomed method", which will be discussed later (Weiss et al, 2006B; Negrini et al, 2009B).

2. Scoliosis intensive rehabilitation in a clinic, means that the patient is admitted into a scoliosis clinic for four to six weeks and then at a later stage for return treatment of three to six weeks depending on symptoms and prognosis (Weiss, 2003). These clinics are only available in Germany.

3. Brace treatment has been found to be effective in preventing curvature progression and reduces the need for surgery (Weiss, 2003; Weiss et al, 2006).

Other forms of treatment for scoliosis were investigated by Romano and Negrini (2008), in an extensive systematic review of the literature. They found 145 texts, including all manipulative, osteopathic, chiropractic and passive techniques (massage, mobilization) performed by an external operator. They concluded a lack of serious scientific data that does not allow any conclusion on the efficacy of manual therapy as an effective treatment of AIS to be drawn (Romano and Negrini, 2008).

2.7 Guidelines for Conservative Management of Scoliosis

Guidelines for the management of scoliosis were established by the SOSORT committee in 2006 (Weiss et al, 2006). The guidelines are based on the risk of progression in a given period of time. The risk of progression is based on the calculation of Lonstein and Carlson described in 2.4 (Lonstein and Carlson, 1984). Each patient with scoliosis has their own natural history and must be considered on an individual basis (Hawes, 2002; Weiss et al, 2006).

The guidelines are:

"1. Children (no signs of maturity, Risser 0)

Cobb angle <15° : Observation (every 6-12 months) by an orthopaedic surgeon

Cobb angle 15-20° : Out-patient physiotherapy and a home exercise programme

Cobb angle 20-25° : Out-patient physiotherapy or SIR if available. A brace indicated if there is presence of chronic pain

Cobb angle > 25° : Outpatient physiotherapy or SIR where available and bracing.

2. Children and adolescents (Risser 0-3, first signs of maturation). This is based on progression risk according to Lonstein and Carlson (Lonstein and Carlson, 1984) rather than Cobb angle measurement.

Progression risk < 40% : Observation

Progression risk 40-60% : Out-patient physiotherapy or SIR if available

Progression risk 60-80% : Out-patient physiotherapy or SIR and bracing.

3. Children and adolescents (Risser 4)

Cobb angle < 20° : Observation

Cobb angle 20-25 ° : Out-patient physiotherapy and bracing if pain is present

Cobb angle 25-35° : Out-patient physiotherapy or SIR and bracing if pain is present

Cobb angle > 35° : Out-patient physiotherapy or SIR and bracing.

4. Adolescents and adults with chronic pain

Cobb angle: Any degree/ size: Out-patient physiotherapy or SIR and bracing if positive effect is proven.

5. Adults

Cobb angle >30°: Out-patient physiotherapy or SIR where available (Weiss et al, 2006)".

2. 8 Treatment Involving 'Observation only'

Children, with Cobb angles 10-20 degrees, are referred to orthopaedic surgeons who have regular intervals for evaluation, including an X-ray every six months to a year, until skeletal maturity is reached (Hawes, 2002; Weiss, 2003). Nothing is done for the children in the early stages of spinal deformity, when it is at its mildest, most flexible and potentially treatable form. There is no positive impact of ‘observation only’ on pain, pulmonary or psychological symptoms associated with IS (Hawes, 2002).

With regular X-rays, on these small Cobb angles, there is an increased risk of breast cancer associated with repeated radiological exposure during active growth (Doody et al, 2000; Levy et al, 1996). A survey by Doody et al (2000) of 5573 female subjects referred for treatment to 14 clinics in the U.S.A. between 1912 and 1965 revealed a nearly twofold increased risk of breast cancer. The average number of X-Rays was 24 per subject. The risk was increased by both an increased number of X-rays and increased radiation dose. This is a problem in management of small curvatures. Physicians have responded by using posterior anterior (PA) X-Rays to reduce direct exposure of breast tissue in girls (DeSmet et al, 1982).

2. 9 Physical Exercises for Scoliosis

The effect and aims of exercise on scoliosis are discussed below and different types of exercises currently used in scoliosis treatment are described.

2.9.1 The Effect of Physical Exercises on Scoliosis

The use of exercise to treat AIS has been controversial for many years. There is a great variety of applied treatments and thus the results of conservative treatment differ (Weiss, 2003). Some studies indicate that specific exercises help scoliosis and others show that exercise does not affect the curvature. Early work by Galenus (AD131-201) showed that exercises were used a long time ago in the form of respiratory exercises and loud singing to expand and balance the thoracic deformity in scoliosis patients (Moen and Nachemson, 1999). From 500BC to the early 1900’s traction, manipulation and supportive braces (using iron or plaster) were used to reverse the rigidity of the curve and push the torso back into alignment, without knowing the cause of the scoliosis (Roaf, 1960) or whether the treatment was effective or not.

Previous work by Harrington (1976), which is very valuable, mentioned in "causes and progression of scoliosis" (Chapter 2.2.3.3), indicated that structural scoliosis is reversible, when spinal mobility and postural balance are restored before growth is complete (Harrington, 1976). If asymmetric loading is removed spinal deformity can be eliminated (Mehta, 1978; Asher, 1984). Hawes (2003) states that early detection and early treatment is the key to successful outcome. In a very small randomised controlled trial on 10 subjects, with a mean Cobb angle of 42 degrees, for an eight day in- patient programme of exercises and traction under the supervision of a physiotherapist, flexibility of the curvature improved by 30 percent (Dickson and Leathermann, 1979). Flexibility was assessed based on how much correction of the Cobb angle can be obtained when the patient side bends (lateral flexion). A flexible curvature will resolve and a rigid curve will not respond. The exercises done were lateral bending to correct the curve and pelvic tilting to mobilise the lumbar lordosis. The flexibility of a spine is the defining characteristic of a structural deformity. Although this study was a very small randomized controlled trial, the description of the type of exercises used is important when supporting the main study/thesis presented here (Dickson and Leathermann, 1979).

Most early studies before 2003 do not support exercise in the treatment of scoliosis (Hawes, 2003). Hawes (2003) in a comprehensive review of the 10000 papers, identified many studies on exercise and its effects on scoliosis, showing no consensus on the effects of exercise up until 2003. Some studies showed that exercise alone will not affect the progression of the curve, with some showing that exercise is of no use at all (Hawes, 2003). However she shows in the review that there is evidence that exercise improves signs and symptoms of scoliosis without surgery (Harrington, 1976; Mehta, 1978; Mehta, 1984; Stokes, 2000). Exercise maintains flexibility of the spine, which is important for rigid curves that progress more rapidly. The more rigid a curvature the more likely the curve will progress (Lonstein and Winter, 1988). Hawes (2003) presents evidence that exercise stabilises curvature progression (Mehta, 1986; Maruyama et al, 2002). She states in her review, that there is not a single study that supports the hypothesis that scoliosis cannot be treated with exercise based therapies, as there is evidence that exercise based therapies can reverse signs and symptoms of scoliosis. Most reviews published, before 2003, indicate that exercise is of no use in the treatment of scoliosis (Hawes, 2003), however these reviews do not provide references to support their statements and no data or inclusion criteria are provided. The exercises that were given in these studies were not specified or described and were general exercises (Shands et al, 1941; Ponseti and Friedman,1950). Negrini et al (2003) in their literature review agree that the literature fails to provide solid evidence for or against the efficacy of physical exercise in the treatment of AIS (Negrini et al, 2003). The literature was found to be of poor quality when the methodological quality was reviewed and none of the studies were randomised (Negrini et al, 2003). However exercise was proposed by the authors to avoid progression, as evidence suggests exercise prevents progression of curvatures. Secondary outcomes of exercise were increased namely neuromotor control and stability of the spine, postural collapse was reduced and breathing function increased (Negrini et al, 2003).

Papers published later in the last decade do however, show significant improvement in pain, stabilisation or improvement in curvature magnitude and torso deformity, reduced psychological distress and measurable improved chest expansion, vital capacity and cardiopulmonary function with exercise (Hawes, 2003; Weiss, 2003). These are important better quality studies with improved methodologies. Exercises in these studies have been specified and described, references are given, inclusion and exclusion criteria are given, control groups have been used and methodology improved. Only a few specific exercises, such as ‘side shift’ exercise, explained later, have been shown to actually improve the Cobb angle (Mehta, 1986; Negrini et al, 2008A).

In a later more comprehensive systematic review of the literature, Negrini et al (2008A), found that exercises reduced the curve progression rate (Negrini et al, 2008A). This review was five years later and contained more papers, and stricter inclusion criteria were also used. Exercises have also been shown to reduce brace prescription, and very specific exercises can decrease progression of scoliosis to when a brace is required (Negrini et al, 2008B).

In a prospective controlled cohort study of Negrini et al (2008B), specific exercises were found to be effective in AIS patients, who were at high risk of progression. This was a good quality study, strict inclusion criteria were used, a comprehensive methodology and there was a sample size of 74. A limitation of the study was that the results are after one year of treatment and therefore further studies should be done over a longer period, to determine the long term effect of the exercises on progression. Exercises should immediately follow 'observation alone', and be done before bracing, to avoid or at least postpone bracing and to arrive at the end of growth with a stable curvature (Negrini et al, 2005). When a brace is prescribed 'exercises are mandatory' (Negrini et al, 2005).

The authors, Negrini et al (2008A), then went on to publish the latest updated systematic review on physical exercises for idiopathic scoliosis (Fusco et al, 2011) (the second author in the 2008 study, becoming the first author in 2011 study). The strict inclusion criteria were the same as the previous systematic review in 2008 and the conclusions were the same, except they added that exercises could improve the Cobb angle and that general exercises are not effective in treating AIS, but appropriate scientifically based physical exercises are however effective (Fusco et al, 2011). In the 2011 review the only randomised controlled trial (RCT) that was presented, was a study in China that included a total of 80 subjects. Subjects were 15 (±4) years of age, with a 24 (±12) degree Cobb angle. After six months of treatment, including gymnastic exercises, postural training and autocorrection, the Cobb angle in the exercise group improved 15 degrees. Noteworthy here is that the mean Cobb angle was not large enough to brace and the study included only six months of treatment (Wan et al, 2005).

2.9.2 Aims of Exercises for Scoliosis

SOSORT was established in Barcelona in 2004 to address the role of conservative therapies in the treatment of scoliosis. This international group of clinicians and scientists specializing in the treatment of scoliosis met in Milan, Italy in January 2005 to produce a consensus paper on the roles of physical exercises in the treatment of IS at risk of brace treatment (Weiss et al, 2006B). The high priority treatment aims of the exercises for scoliosis identified by the authors included:

- "Autocorrection of the spine in a 3 dimensional plane, including restoration of sagittal profile
- Autoelongation - self elongation of the spine
- Stabilising the corrected posture
- Ergonomy - training in Active Daily Living
- Respiratory capacity (function)
- Respiratory education
- Patient and family education on scoliosis theory

Other aims identified by the authors but of low priority were:

- Coordination
- Equilibrium
- General motor capacity
- Muscle endurance
- Muscular strength
- Neuromotor control of spine
- Side shift of the pelvis"(this exercise will be explained later)

2.9.3 Types of Exercise for Scoliosis

There are various conservative treatment methods for scoliosis around the world. These methods will be briefly described:

1. The Schroth programme, originating in Germany
2. The SEAS concept, The 'Scientific Exercises Approach to Scoliosis', in Italy
3. The Lyonnaise Method, in France
4. The Dobosiewicz Method, in Poland
5. Side Shift exercises, in England

2.9.3.1. The Schroth Programme

The Schroth Programme was designed by Katharina Schroth (Lehnert-Schroth, 2007) and is the method used in Bad Sobernheim, Germany, at the Schroth

Spinal Deformities Rehabilitation Centre (Weiss, 2006). The Schroth method is part of the Scoliosis Intensive Rehabilitation (SIR) inpatient programme used at the clinic. The aim of the Schroth method is to enable the patient to achieve postural corrections for themselves, with exclusive use of trunk muscles and to use these postures in daily activities (Weiss and Maier-Hennes, 2008). The physiotherapist gives instructions on how patients should correct their posture in different parts of the trunk, by means of exteroceptive stimulation or by provoking balance reactions. Proprioceptive stimulation through manual passive corrections on the deformity and through changes in articular position, passive traction-compression movements or manual relaxation, activation or elongation tests of elastic structures are used. The advantage of this programme is the specificity of postural corrections indicated for different curve patterns and use of mechanisms to increase postural correction in three dimension (3D).

Schroth therapy uses five principles for correction (Weiss, 2006; Weiss and Maier-Hennes, 2008).

1. Axial elongation: Self elongation actively using trunk muscles.
2. Deflexion: Correction of different body parts in the frontal plane.
3. Derotation: Detorsion, to achieve better alignment of the spine in frontal and sagittal planes
4. Rotational Breathing: The deformity of scoliosis causes an imbalance in the trunk muscles, which results in modified breathing mechanics. Rotational breathing exercises involve contraction of convex areas of the chest, the inspired air is directed to the concave areas of the chest and the ribs lengthen and mobilise soft tissues in these regions (Weiss, 1991). The therapists use the pressure of their fingers to stimulate expansion of the chest wall on sunken areas (concave areas of the curve) to encourage ventilation into these sunken areas. The effect of this work by the patient is a proprioceptive reinforcement of the sensation of detorsion reaching the spinal column (Weiss and Maier-Hennes, 2008). Weiss (1991) showed a 15-18 percent improvement in vital capacity and a 20 percent improvement in chest expansion using this method of physiotherapy. There is improved mobility of the ribs which also improves cardiopulmonary performance with these exercises and prevents progression of the curvatures (Weiss, 1992).

5. Stabilisation: This is maintenance of the spinal correction, while producing an isometric tension of all the trunk muscles in the exhalation phase. Different curve patterns have specific correction mechanisms which are taught (Weiss and Maier-Hennes, 2008). Studies of the Schroth Method are presented in Table 2.1 below.

Table 2.1 Studies of the Schroth method of physiotherapy.

Authors	**Country**	**Sample (n)**	**Study Type**	**Mean: Age, Cobb**	**Main Findings**
(Weiss, 1991)	Germany	813	Retrospective	10-17yrs	Increase in vital capacity, by 14-19%, and chest expansion. (SIR)
(Rigo et al, 1991)	Spain	43	Retrospective	12yrs 19°	Stabilisation of curvatures. (outpatients)
(Weiss, 1992)	Germany	118	Retrospective	10-15yrs 31°	Prevents progression of curvatures. Stabilisation of curve magnitude and torso deformity. (SIR)
(Weiss, 1993)	Germany	311	Retrospective	12- 69yrs 50°	Decrease in pain.
(Weiss and Cherdron, 1994)	Germany	37	Pre / Post interview study	20- 57yrs	Positive impact on psychological distress. Emotional stabilisation of subjects.
(Weiss et al, 1997)	Germany	181	Retrospective	12.7yrs 27°	Decrease in progression of curves. (SIR)
(Weiss et al, 1999)	Germany	1454	Retrospective		Decrease in lateral deviation of spine after in patient exercises using the formetric system, for surface anatomy.
(Weiss et al, 2003)	Germany	181 135© ©Control Group	Prospective age & sex matched controlled	9- 15yrs 21° 29°©	Reduction in incidence of progression. Cobb angle 43° decreased to 39°. (SIR) Supervised exercise regime.
(Otman et al, 2005)	Turkey	50	Retrospective	14.5yrs 26.1°	Positive influence on Cobb angle, vital capacity, strength and posture. After a year Cobb angle was 17.8° (outpatients)
(Weiss et al, 2006D)	Germany	206	Questionnaire	15.7yrs 35.8°	AIS subjects have low stress with their deformity, during Schroth in patient therapy.
(Weiss and Klein, 2006)	Germany	18 18©	Prospective Controlled trial	14-15yrs 34.5° 31.6°	Improvement in lateral deviation and surface rotation. (SIR)
(Rigo et al, 2007)	Spain	50	Retrospective	15.7yrs	Shroth exercises correct the spine in three dimensions, maintain sagittal angles close to normal values.

2.9.3.2 The SEAS Concept

The SEAS Concept originated in Italy about 30 years ago and is derived from the Lyonaise school (Romano et al, 2008). The SEAS programme presented by Negrini et al (2006) has constantly been updated as new findings become available (Negrini et al, 2006B). The main characteristics of SEAS are both a team approach and a cognitive- behavioural approach. The team includes the physician, the physiotherapist, trainer and orthotist along with the patient and his/ her family. The SEAS programme includes active self-correction in three spatial planes rather than passive correction which is done in most schools of scoliosis exercise. Active self-correction is achieved by the patient by using the deep spinal paravertebral musculature. Active movement is much better than passive movement to learn neuro-motor behaviours such as posture (Brooks, 1983). Increasing spinal stability is a primary goal of SEAS. Improving spinal stability reduces postural collapse and consequent spinal structural deformation. Improvement of balance reactions is another goal, because of the postural deficits associated with balance dysfunctions (Romano et al, 2008). Preservation of normal sagittal curves is a goal, as sagittal curves are often reduced in a scoliotic spine. Further goals are to improve aerobic functioning and develop a positive self image.

Modalities used are posture rehabilitation, using mirrors and tactile input; muscular endurance, strengthening in the correct posture, using isometric contractions of paravertebral, abdominal, shoulder girdle and lower limb muscles; development of balance reactions, active self–correction on unstable surfaces and neuromotor intergration, using active self correction with global movements such as walking. Exercises are done to reduce the side effects of immobility from the brace itself and to improve range of movement of the spine on all planes so as to allow the brace to exert maximum possible correction. The SEAS programme encourages sports and recreational activities in the brace so as not to limit patients' personal and social lives. Studies on SEAS treatment are presented in Table 2.2 on the next page.

Table 2.2 Studies on SEAS treatment.

Authors	Country	Sample (n)	Study Type	Mean: Age, Cobb Angle	Main Findings
(Negrini et al, 2006C)	Italy	27	Prospective controlled	27°thoracic 26° distal	Possible to reduce a Cobb angle and apical rotation using active self correction (SEAS method).
(Negrini et al, 2006B)	Italy	48= 23 25©	Prospective controlled	12.4 yrs 15°	The number of brace subjects was reduced. SEAS group had 28.9% improvement versus control group (standard exercises) had 5% improvement. SEAS exercises more effective than standard exercises.
(Negrini et al, 2006D)	Italy	110	Prospective controlled	13.5 yrs 31°	Efficiency of SEAS exercises for preparation to bracing.
(Negrini et al, 2008B)	Italy	74= 34 39 ©	Prospective Controlled Cohort	12.4 yrs 15°	Improvement in the SEAS group was 5° and better than the control group, which had non specific exercises, normal physiotherapy. SEAS prevent / delay a patient going into a brace and prevent progression of curves.
(Negrini et al, 2008D)	Italy	1	Case Study	25 yr 47°	Adult scoliosis can be reduced by SEAS exercises. Reduced to 28.5° in a year, a recovery of postural collapse that occurred after skeletal maturity.
(Zaina et al, 2009B)	Italy	68	Retrospective controlled	15 yrs 22 ±2°	Exercises can prevent postural collapse during weaning process. Exercises were not described.

The SEAS programme does not describe different approaches to individual curve patterns and therefor specific exercises are not given for specific curve patterns according to Weiss (Weiss, 2006). Specific exercises are not documented in the studies presented above and in Weiss's opinion this lack of specific exercises is a weakness of the programme as the exercises are generalised.

2.9.3.3 The Lyonnaise Method

The Lyonnaise Method aims at 3-D postural correction as well as the improvement of skills the patient needs for autocorrection. Exercises are not performed asymmetrically. Corrections are performed to reach a symmetric appearance. Sagittal correction is mainly corrected with the help of exercises done in the brace. Compared to the Schroth programme a functional overcorrection in 3-D is the aim. According to Weiss (2006), many exercises from the Lyonnaise school may lead to total kyphosis, which is not effective (Weiss, 2006). There are no prospective studies available for the Lyonnaise method with an untreated control group. There is a retrospective study by Mollon and Rodot (1986), on 210 cases, however its on very small curves (Weiss, 1992). In the exercise group (160 subjects) the average Cobb angle was 17 degrees and in the control group (50 subjects), the Cobb angle was 13 degrees. In the exercise group 62.5 percent improved or stabilised and in the control group only 20 percent improved. This study had an appropriate sample size and a control group, however curves of this size do not have a high risk of progression and can remain stable or progress.

2.9.3.4 The Dobosiewicz Method (Dobomed)

The Dobomed method is used in Katowice, Poland and was developed in 1979 by Professor Dobosiewicz (Dobosiewicz et al, 2005). This method involves three-dimensional autocorrection with primary curve mobilisation towards the correction of the curvature, with special emphasis on kyphotization of the thoracic spine (Dobosiewicz et al, 2008). Most scoliosis patients have a reduced kyphosis. Exercises are done in closed kinetic chains, such as four point kneeling, two point kneeling, sitting or standing, and developed on a symmetrically positioned pelvis and shoulder girdle, followed by active stabilisation of the corrected position, and endured as a postural habit. The desired movement of the vertebrae is kyphotization, an increase in the kyphosis, which is a backward, posterior displacement of the vertebrae. Axial derotation of the vertebrae is obtained partly by movement of the thorax versus a stable pelvis and shoulder girdle and partly by asymmetrical breathing. The treatment focuses on the area of the apical vertebra. On the concave side of the curve a strong local hand pressure is applied during inspiration and during expiration on the convex side a subtle facilitation is applied. During expiration, correction is stabilised by an isometric contraction. DoboMed has been used as both single therapy and with bracing. DoboMed has been shown to stabilise the Cobb angles and vertebral rotation, improve respiratory function and improve general exercise efficiency in retrospective and prospective studies (Dobosiewicz et al, 2008), shown in Table 2.3 on the next page.

Table 2.3 Studies using Dobomed method of physiotherapy.

Authors	Country	Sample (n)	Study Type	Mean : Age, Cobb	Main Findings
(Dyner-Jama et al, 2000)	Poland	124	Prospective controlled trial	5-16 yrs 12.1 yrs	Increase in Forced Vital Capacity and FEV1. Improved respiratory capacity.
(Durmala et al, 2002)	Poland	58 31 ©	Prospective controlled trial	10-16 yr 13.1 yrs	Higher exercise efficiency in girls, treated with Dobomed. Max O_2 uptake and workload significantly higher in Dobomed group.
(Dobosiewicz et al, 2002)	Poland		Retrospective		Inhibit progression of small a moderate scoliosis. Decrease lateral curvature of spine and angle of rotation.
(Durmala et al, 2003)	Poland	136	Retrospective	6-18 yrs	In 31-39% of cases there was a decrease in Cobb angle according to segment of spine considered.
(Dobosiewicz et al, 2006)	Poland	152	Retrospective	14.2 yrs 25.9°	Stabilisation of Cobb angles and vertebral rotation.
(Dobosiewicz et al, 2006B)	Poland	198	Retrospective	9 yrs 25-27°	Single and double major curves in in-patient rehabilitation, Cobb angles and apical rotations stabilised in most cases.
(Szota, 2006)	Poland		Prospective		Inhibit curve progression in small and moderate scoliosis.
(Durmala et al, 2007)	Poland	20	Retrospective	27° ±7	Stabilisation of curves. Period of observation > 36 months.

© is the control group

The effectiveness of Dobomed method depends on the curve flexibility and the compliance of the patient (Dobosiewicz et al, 2008). Dobomed is not recommended for small children as active cooperation is a basic requirement (Dobosiewicz et al, 2005).

2.9.3.5 Side Shift Exercise

Side Shift exercise was originally described by Mehta (1986). The exercise consists of lateral trunk shift to the concavity of the curve. Lateral tilt at the inferior end vertebra is reduced or reversed, and the curve is corrected in the side-shift position (Mehta, 1986). The patients are instructed to repetitively shift their trunk to the concavity of the curve in standing and maintain the side-shift position for 10 seconds, then return to neutral. The side shift can be done with a hitch exercise, which is lifting the heel on the convex side of the curve, keeping the hip and knee straight on that side, holding for ten seconds. Both exercises are done 30 times per day (Maruyama et al, 2002). Studies using side shift exercises to stabilise curvature progression are presented below in Table 2.4.

Table 2.4 Studies using Side Shift exercises.

Authors	**Country**	**Sample (n)**	**Study Type**	**Mean Age Cobb <**	**Main Findings**
(Mehta, 1985)	England	35	Retrospective	14.1yrs 23.8°	After 1.9 yrs of treatment 21% improved 5° or more, 50% stabilised.
(Den Boer et al, 1999)	Poland	44 120 - (braced)	Prospective controlled trial	13.6 yrs 20-32°	Progression in Cobb angle over 2-3 year period was not statistically significant between side shift group and braced group.
(Maruyama et al, 2002)	Japan	69	Retrospective	16.3yrs 31.5°	After 4.2 year follow-up, 22% of curves progressed and 14% improved (4% by 10° or more). A usefull treatment option after skeletal maturity. Hitch exercise was included.
(Maruyama et al, 2003)	Japan	53	Retrospective	16.3yrs 33.3°	After 3.5 year follow up curves were 32.2°. Curves stabilised.

Side shift exercise addresses the deformity in the frontal plane only and postural correction requires restoration of lordosis and kyphosis (Weiss, 2006).

2.10 Scoliosis Intensive Rehabilitation (SIR)

Scoliosis Intensive Rehabilitation (SIR) is the only in-patient rehabilitation programme that exists. It is in Bad Sobernheim, Germany at the Asklepios Katharina Schroth Spinal Deformities Rehabilitation Centre (Weiss, 2006). SIR involves individualised exercise programmes combining corrective behavioural patterns with physiotherapy methods following the principles of Lehnert-Schroth, Schroth therapy (Weiss, 2003; Weiss, 2006). The first treatment is a 4-6 week visit and return treatments for a period of 3-6 weeks. Treatment is 5-6 hours per day, six days a week and a home programme with the same exercise regime for 30 minutes per day. The aim of the in–patient treatment is for patients to achieve correct posture without a therapist and to maintain this posture in normal daily activities. After assessment by a multi disciplinary team, the patients participate in a structured programme, with therapy provided by the team. Patients are discharged with a home programme of four exercises for 30 minutes, to be done daily, in order to maintain improved postural balance. Studies of SIR not mentioned in Table 2.1 previously, are presented in Table 2.5 below.

Table 2.5 Studies using in-patient SIR.

Authors	Country	Sample (n)	Study Type	Mean: Age Cobb	Main Findings
(Weiss, 1992B)	Germany	107	Retrospective	10.9 - 48.8yrs 43°	Improvement in 44% of cases of 5° or more and 3% worsened. Mean Cobb angle was 39° after 4-6 week exercise programme.
(Weiss and Bickert, 1996)	Germany		Retrospective	Young adults	Improvement of chest expansion and cardiopulmonary function, parameters of right heart stress.
(Freidel et al, 2009)	Germany	141	Prospective	11-16yr 17-21yr >21yrs	Improvements in HRQoL, anxiety and pain. Average lateral deviation, angle of trunk rotation and VC improved significantly.

2.11 Brace Treatment

Bracing for scoliosis has been used for more than fifty years, however its effectiveness is still debatable and controversial (Lou et al, 2008). Some researchers believe that braces do not alter the natural history of scoliosis and curvatures progress, whilst others believe braces can stop progression of curvatures (Goldberg et al, 2001; Karol, 2001; Kim et al, 2009). In a systematic review of clinical trials, it was concluded that the effectiveness of bracing was not yet established (Lenssinck et al, 2005). Different results are mainly due to non-consistant inclusion criteria and different definitions of effectiveness (Richards et al, 2005). Some studies include male and female subjects, some include only compliant subjects. Some studies used progression of less than five degrees as success outcomes and over five degrees of progression as failure, whereas in some studies curves progressing to surgery was defined as failure. Reported failure rates of bracing, when defined as percentage of cases progressing to surgery, may be due to the quality of the brace itself and also patient care during treatment (Negrini et al, 2009B). Large variability of results of bracing can also be due to differences in compliance to brace wearing (Negrini et al, 2009). Much research is still required to establish the effectiveness of brace treatment as there are still many unknowns regarding brace treatment (Lou et al, 2008). Examples of these unknowns are:

- How many hours a day must the brace be worn to achieve optimum results?
- What is the best weaning protocol?
- How much "in brace" correction is needed to obtain good results?

Standardisation of criteria for AIS brace studies has recently been determined by the Scoliosis Research Society (SRS) Committee so that valid and reliable comparisons can be made as previous studies lacked consistency in inclusion criteria and definitions of brace effectiveness (Richards et al, 2005). Recommended inclusion criteria for future studies consist of: subjects are above 10 years of age when brace is prescribed, Cobb angles 25-40 degrees, female or male (not both), no prior treatment. Assessment of brace effectiveness should include percentage of subjects who have ≤ five degree curve progression and percentage of subjects who have ≥ six degree progression at maturity. These criteria set out by the SRS committee combined with the SOSORT guidelines (2006) for management mentioned previously, have resulted in conservative treatment of scoliosis having better results in preventing progression of curvatures, than what had previously been reported in the literature (Negrini et al, 2009).

2.11.1 Function of the Brace

The primary function of the brace is to stop progression of the curvatures and maintain the curve at an acceptable level through the high risk growth phase of adolescence (Weiss, 2003; Lou et al, 2008). In a review of the literature by Hawes (2002), bracing has not resulted in significant improvements in the magnitude of curvatures (Hawes, 2002). Compliance and initial correction effect in the brace are the two most important variables associated with good brace outcomes (Landauer et al, 2003; Weiss, 2003). Two studies showed that a bracing programme for AIS significantly reduced the frequency of surgery by 50 percent (Rigo et al, 2003; Weiss et al, 2003B). In a systematic review of the literature AIS braced patients, who resulted in having surgery were extremely varied between 1- 43 percent, indicating varied rates of curve progression (Dolan and Weinstein, 2007).

Scoliosis is a three dimensional condition and when using a brace to correct a spinal curvature all three dimensions have to be addressed in order to allow correction in the frontal, horizontal and sagittal plane (Weiss et al, 2006C). Frontal and horizontal corrections are the aim of most bracing systems, however the sagittal plane corrections and preservation of lumbar lordosis were focused on, only in 2004 (Weiss and Rigo, 2008B). Correcting the scoliotic curve in the frontal plane was the most important principle followed by derotating the major curve (Lou et al, 2008). Two concepts of brace designs have been discussed in the literature, one is that the brace provides mechanical support for the body (passive component) and the other is that the patient pulls her body away from the pressure sites (active component) imposed by the brace (Lou et al, 2008). The two components should work together and the pressure from the pad areas should push on the rib cage and be transferred to the spine. However the mechanism of action by which braces prevent progression is not well understood (Rigo et al, 2006).

Generally bracing should unload the growth plates of the apical vertebra on the concave side of the curvature, however there is limited evidence to show this. Stokes has shown that an imposed vertebral deformity can be corrected by reversing the load used to create it (Stokes, 2000). There are many contradictory, conflicting brace designs and concepts to support the spine and no single biomechanical concept is accepted universally by the SOSORT members to correct scoliosis (Rigo et al, 2006). Each type of brace has its own biomechanical concept and there are many treatment methodologies. Methods of correction are quite diverse. The most commonly accepted principle is the ‘three point concept’.

The three point concept involves correcting the curve in a frontal plane. An example is, in a right thoracic curve, the three point forces will be applied laterally to left lumbar, right thoracic convexity (over the apex of curve) and left upper thoracic (Lou et al, 2008). At the 2005 annual SOSORT meeting, the most commonly used brace was found to be the Cheneau brace. No reasons were given for this finding.

In-brace correction and compliance are the main predictors of successful outcome of treatment (Weiss and Rigo, 2008B). In brace correction is dependant on curve pattern, age, sex, Cobb angle and stiffness of the curve. Higher “in brace” corrections are said to have better results (Landauer et al, 2003).

2.11. 2 Guidelines, Indications for Bracing

Indications for bracing are included in the guidelines for the conservative management of scoliosis, established by the SOSORT committee (Weiss et al, 2006) described in 2.7. Results of corrective bracing for AIS are highly variable and because failure rates (cases progressing to surgery) are so variable, criteria for success of brace treatment were identified by SOSORT in 2008 (Negrini et al, 2009B). The aim of the criteria was to increase efficiency and compliance to treatment. There are 14 recommendations:

1. “The physician or orthopaedic surgeon responsible for treatment must have experience (at least two years), competence and previous training in scoliosis. Training and experience must be continuous.
2. The orthotist constructing and fitting the brace must be experienced (at least two years) and trained in constructing and fitting braces. Experience includes constructing two braces per week for at least two years.
3. Physician, orthopaedic surgeon, orthotist and physiotherapist must work together in a multiprofessional team. A team approach is the best solution for compliance achievement and maintenance according to the SOSORT Consensus 2008.
4. The multiprofessional team must all give thorough advice and counselling to patients and their family. Commitment, time and counselling are required to increase compliance.

5. Compliance is not only to treatment, but also to the treating team. Patients and their family must be given time to communicate with each of the multiprofessional team.

6. The brace must be checked by each member of the team. Corrections done by the orthotist and also on the advice of the physician and physiotherapist specifically trained in scoliosis treatment.

7. The physician and orthopaedic surgeon must prescribe the exact number of hours of brace wearing and use various methods to improve compliance, such as photos, brochures.

8. The orthotist must communicate and discuss with the physician the brace prescription. Each brace check by the physician and orthotist must:

  a) check the fitting of the brace
  b) check the scoliosis correction in all three planes
  c) check the aesthetic correction
  d) maximise the brace tolerability, reduce visibility
  e) apply all changes
  f) check the patient is applying brace correctly
  g) assess the patient's mood and provide counselling

9. Brace check has to be clinical and / or radiographic.

10. The multiprofessional team must check the brace and patient compliance regularly.

11. The physician, orthopaedic surgeon must follow up the braced patient regularly every 3-6 months.

12. The brace must be changed for a new one as soon as the child grows and he brace loses efficiency. This needs to be suggested by the orthotist.

13. The orthotist has to regularly check the brace.

14. Scoliosis specific trained physiotherapist has to regularly check the brace and reinforce compliance as they have regular contact with the patient (Negrini et al, 2009B)." There was no criteria included for physiotherapy experience.

2.11.3 Braces Used in South Africa for IS

The three braces used in South Africa will be described: The RSC brace (used in this study), the Boston brace and the Milwaukee brace.

2.11.3.1 Rigo System Cheneau (RSC) Brace

Treatment of scoliosis with the Cheneau brace is currently the most practised conservative method in Germany, Austria, Spain and Poland (Weiss, 2003; Rigo et al, 2006). The RSC brace has been used by one orthotist in South Africa since 2004. The Cheneau brace is defined as a thermoplastic brace modelled on a hypercorrective positive plaster mould of the patient (Rigo, 2005). Corrective pads are not added into a tubular plastic mould, as in the Boston technique mentioned later, but designed directly as part of the positive mould. The brace shape, depth and orientation of the pads, pressure areas, are built to act specifically on the convex areas of the deformed trunk. Correction is through distortion forces. Large expansion spaces are built into the brace to allow active correction by breathing movements directed to the spaces. Breathing mechanics produce the necessary internal active forces to push out the sunken areas of the trunk as well as the sunken spine. Most bracing systems fail to address all the different types of curve patterns (Weiss, 2003). The original Cheneau is based on two curve patterns. The original Cheneau classification of braces had some failures and resulted in inadequate in-brace corrections, as not all curve patterns were addressed (Rigo et al, 2010). After working with the Cheneau brace for 15 years Dr Manuel Rigo, in Barcelona, then developed the first classification to correlate curve pattern and brace design (Rigo, 2005). The Rigo classification addresses 15 curve patterns and was developed to define specific principles of correction required for efficient brace design. The Rigo classification has lead to better results in treatment (Weiss, 2003). The classification includes radiological and clinical criteria. The radiological criteria are used to differentiate five basic types of curvatures:

(I) Imbalanced thoracic (or three curve pattern)
(II) true double (or four curve pattern)
(III) non three, non four without lumbar curve pattern
(IV) single lumbar
(V) single thoracolumbar

The Rigo classification which correlates with brace treatment has acceptable intra and inter- observer reliability (Rigo et al, 2010). Rigo et al (2010), demonstrated that the radiological criteria of the Rigo classification, have good inter-observer and intra-observer reliability. Kappa values were over the acceptance value of 0.70. The intra-observer Kappa value was 0.87 and inter-observer kappa value was 0.71. For many decades an effort has been made to classify curve patterns, however with poor inter-observer and intra-observer reliability (Rigo et al, 2010). The curve pattern is classified by specialist scoliosis brace designers according to the Rigo classification and then an appropriate model (out of a library of 45 different moulds) is chosen, considering curve pattern, patient's age and curve severity (Weiss, 2003). Based on static and dynamic measurements a foam model is produced on which the brace is constructed.

The RSC brace provides detortional forces by combining the following biomechanical principles: Translation and three- point pressure system/s in the frontal plane, pair/s of forces in the transverse plane, physiological profile and sagittal alignment (Rigo et al, 2010). The pressure areas are designed in a specific shape, level and direction for the correction in the frontal plane and at the same time in the transverse plane. The pressure areas form pairs of forces for derotation of the spine and trunk. Therefor detorsion is produced by combining forces in the three planes of the body: 1. derotation 2. deflection and 3. sagittal normalization (Rigo and Weiss, 2008).

1. Derotation is 'regional' meaning the thoracic area is derotated against the lumbar region and against the upper trunk and derotation is 'local' meaning derotation of the individual vertebrae. Local derotation is achieved at the apical level of the curve and is produced by a pair of forces acting at the apical level by pressure areas of the brace.

2. Deflection is correction in the frontal plane by translation of different sections of the trunk and the three- point pressure system. The design of the brace depends on the curve pattern. Translation is produced by pressure areas on the brace pushing on the convexities. The pressure areas simultaneously push against each other at different trunk levels. In a right thoracic scoliosis, the pelvis and lumbar convexity are pushed to the right, thoracic convexity is pushed to the left and upper thoracic convexity to the right. A right trochanter counter-pressure is needed to maintain balance in the frontal plane. See Appendix XIII, on page 238.

3. Sagittal normalization. The brace has a normal physiological profile in the sagittal plane and every trunk section must be aligned to allow such a profile. The mechanism to correct thoracic lordosis is based on breathing mechanics, which involve breathing and movement into the sunken areas of the trunk and spine (Rigo, 2005). In the lumbar region the sagittal alignment is achieved by a lumbar pad which pushes from dorsolateral to ventro-medial. The ventral component derotates and translates the lumbar apex to ventro-medial.

Studies on the Cheneau brace are presented in Table 2.6 on the next two pages.

Table 2.6 Studies on the Cheneau Brace.

Authors	Country	Sample (n)	Study Type	Mean : Age, Cobb	Main Findings
(Hopf and Heine, 1985)	Germany	52	Retrospective		Average primary correction was 41%.
(Liljenqvist, 1998)	Germany	89	Retrospective	30°	Primary correction of 37%. Five years after weaning, Cobb angle was 31°. No significant increase.
(Rigo, 1999)	Spain	49	Retrospective	12.2 yrs 36.4° Major <	Three dimensional correction of back shape, including restoration of thoracic kyphosis. Cosmetic improvement in deformity.
(Rigo et al, 2002)	Spain	105	Retrospective	12.5yrs 36.8°	In brace correction was 25.9° (31%). Prevents progression of Cobb angle and torsion angles, including large Cobb angles with low primary in brace corrections.
(Kotwicki et al, 2002)	Poland	18 : 11- Juvenile 7- AIS	Retrospective	28°	Thoracolumbar curves in a Cheneau brace achieved most in-brace correction after 3-8 months of treatment. Correction of Cobb angle was 67%, mean apical rotation correction was 52% (exceeding that of surgical implant systems). Mean rib hump correction was 42%. Normal sagittal contour in 15 subjects.
(Landauer et al, 2003)	Austria	62	Retrospective	10-14 yrs 20-40°	After one year of weaning out the brace, compliant subjects with high initial correction improved 7°. Compliant subjects with low initial correction maintained their curves. Poor compliance resulted in curve progression.
(Weiss et al, 2003)	Germany	343	Retrospective	15 yrs 33.4°	Reduction in the incidence of surgery with the Cheneau brace and SIR.
(Wood, 2003)	United Kingdom	23	Retrospective	>30°	After four years of brace wearing a significant decrease in lateral deviation, vertebral rotation and topography. Significant decrease in major (35%) and minor (32%) Cobb angles and significant increase in trunk length.

(Kinel et al, 2007)	Poland	45 22- (braced) 23- (To have surgery)	Comparison of 2 groups, matched for age and cobb angle.	14.1 yrs 59.7° 14.9 yrs 55°	After a year of brace treatment, rotational deformity of subject's back was smaller in the braced group compared to the group admitted for surgery.
(Kinel et al, 2007A)	Poland	50 24- (braced) 26- (no brace)	Comparison of two groups. Female, 10-16yrs, Cobb=25-40°	14.1 yrs 35°±4.8 13.1 yrs 33°±4.9	Brace was worn minimum 16 hours for more than 6 months. Braced girls revealed less clinical deformity than non-treated girls. Treatment should consider clinical deformity not only radiological.
(Maruyama et al, 2007)	Japan	39	Retrospective	12.8 yrs 37°	Progression of curves was less and better than natural history reported by Bunnell (1986).
(Pham et al, 2007)	France	63	Retrospective		Stabilisation of curvatures.
(Cinnella et al, 2009)	Italy	152	Retrospective		Cobb angle improvement of correction of 23% at the end of treatment, after 5 years the improvement was 15% compared to the beginning of treatment.
(Cheneau et al, 2009)	France	7	Retrospective	5.6 yrs	Full time bracing of congenital scoliosis, with wedge vertebra and hemivertebra after a 2 year follow-up, resulted in significant improvement in Cobb angle and wedge angle.
(Levitskiy et al, 2009)	Ukraine	260		10-16yrs	All children had problems adapting to the brace. Monitoring emotional response to treatment with a psychologist's assistance will improve quality of treatment.
(Durmala et al, 2010)	Poland	25	Prospective	10-14 yrs 26.1°±8	Therapy was 36-89 months, with Dobomed, and last X-ray was 6 months after brace weaning completed. Mean brace wearing per day was 11.9±5.5 hours. Stabilisation of Cobb in 56% of subjects, 3 considered for surgery.
(Zaborowska-Sapeta et al, 2011)	Poland	79	Prospective	20-45°	After one year of weaning out the brace, progression was prevented in 48.1% of subjects. Bracing reduced incidence of surgery in comparison with natural history.

Studies using the RSC brace are presented in Table 2.7 below.

Table 2.7 Studies on the Rigo System Cheneau Brace.

Authors	Country	Sample (n)	Study Type	Mean : Age, Cobb	Main Findings
(Rigo, 2003)	Spain	1	Case report	12yrs10 m 53°	Initial Cobb was 53° (TL) and 34° (T). Reduced after 3 years of bracing and exercise, 2 years weaning to 36° (TL) and 31° (T). Surface topography and sagittal profile improved significantly. Surgery had been recommended initially.
(Rigo et al, 2003)	Spain	106	Retrospective	15yrs	Conservative management reduces number of children requiring surgery.
(Rigo, 2007)	Spain	32	Retrospective	12±1.2 34± 7°	Primary in brace correction was 41.5% ±16 and was improved on by technical intervention.
(Rigo et al, 2009)	Spain	10	Retrospective	5-13 36°	In brace correction > 45%. After a year, correction of vertebral wedging in the apex was ≥ 50%. Correction of trunk asymmetry.
(Rigo and Gallo, 2009)	Spain	11 10 ©	Case control study. Comparison of two groups	10.5 yrs 29.5 Long thoracic curves	Study group were treated with "3 curve brace with open pelvis", control group were treated with classical RSC brace. In brace correction was 76.7% in study group, 43.3% in control group. In brace correction axial rotation was 55.9% in study group and 29.9% in control group.
(Gallo et al, 2011)	Spain, Germany	147 (25 fitting SOSORT criteria)	Retrospective	12 yrs 7-65°	Significant primary in-brace corrections after 8 weeks in the brace. Major Cobb was 47% and minor Cobb was 37%. SOSORT group had 61% in- brace correction in major curve, 52% in minor curve.
(Maruyama et al, 2011)	Japan	54	Retrospective	12.5 yrs 36.5°	Early results show an in brace correction of 36%.

In a comprehensive review of the literature, Weiss (2003) and the SOSORT committee have shown that the natural history of scoliosis has been altered by the RSC brace (Weiss, 2003; Weiss et al, 2006). Important for this study, is the study by Landauer et al (2003) shown above, which had very tight inclusion criteria and was limited to 62 female subjects, aged 10-14 years, with only a right thoracic idiopathic curve between 20-40 degrees and therefor the sample of subjects had high homogeneity. However the authors acknowledged that the compliance score used was newly developed and had not yet been validated. The study did not state how many hours the brace was worn to achieve an improvement in the Cobb angle and the study only refers to one curve type, right thoracic curves. This study demonstrates the importance of considering compliance, as compliance resulted in improvement in the Cobb angle. Not even the brace with the highest standard of construction, will be able to halt the progression of a curvature in every case (Weiss and Rigo, 2008B). There are failures, where curves still progress in the brace (Weiss and Rigo, 2008B).

2.11.3.2 The Boston Brace and Milwaukee Brace.

The Boston and Milwaukee Braces are described in Table 2.8 on the next page.

2.11.4 Braces used internationally, not in South Africa for IS.

There are many different types of braces used internationally for AIS, but not in South Africa however, some of these are shown in Table 2.9 on page 56.

Table 2.8 The Boston and Milwaukee Braces.

	Boston Brace	**Milwaukee Brace**
Introduced by:	Hall Miller of the Boston Children's Hospital in the early 1970's (Wynne, 2008).	In 1945, by Blount and Schmidt of the Medical College of Wisconsin and Milwaukee's Children's Hospital (Galante et al, 1970).
Design and Function	A rigid, full time brace. Symmetrical standardised modules (orthoses) are used from a library. The brace is copolymer plastic and extends from below the breast to the beginning of the pelvic area anteriorly and just below the scapula to the middle of the buttocks posteriorly. It is designed to keep the lumbar area of the spine in flexion, by pushing the abdomen in and flattening the lumbar lordosis, and reducing thoracic kyphosis. By reducing the lordosis, there is a reduction in lateral deviation of the curve (Wynne, 2008). Thoracic flatback is a negative aspect of this brace (Weiss and Rigo, 2008B). Loss of lumbar lordosis correlates with reports of low back pain in adulthood (Glassman et al, 2005). Three main pads are placed to provide pressure on the curve and areas of 'relief ' are provided opposite the areas of pressure. The skill and training of the orthotist applying the brace dictates the patient outcome (Wynne, 2008).	Originally the brace was used for kyphosis deformities and scoliosis (Moe and Kettleson, 1970) and in South Africa it is still used for these conditions. Internationally this brace is used for high thoracic curves and kyphosis. The foundation of the Milwaukee brace is a plastic pelvic girdle, in close contact with the lumbar spine and iliac crests (Galante et al, 1970). Lumbar lordosis is flattened to achieve correction of the scoliosis. The flattened lordosis in this brace is related to thoracic and lumbar flat back syndrome (Rigo and Weiss, 2008). Erected from the pelvic base are three metal uprights, that extend the length of the torso to a neck ring above the shoulders. The pelvic base in conjunction with the neck ring provide a longitudinal traction force on the spine. The neck ring keeps the head centred over the pelvis. Straps attached to the metal uprights hold pressure pads placed over the apex of the scoliosis curvatures in the transverse plane, providing corrective forces .
Studies done	A prospective study of 111 subjects wearing a Boston brace and 129 subjects without a brace, receiving 'observation' only in the control group (Nachemson and Peterson, 1995), showed a 74% success rate in the brace group, where there was no increase in the curvature and in the observation group a success rate of 34%. An increase of six degrees of Cobb angle was considered a failure. It was concluded that bracing alters the natural history of AIS in the short term. The Boston brace when used 18 or more hours a day is effective in preventing progression of curves 35-45° and can halt long term progression at a mean of 9.8 years after bracing has been	A large credible retrospective review of 1020 subjects using this brace, for AIS (1954 to 1979), found that the brace altered the natural history of scoliosis in 60% of subjects and prevented progression of 20-39° curvatures (Lonstein and Winter, 1994). This was the only study to compare the results of bracing to the natural history of scoliosis. There were strict inclusion criteria. The outcome of the brace was considered a failure if the curve increased five degrees or more. Of the 1020 subjects, 229 (22%) required operative intervention. This rate was higher in curvatures greater than 30° and Risser 0 at the start of brace wearing. Rates of failure for double curve patterns were higher than that for single thoracic curve patterns. In curvatures 20-39° the

	discontinued (Wiley et al, 2000). This long follow-up, shows that the brace alters the natural history of scoliosis. Supporting this study is a long term, 19.2 year follow-up study on 109 subjects by (Lange et al, 2009). In 86 subjects the curve was the size at the start of bracing and had progressed 5.9° from weaning. Six subjects had major progression. In the 109 subjects, their scoliosis did not affect pregnancy or delivery and HRQoL results were in normal range. The Boston brace does not completely correct the three-dimensional deformity associated with thoracic IS, although it can reduce the Cobb angle in the frontal plane (Labelle et al, 1996). The brace had no effect on the rotation of the apical vertebra or on the rib hump, however it prevents progression of the curvature. A good primary correction in the brace is related to a good final result (Peltonen et al, 1988). The Boston brace was more efficient than the Milwaukee brace, which was responsible for a disproportionately large number of failures irrespective of curve magnitude and skeletal maturity (Montgomery and Willner, 1989). The Milwaukee brace had a five times greater risk of failure than the Boston brace. The authors do not state why they thought they got these results. Compliance in each brace was not measured and as the Milwaukee is more visible than the Boston, compliance could have been an issue. An important result of this study is that a predictor of brace failure is a large initial curve magnitude.	rate of failure was lower than a group of 727 subjects, in a separate study, who were not managed with the brace but were monitored with respect to progression. The average time of brace wearing was three years and ten months. This study was done over a long period, 25 years, and was very comprehensive. Lonstein and Winter (1994) recommended that immature adolescents who have a curve more than 25 degrees and a Risser sign of 0 be managed with a brace immediately, rather than after progression has been noted. This statement supports the current SOSORT criteria for bracing already mentioned. The authors state that the Milwaukee brace can control high thoracic curves, which underarm orthoses cannot. The effect of the brace on the sagittal profile was not mentioned. In contrast to this study is a study done by Noonan et al (1996) on 111 subjects in Iowa City. They found that 48% of subjects had five degrees of progression at the time the Milwaukee brace was discontinued and 42% required operative intervention. They concluded that it is impossible to state that bracing effectively alters the natural history of scoliosis (Noonan et al, 1996). This study was a lot smaller, it contained juveniles (eight years old) and adolescents, not as strict inclusion criteria, and the average brace wearing time was less, namely one year eight months. There was also no natural history group for comparison. Authors acknowledged that a prospective controlled study needed to be done with strict inclusion criteria.

Table 2.9 Different Types of Braces used Internationally.

	Charleston Brace	Lyon Brace	SpineCore Brace
Introduced by:	Dr F Steed and Mr R Hooper in Orlando, Florida, USA in 1979 (Grivas et al, 2008).	Pierre Stagnara in 1947 in France (De Mauroy et al, 2008).	Prof C Rivard and Dr C Coillard, Canada in 1992 (Coillard et al, 2008).
Type of Brace; Hours worn	A rigid, night brace.	A rigid, full time brace.	A flexible, non rigid, full time brace. It uses adjustable bands and a cotton vest that allow flexibility.
Curve size	Single lumbar / thoracolumbar curves 20-35°.	Lumbar and thoracolumbar curves 30-50°.	Curves above 15 degrees, best on non-rigid curves.
Physiotherapy	General exercises run by a physiotherapist.	Symmetrical exercises in the frontal plane.	A specific set of 'spinecore' physiotherapy exercises is recommended. Brace is worn during sport.
Studies done	Progression of double curves in this brace is high. Katz et al (1997) compared the efficiency of the Charleston to the Boston brace and found the Boston braced achieved statistically superior results to the Charleston (Katz et al, 1997). Progression rates in the Boston were 43% and in the Charleston, progression was 83%. The Charleston brace was found to be the least successful type of brace by Rowe et al (1997), in the only meta-analysis study available on the efficacy of non-operative treatment modalities for AIS (Rowe et al, 1997). They found 23 hours of brace wearing, was the most successful bracing regime.	A long term follow up of subjects in these braces showed the rib hump declining to half the size and surgical treatment can be prevented in 98% of the subjects (De Mauroy et al, 2008).	A prospective RCT was done on 47 subjects with Cobb angles 15-30°. A correction was achieved in 50% of the treated subjects. The control group progressed more than 5°. The brace was effective in changing the natural history of scoliosis (Coillard et al, 2011). A prospective study was done on 639 IS subjects, by Coillard et al (2008). Stabilisation or correction (+ 5°) of the curvature was achieved in 74% of cases. Positive results showed that 93% of subjects stabilised or corrected their Cobb angle up to two years after of weaning out the brace (Coillard et al, 2007), thus maintaining long term correction or stabilisation and an alteration in the natural history of scoliosis (Coillard et al, 2003). In Poland, a study by Szwed et al (2009), showed similar results. In a group of 50 subjects with AIS, 48% corrected (+5°), 28% stabilised, 14% progressed (>5°) and 10% required surgery. The brace leads to stabilisation of the curves in the majority of subjects.

2.11.4 Complications of Brace Wearing

2.11.4.1 Discomfort

Some patients refuse to wear the brace because of discomfort and sometimes they do not wear it as long as prescribed because they are uncomfortable (Mehta,1978; Lou et al, 2008). They find it restrictive and it draws unwanted attention to themselves. Physical function and social activities are generally less for braced patients (Vitale et al, 2001). Patients are weaned into the brace initially, because of the discomfort in the beginning. They increase the brace wearing hours slowly to begin with until 23 hours of brace wearing is reached (Schommer, 2002). After a month of wearing the brace full time most of the patients are comfortable.

2.11.4.2 Pressure- Induced Skin Problems

Pressure of the brace, heat and sweating can result in skin irritation, which can result in an outbreak of sores or rashes (Hawes, 2002). The best way to prevent a skin irritation is to wear an undergarment, such as a body stocking, leotard or T-shirt and make sure it fits snugly with no wrinkles (Schommer, 2002). Cotton material allows excess perspiration to evaporate and the skin to breathe. No lotions should be applied to pressure areas as these keep the skin moist. Pressure induced skin problems can also be from a brace that does not fit properly (Schommer, 2002).

2.11.4.3 Pulmonary Dysfunction

Some brace designs, encircle the torso and restrict the movement of the chest wall during breathing, causing pulmonary distress (Hawes, 2002). Changes in respiratory function however have been shown to be reversible as soon as the bracing is stopped (Korovessis et al, 1996). Korovessis et al (1996), showed in a small study on the Boston brace, that the vital capacity, forced vital capacity, functional residual capacity and residual volume were all lower while the brace was on, compared to when the brace was off. There were no long term side effects on pulmonary function once bracing was stopped. A comprehensive review of the literature shows that braces mentioned previously that cause thoracic lordosis, such as the Milwaukee and the Boston brace can cause pulmonary dysfunction (Hawes, 2002; Rigo and Weiss, 2008). The thoracic kyphosis is flattened and becomes lordotic, with a decrease in chest wall space for the lungs and therefor increases in pressure on the lungs. Contrary to this Pehrsson et al (2001), showed that pulmonary function is increased 25 years after brace treatment (Pehrsson et al, 2001). They suggest that improved chest wall alignment, caused by the brace, was sustained over time and this allowed increased chest wall compliance as the patients aged.

2.11.4.4 Psychological Distress

If normal pulmonary functioning is affected by restricting chest wall movements in growing children, there will be physiological changes that have psychological consequences (Hawes, 2002). Bracing can be a disagreeable and even a traumatic experience, which can leave emotional scars (Hawes, 2002). Psychological issues have been blamed for lack of compliance to wearing the brace. Approximately nine percent of girls will discontinue wearing a brace because of psychological distress (Korovessis et al, 1996A). Teenagers are usually sensitive about their appearance and are embarrassed to be seen as “different” when wearing a brace. Self image is decreased during the brace wearing period, however it returns to normal after completion of the brace wearing period (Asher and Burton, 2006). Mental health shows no difference among brace and control groups at a 20 year follow up of brace wearing (Danielsson et al, 2001).

Braces used in the treatment of AIS are reported to cause stress (Eliason and Richman, 1984; Reichel and Schanz, 2003). There is however considerable controversy over whether brace treatment negatively affects health related quality of life (HRQoL) in scoliotic patients (Vasililiadis et al, 2006B). Quality of life is a multidimensional construct composed of functional, physical, emotional, social and spiritual well-being. The SOSORT 2005 consensus paper, reported that only 1,48 percent of scoliosis studies included a measure of HRQoL (Negrini et al, 2006). Several reviews of the literature show that bracing does not affect the HRQoL in scoliotics (Maruyama, 2008) and some reviews show the brace does affect the HRQoL (Reichel and Schanz, 2003; Tones et al, 2006).

As a result of the controversy surrounding the HRQoL in scoliosis patients wearing braces the Brace Questionnaire (BrQ) was designed to test HRQoL in brace treated scoliosis patients (Vasililiadis et al, 2006B). HLQoL deteriorates by the end of conservative management using the BrQ (Vasililiadis and Grivas, 2008). In their study the AIS subjects scored lower at the end of treatment in all domains of the BrQ, but significantly in the domains of general health perception, physical functioning, emotional functioning, self-esteem and aesthetics, bodily pain and social functioning. One possible explanation is the production of stress reported during conservative treatment with an orthotic device (Weiss et al, 2007A). The impact of the brace to the self and body image is the main contributing factor to stress production (Vasililiadis et al, 2006B). Different psychological reactions during the initial period of treatment with a brace and physiotherapy can be panic, negative moods, depression, anger and feelings of responsibility for the illness (Vasililiadis and Grivas, 2008). This study highlights the importance of HRQoL measurement in assessing how AIS patients perceive the impact of their disease. These authors state that HRQoL variables are more important than radiographic results and pulmonary function in the conservative management of AIS. Psychological stress can also result from spinal-deformity pain (Rush et al, 2000). Back pain can cause depression, rather than depression causing back pain (Ahn et al, 2001).

Brace stiffness and rigidity may affect physical functioning and vitality (Vasililiadis et al, 2006). Clinical variables that may affect HRQoL during brace wearing are; severity of the condition, skeletal maturity, duration of brace treatment and degree of correction (Climent and Sanchez, 1999). Clinicians need to be aware of factors that affect social wellbeing and how these factors relate to psychosocial functioning (Vasililiadis et al, 2006B). Psychological stress of AIS patients can be estimated using the Bad Sobernheim Stress Questionnaire (BSSQbrace) (Botens-Helmus et al, 2006). The BSSQbrace questionnaire was designed to measure the coping strategies a patient uses and the impairment a patient feels, whilst wearing a brace. This instrument takes five minutes to complete and can be used as a daily routine in out patient management when information has to be gained fast. In comparison, the BrQ is used more for research purposes and has more information. Kotwicki et al (2007), used the BSSQbrace questionnaire in a large credible study on 111 girls and found that AIS subjects managed with exercises and a brace suffered little stress from the deformity, however the brace increased the level of stress over the stress induced by the deformity (Kotwicki et al, 2007C). Braced subjects showed more stress because of the orthosis, than because of the disease. Brace wear exerts a greater impact on body image and HRQoL than the deformity itself (Tones and Moss, 2007). Family and peer support and encouragement are important during the brace treatment period (Lou et al, 2008). Continuous monitoring of stress levels allows the possibility of modification of the treatment in order to maintain good compliance (Kotwicki et al, 2007C).

2.11.5 Compliance of Brace Wearing

In a review of the literature done by Weiss (2003), compliance and initial in-brace correction effect in the brace are the two most important variables associated with good brace outcomes (Landauer et al, 2003; Weiss, 2003). Compliance in wearing a brace has favourable results, with 90 percent of curves not progressing (Goldberg et al, 2001; Rahman et al, 2005). Lack of compliance, which is always associated with curve progression, can be caused by psychological distress (Hawes, 2002). A patient's ability to benefit from the brace will depend on the patient's physical, emotional and social wellbeing. A patient's' belief in treatment outcome is one of the important factors predicting compliance (Borders, 1986). The amount of time a brace is to be worn is generally based on intuition (Lou et al, 2008). The recommended time to wear the brace is 23 hours per day and this number is not based on any objective data. Although bracing has been used for over 50 years, there are still many unknowns, for example how much wear time is needed for optimal treatment outcome (Negrini and Grivas, 2010). The best weaning out protocol is also not known (Lou et al, 2008; Zaina et al, 2009).

In many studies compliance with brace wear is measured by asking the subjects how many hours they wore the brace each day (Landauer et al, 2003). Some researchers look for wear on the brace to determine whether this matches the patient's report. A study done by Takemitsu et al (2004), on 61 subjects with AIS, showed that subjects complied with 75 percent of the prescribed regime and on average over reported their hours of brace wear to their physicians (Takemitsu et al, 2004). A compliometer, a small device put in the brace, is recommended by Vandal et al (1999), to get a more objective measure on actual compliance (Vandal et al, 1999). These devices can be unreliable however (Lou et al, 2008).

As a result of the variability in which compliance is measured the International Research Society of Spinal Deformities was prompted to develop new tools to measure compliance more objectively (Bagnall et al, 2009; Negrini and Grivas, 2010). Some devices use temperature or humidity sensors for measuring purposes, while others use pressure sensors. These devices however can be unreliable if the patient loosens the brace or bends forward reducing the pressure on the pad. Inserting these devices also adds to the expense of the brace.

Reported failure rates, defined as percentage of cases progressing to surgery, of corrective bracing for IS are highly variable. This may be due to the quality of the brace, compliance to treatment regime and patient care during treatment (Negrini et al, 2009; Negrini et al, 2009B). SOSORT therefor developed the Consensus on management of scoliosis patients treated with braces in 2008 (described in 2.11.2) to improve efficiency of treatment. A later study by Negrini et al (2009), that used the SOSORT criteria and focused on compliance, found that conservative treatment based on bracing and exercises produced results which were much better than reported previously (Negrini et al, 2009).

2.11.6 Brace Weaning

The optimal “weaning out the brace” protocol is not known (Lou et al, 2008). Brace weaning is a critical phase of AIS treatment that has not been standardised and there are no data available regarding the best way to wean (Zaina et al, 2009). Various measures of skeletal maturity are used to initiate weaning from a brace, resulting in different outcomes (Rivett et al, 2009A). Indicators used for skeletal maturity are chronological age, skeletal age of hand and wrist, Risser Sign, timing of menarche, peak height velocity. None have been shown to be accurate enough to predict spinal growth potential in AIS (Escalada et al, 2009). The correction of the curvature gained during brace treatment is quite frequently lost in the brace weaning phase (Zaina et al, 2009B). Premature weaning can negate any beneficial effects of bracing (Rivett et al, 2009A). Controversy as to the effectiveness of bracing for AIS exists, and also because of variations of brace type and lack of standardisation of application (Rowe et al, 1997).

Many orthopaedic surgeons in South Africa wean their AIS patients on the Greulich and Pyle Index for bone age assessment, which uses 'atlas matching' of an X-ray of the left wrist to assess bone age and skeletal maturity (Groell et al, 1999). In a case study by Rivett el al (2009), there was an eight to 11 month gap in fusion of the wrist and fusion of the iliac apophysis, with the wrist fusing first. The iliac apophysis is closer to the spine and a more appropriate system for assessing skeletal maturity (Rivett et al, 2009A). The Risser Sign is a five- point grading system of the iliac apophysis, that has been shown to be valuable in the determination of skeletal maturity and prediction of spinal curve progression (Greiner, 2002). The definition of the Risser Sign was included in 2.4 of this literature review. A number of studies have evaluated and supported the reliability of the Risser Sign (Bull et al, 1999; Greiner, 2002; Risser, 2010). The appearance of the iliac apophysis on anterior posterior X-rays is more accurate than a posterior anterior view (Izumi, 1995). The reason for this is the full length of the iliac apophysis cannot be adequately visualised in a posterior anterior view, as medial and lateral aspects are superimposed over the ilium.

Hoppenfeld et al (2004), found that the mean linear growth rate of girls after Risser 4 was 1.75cm and boys 2.46cm. They found no growth after Risser 5, or after closure of the rib epiphyses or proximal humeral growth plates, and they concluded that other growth centres should be evaluated, in conjunction with serial height measurements in the determination of skeletal maturity (Hoppenfeld et al, 2004). These results are important, because in Europe there is no consensus on weaning and researchers have started weaning at Risser 3 and some at Risser 4+. Rigo (2007B) weans around Risser 4+ provided all patients are compliant and continues bracing for 16 hours per day for six to 12 months. Negrini et al (2008), starts weaning at Risser 3, when wearing of the brace is gradually reduced, by no more than two or three hours every six months, allowing the patient to maintain correction (Negrini et al, 2008C). In this large retrospective study, it is not stated why weaning at Risser 3 was started, but the authors admit there is no standardisation of when weaning should be started They state that loss of correction during brace weaning in AIS treatment is frequent and therefor stress how important it is to do stabilisation exercises during this period to prevent the loss of correction (Zaina et al, 2009B). Exercises can prevent a postural collapse occurring when the spine is progressively released from the passive support of the brace. Wearing of the brace for many years can cause progressive muscular atrophy and loss of strength (Eisinger et al, 1996), and postural collapse during weaning can be more dramatic (Eisinger et al, 1996; Zaina et al, 2009). Negrini et al (2009A), found all clinical data, such as scoliometer readings and Cobb angles, worsening within four hours of removing the brace. Postural collapse occurred after one hour and scoliometer readings changed after two hours. This was a small study and demonstrates postural behaviour during weaning. The study also demonstrates the importance of clinical examination during weaning.

Reliable methods are needed to assess skeletal maturity, and the Risser sign seems to be appropriate combined with serial height measurements (Rivett et al, 2009A). Peak height velocity, the occurrence of a period of maximum growth, occurs with the most (peak) curve progression, one year before menarche (Escalada et al, 2009). This period is when most bracing treatments are prescribed. At six months post-menarche there is height deceleration, however there is still a risk of progression in girls with moderate-severe curves despite bracing. The assessment of height velocity may be useful at the time of assessment of how long bracing has to be indicated and when weaning should be started (Escalada et al, 2009).

2.12 Spinal Fusion Surgery

Spinal fusion surgery has been used as a treatment for scoliosis for nearly 100 years (Hawes, 2006). A systematic review of the literature by Dolan and Weinstein (2007), showed the prevalence of surgery after observation and after brace treatment in AIS was extremely variable ranging from one to 43 percent (Dolan and Weinstein, 2007).

2.12.1 Indications

A comprehensive review of over 1500 articles that were published between 1995 and 2005 found that spinal fusion surgery is currently recommended when curve magnitude exceeds 40-50 degrees (Hawes, 2006). Indications for surgery are a progressing curve in a growing child, thoracic lordosis in a large curve, severe deformity of the trunk and pain not controlled by conservative management (Shindle et al, 2006). The main indication for surgery is psychological, as a result of cosmetic concerns about deformity (Goldberg et al, 2001; Hawes, 2002). The goals of surgery were originally to leave the patient with a very minor deformity, however these goals have now changed because one in three patients lose post-operative correction 1-10 years after surgery (Hawes, 2006). Currently the goals are preventing progression of the curve, reducing the curves, to balance and stabilise the spine. Goals include obtaining a solid fusion, minimizing the number of levels fused and avoiding complications (Shindle et al, 2006).

2.12. 2 Methods Used

The basic principal of surgery used since 1911, is to use the spinal vertebra as components of a beam cemented into place to force an upright posture (Hawes, 2006). Posterior, anterior or thoroscopic incisions are made and vertebrae are fused together using a paste of bone harvested from the patient's iliac crest, ribs or a bone bank. The expectation is that this mixture will heal together and result in a rigid spinal column, which should last a lifetime. In the 1960's rigid rods were introduced, including screws, wires, hooks and steel frames, to reinforce the stability of the spinal fusion and reduce the pseudoarthrosis, and lack of fusion, rate. Failure of the spinal fusion requires re-operation to restore the curvature correction (Hall, 1998).

There are many types of instrumentation used such as the Harrington hook-rod system and the Cotrel and Dubousset instrumentation. Harrington rod instrumentation improves the Cobb angle by 48 percent (Cochran et al, 1983).

The amount of correction achieved by spinal fusion depends on the flexibility of the spine, the more flexible, the more correction obtained (Hawes, 2006). A correction of 40-50 percent is normally achieved by spinal fusion, with some surgeons reporting 60-80 percent improvement. Forcing higher levels of correction comes with risks of neurological damage and other complications. Most clinics report patients maintaining a correction of 40 percent after a 10 year follow up (Hawes, 2006). The surgical correction of curvatures is not however completely maintained during adulthood (Hill et al, 2002). There are studies showing loss of correction of 13-27 percent, two years after surgery (Hawes, 2002).

2.12. 3 Effects of Surgery

Surgery does not eliminate the curvature, but reduces it to a smaller magnitude and freezes it there (Hawes, 2002). There is no evidence that surgery changes signs and symptoms of scoliosis according to several comprehensive reviews of the literature (Hawes, 2006; Hawes and O'Brien, 2006; Weiss and Goodall, 2008C). Reduced pulmonary function in scoliosis patients is due to a loss of skeletal mobility secondary to the spinal curvature (Bowen, 1995). A complication of spinal fusion surgery is a reduction in spinal and skeletal mobility. Therefor a spinal fusion to improve the Cobb angle does not occur with a matching increase in respiratory function. Hawes (2006), found no significant increase in VC, TLC or exercise capacity after surgery (Hawes, 2006). Surgeons have generally not included spirometry as part of the outcome analysis found in an extensive literature review by Hawes (2006). The only available data came from a single study by Pehrsson et al (2001). They showed in a group of 141 subjects, aged 11-19 years, the percentage predicted VC increased from 67(±13) percent before surgery to 73(±11) percent at 1.3 years after surgery. At a 22 year follow up VC was 84 (±13) percent, which was a significant improvement. Surgery was done through posterior fusion only. They also concluded that braced subjects also increased their pulmonary function over time from 77 to 89 percent. This long study, 25 years follow-up, does not conclude that surgery had a better result than bracing on lung function. The authors admit the increase in VC might be related to growth of the lungs or function of the thoracic cage.

Reviews of the literature show that surgery to improve the lateral curvature does not eliminate the rib hump, which often deteriorates after spinal fusion (Hawes, 2006; Weiss and Goodall, 2008C). Comprehensive reviews have shown the rib hump is the primary cosmetic concern in AIS and is the main reason patients seek surgical correction (Hawes, 2002; Shindle et al, 2006). As a result of this cosmetic concern, surgeons now use surgical removal or resection of seven or more ribs involved in the rib hump (Leathermann and Dickson, 1988; Hawes, 2006). This procedure, a costoplasty, is used more frequently to improve appearance and the ribs are harvested for use in the spinal fusion. This procedure however has been shown to reduce the volume of the chest cage and to substantially impair pulmonary function (Lenke et al, 1995; Weiss and Goodall, 2008C).

Several large comprehensive reviews have shown spinal fusion surgery has not been a reliable method to relieve back pain and improve quality of life in scoliosis patients, and in some cases pain can increase after surgery (Asher and Burton, 2006; Hawes, 2006; Weiss and Goodall, 2008C). In the only large controlled outcome study of 1476 scoliosis subjects with and without surgery were compared with 1755 age-matched controls. Pain was increased for all scoliosis subjects, however in the surgically treated group the ability to manage pain was seriously limited (Danielsson and Nachemson, 2001). In a systematic review of the literature by Weiss and Goodall (2008), pain is the primary indication for re-operation. In adult patients with scoliosis, surgery is carried out to relieve pain (Hawes, 2006; Weiss and Goodall, 2008C). A study by Bettany et al (1995), on 130 subjects at the Royal National Orthopaedic Hospital in London, showed that most surgery techniques do not relieve pain and emotional problems, such as self esteem associated with scoliosis (Bettany et al, 1995). In another study by Pratt et al (2002), after surgery, patients' concerns regarding their own scoliosis were perceived to be less, however there was no change in body image after surgery (Pratt et al, 2002).

Some surgeons report that the majority of their patients are happy with their appearance after surgery and others report the opposite (Hawes, 2002). However a 35 year meta-analysis of surgical outcome in AIS was done on 11000 subjects by Haher et al, 1995 (Haher et al, 1995). They found patient satisfaction after surgery was subjective and did not reflect the benefits of surgery, with reference to preserving lung function in thoracic curves nor preventing osteoarthritis in lumbar curves. According to Weiss (2010A), there is no objective evidence supporting the assumption that patients have experienced benefits from undergoing spine surgery for spinal deformities (Weiss, 2010). In this review, using the Pub Med database only, no prospective controlled studies or randomised controlled trials supporting surgical intervention were found as a treatment option, only retrospective studies. There is a 29 percent risk of re-operation within 10-20 years of the first spinal fusion operation and >30 percent risk in real long term cases, found in several reviews (Hawes, 2006; Weiss and Goodall, 2008C).

2.12.4 Complications

One of the major goals of surgery is to avoid complications. The overall rate of complications remains high (Hawes, 2006; Weiss and Goodall, 2008C). The lack of standardization of the reports on complications does not allow final conclusions on the numbers experiencing complications. The estimation of risk for the individual case cannot be concluded. The long term risks of scoliosis surgery have not been reported (Weiss and Goodall, 2008C). In adults, the incidence of complications at one of the premier spine centres in the USA is greater than 50 percent (Islam et al, 2001). The Scoliosis Research Society (SRS) Morbidity and Mortality Reports (2002-2005) state that 0,2 percent of all patients with spinal fusion died mainly from cardiac causes, 0,8 percent had neurological deficits and infections were in 0.9% - 3.4 percent (Weiss and Goodall, 2008C). Overall complication rate was 8.6 percent. Unfortunately the SRS members voluntary submitting data over these years was 35-70 percent., The complexity of spinal surgery is reflected in the diversity of complications that may result months or years later (Hawes, 2006). Complications of surgery found in three extensive reviews of the literature (Hawes, 2002; Hawes, 2006; Weiss and Goodall, 2008C), presented on the next page, include:

Death and neurological damage

The incidence of death is reported to be less than one percent. Effects of neurological damage post surgery include partial or total paraplegia, quadriplegia or peripheral nerve deficit.

Loss of normal spine function

Each spinal surgery case has irreversible loss of normal active range of movement in the spinal column, including in the non-fused segments. There is a loss of normal ability of the spine to move. Surgery exchanges one kind of deformity for another.

Strain on un-fused vertebrae

There is a high risk of injuring vertebra above and below fusion. Degenerative disc changes are more common in these patients, 22 years after treatment (Danielsson and Nachemson, 2001). There was more pain in the surgery patients when compared to controls in this study, but the surgery patients had no dysfunction 23 years after surgery (Danielsson and Nachemson, 2003). However, five percent required additional curve-related surgery.

Pain

Pain is the primary indication for re-operation (Hawes, 2006). Some Patients report relief from pain, others not. Pain at the graft site has been reported as much as 24 percent, with 15 percent reporting severity of pain interfering with daily activities. The rods may poke out from the spine and cause discomfort, when any pressure is placed against the back, as when the patient is sitting in a chair or lying flat on their backs.

Infections and inflammatory processes

Infections from surgery may manifest months or years later, with 5-10 percent developing deep infections 11-45 months after surgery (Tribus and Garvey, 1995; Richards and Emara, 2001; Hawes, 2006). Infection has been detected more than eight years after surgery. Inflammatory responses to metallic instrumentation can occur with or without infections. Additional surgery may be required to remove the instrumentation.

Broken hardware and failed fusion

Curves can continue to progress after spinal fusion, due to broken rods or failure of instrumentation. Pseudoarthrosis or failure of a bone graft can occur years after surgery and can be difficult to diagnose. Crankshaft phenomenon occurs in young children when spinal growth continues to rotate around the fusion (Lee and Nachemson, 1997; Roberto et al, 1997).

Decompensation and increased sagittal deformity

Decompensation or development of new deformities involving changes in sagittal profile and coronal balance can occur as a result of surgery. Reducing a lateral curvature in a thoracic scoliosis can exacerbate the sagittal deformity and flatten the cervical, thoracic and lumbar spine, resulting in a flatback posture (D'Andrea et al, 2000; Yang and Chen, 2003).

Increased torso deformity

The rib hump can get worse after surgery. If the rib hump magnitude improves immediately postoperatively, most of the correction will be lost later and can be worse than before the surgery.

Salvage surgery

Due to complications mentioned above re-operation may be necessary. Even the most stable fusions can fail in response to a sudden force, such as a car accident. Cases of patients having five or more salvage surgeries have been documented (Islam et al, 2001). In one study on 110 adolescent subjects 21 percent required implant removal within a 10 year follow-up (Bago et al, 2003). Complications after salvage surgery can be very high, with failure of fusion in > 50 percent of patients.

2.12.5 Studies

No prospective controlled studies or randomised controlled trials were found only retrospective studies. Most studies describe quality of life after surgery and not complications after surgery (Asher et al, 2003; Anderson et al, 2006; Danielsson, 2007). In light of the unknown long-term side effects of surgery and the lack of evidence that surgery changes signs and symptoms of scoliosis a randomised controlled trial is long overdue (Weiss, 2010A). In view of the high rate of complications associated with surgery, the limited gains derived from surgery should be assessed and clearly explained to patients before the procedure is undertaken. There is little evidence that surgery reliably and significantly improves prognosis for suffering and disability for young adults with scoliosis (Hawes, 2006). No long term studies have shown that health and function of scoliosis patients have improved significantly with scoliosis surgery. A conclusion of Hawes (2006), in a large very comprehensive review of the literature is that research is needed to examine other non-invasive therapies to stabilise or reverse mild scoliosis before it progresses to a spinal deformity with the potential to cause a lifelong struggle with symptoms (Hawes, 2006). Early treatment is required to prevent functional curvatures becoming structural curvatures. Screening programmes were developed with the goal of allowing early intervention in the disease process and thereby preventing the need for surgery.

Of 9000 papers published on scoliosis in the last 40 years only two percent are on ‘prevention and control’ (Hawes, 2006). Hawes (2006), states that the data in her study do not support the long standing policies of surgeons ‘waiting and watching’ childrens curvatures progress to being moderately severe structural deformities (Hawes, 2006). Data suggest preventing asymmetric loading, maintaining curvature flexibility and restoring postural balance should be the focus of therapies (Hawes and O'Brien, 2006). Preventing progression of curvatures and maintaining quality of life should be the aim of alternative methods rather than surgery (Hawes, 2006; Hawes and O'Brien, 2006; Weiss, 2010).

2.13 Conclusion

The cause of Idiopathic scoliosis is not known. It is a developmental process, whereby asymmetric loading is the primary driving force for development and progression of spinal deformity. Spinal curvatures can be diagnosed in the early stages before pathological deformity. Curvatures can be reduced by reversing the state of continuous asymmetric loading and restoring balance. Vertebral deformity in structural scoliosis can be reversed before growth is complete. Progression of curvatures is related to the growth rate, age of the patient, size of Cobb angle and many others factors.

The main aim of conservative treatment has been to stop curvature progression. Other aims are improvement of pulmonary function, treating pain and improving the aesthetic appearance. The effect of exercise to treat IS is not clear. Some studies show that exercise does not affect the curvature and some studies show that specific exercises improve signs and symptoms of scoliosis and prevent progression rates of curvatures. Bracing for scoliosis has been used over the last 50 years and its effectiveness is also not clear. Braces have however been shown to prevent the progression of curvatures and reduce the incidence of surgery. There are a large number of unknowns regarding brace treatment, for example, ideal number of brace wearing hours to achieve optimal results and the most effective brace weaning protocol. Although the main predictors of a successful outcome of brace treatment are the in-brace correction and compliance, other factors involved in successful management are not known. There is very little evidence showing that conservative management improves Cobb angles.

Spinal fusion surgery has been used as a treatment for scoliosis on curves of 40-50 degrees for 100 years. The goals of surgery are the prevention of the progression of curves, so reducing the curves and stabilising the spine. Cosmetic concerns are one of the main reasons for surgery. A correction of 40-50 percent is normally achieved. However the overall rate of complications of surgery is high and a lack of standardisation of reports of complications does not allow conclusions to be drawn. There is also no evidence showing that surgery changes signs and symptoms of scoliosis. There are no prospective controlled studies supporting surgical intervention as a treatment option.

Research is needed on non-invasive therapies to stabilise or reverse scoliosis before it progresses to a deformity with lifelong difficulties with signs and symptoms.

Chapter 3

MEASURING INSTRUMENTS

Measuring instruments used in this study will be discussed in this chapter. Their suitability, reliability and validity will be presented.

3.1 Cobb Angle

The Cobb angle is the universal gold standard for measuring the magnitude of scoliosis (Cobb, 1948; Newton and Wenger, 2001; Hawes, 2002). The Cobb angle is used to diagnose scoliosis and to assess whether a curvature is getting worse, stabilising or improving (Lonstein, 1995). It is an objective measure using a ruler, pencil and protractor on an X-Ray which has been taken in the standing position (Newton and Wenger, 2001). The Cobb angle is the angle drawn between lines drawn on the end plates of the most tilted vertebra into the curve. Two lines are drawn, one on the superior end plate of the upper end vertebra and a line is drawn through the inferior end plate of the lower vertebra. The degree of tilt between these vertebra defines the Cobb angle (Newton and Wenger, 2001). See Figure 3.1 measurement of the Cobb Angle below.

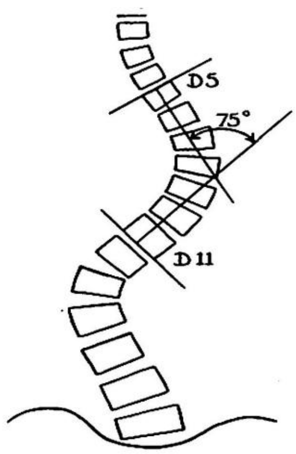

Figure 3.1 Measurement of the Cobb Angle according to Cobb (1948). In 'Outline for the study of scoliosis in Instructional Course Lectures.' The American Academy of Orthopedic Surgeons. Ann Arbor, JW Edwards. 5: 261-275.

Progression or improvement of a curve is considered a difference of more than five degrees between two X-rays (Peterson and Nachemson, 1995). Scoliosis is classified as mild if the Cobb angle is 10-24 degrees, moderate if 25-50 degrees and severe if > 50 degrees (Hawes, 2002). There are limitations of the Cobb angle measurement. The reliability of the measurement exhibits a range of reported values, with intraobserver variation for a single X-ray often less than two degrees (Goldberg et al, 1988; Peterson and Nachemson, 1995; Fernando et al, 2001). Interobserver variation ranges from two to ten degrees in different studies (Capasso et al, 1992; Kittleson and Lim, 1970). Table 3.1 presenting other studies with intraobserver and interobserver variations follows.

Table 3.1 Intraobserver, Interobserver variations of Cobb angle measurements.

Intraobserver	**Interobserver**	**Authors**
4,3°	4,9°	Dutton et al, 1989
3,2°	2°	Pruijs et al, 1994
3,8°	0-10°	Carman et al, 1990
3°	-	Scholten and Veldhuizen, 1987
2,2° - 3°	5°-7°	Capasso et al, 1992
4,9°	7,2°	Morrissy et al, 1990

Measurements chosen should be performed in the best possible way in terms of reliability and validity, especially in large curvatures with poor prognosis (Kittleson and Lim, 1970). The intrinsic error in measurement can be reduced to less than three degrees when a careful examiner uses a thin lead pencil and measures the same end vertebra (Morrissy et al, 1990). The end vertebra needs to be accurately selected and one examiner must measure all patient's X-rays. The most frequent and significant error is the choice of end vertebra (Capasso et al, 1992; Gstoettner et al, 2007). Once the correct vertebra is chosen, intraobserver reliability is close to 95 percent. Care should be taken to select an accurate protractor for measurement (Morrissy et al, 1990). A protractor that has a clearly inscribed base-line is essential, as a protractor with a cut edge as baseline is not accurate. If the end plates of the vertebra are not clearly visible on the X-ray, the margins of the pedicles can be used to draw lines on (Kittleson and Lim, 1970). The most oblique vertebra is the most tilted vertebra (Jeffries et al, 1980).

X-rays should be taken in exactly the same position using the same machinery to avoid errors. Errors of five degrees or less have been reported from a slight position change in the patient relative to the X-ray machine (Goldberg et al, 1988). Appropriate patient positioning while standing must be accurately supervised to prevent errors (Capasso et al, 1992). Standing height in a child can vary in a day due to posture and can result in Cobb angle variation by five degrees on average (Beauchamp et al, 1993). Therefor X-rays should be taken at the same time of day, in the same X-ray department with the same radiologist correcting the posture.

The main limitation of the Cobb angle is that it reduces a three dimensional deformity to a two dimensional image (Capasso et al, 1992; Gstoettner et al, 2007). The scoliotic spine rotates and the Cobb angle on its own does not provide a true measure or three dimensional representation of the deformity. As a result of this limitation an accurate method of measuring vertebral rotation is recommended (Scholten and Veldhuizen, 1987). Vertebral rotation measurement will be covered in the next section. Despite the limitations of the Cobb angle measurement, the Cobb angle remains central to aspects of diagnosis and treatment of scoliosis (Newton and Wenger, 2001). There is no standardisation in comparing Cobb angles in two groups of subjects, with different curve types, in the literature and therefor several methods were used in this study that were used in the studies that follow. In some studies, major and minor curves are compared (Weiss,1992; Rigo et al, 2002; Wood, 2003), some studies compare the worst (major) curves (Negrini et al, 2006B; Negrini et al, 2008B; Zaina et al, 2009B), some compare the specifically different curve types (Kotwicki et al, 2002; Landauer et al, 2003; Rigo and Gallo, 2009) and some compare the average of all the Cobb angles (Otman et al, 2005; Rigo, 2007; Rigo et al, 2009). Some studies compare curves in the thoracic region and in the lumbar region (Gallo et al, 2011).

The Cobb method is used to measure the magnitude of sagittal curvatures. For kyphosis measurements the intraobserver variation is 3,3° and interobserver variation was less than seven degrees (Carman et al, 1990). Kyphosis values in a normal adolescent spine are 20 - 50°(Durmala et al, 2009). Lordosis values in a normal adolescent spine are 25 - 50°(Durmala et al, 2009). A study by Rigo et al (2006B) on 207 girls, with mild scoliosis curves, mean Cobb angle 26 ±13.6 degrees showed there was no significant difference between the kyphotic angle of a non-scoliotic spine (51,5°±10) and a scoliotic spine (48,7°± 9,4) (Rigo et al, 2006B). The lordotic angle however, was significantly lower in scoliosis patients (39,3°±9,4) than non scoliosis patients (42,3°±8,8) except in mild curves of five to 19 degrees. Both angles decrease in progressive curves (Rigo et al, 2006B). In a non scoliotic spine degree of kyphosis and lordosis increases with age, with a higher increase in females (Fon et al, 1980; Lin et al, 1992).

3.2 Vertebral Rotation

In the scoliotic spine the vertebral column laterally curves and the vertebra rotate around the vertical axis of the spinal column. Vertebral rotation increases with increasing Cobb angle and is a reflection of the severity of the deformity (Burwell et al, 1983; Leathermann and Dickson, 1988). Measurements of the vertebral rotation is significant in the prognosis and treatment of scoliosis curves (Perdriolle and Vidal, 1985). The angle of axial rotation measured by a perdriolle torsiometer predicts the incidence of progression of a curve better than the size of the Cobb angle (Perdriolle and Vidal, 1987). One method of measuring the vertebral rotation is with a Perdriolle torsiometer, although there are other methods, the Perdriolle method is the most commonly used method in Europe (Weiss, 1995).

The Perdriolle method was used in this study. It is a simple, convenient and reliable method to measure vertebral rotation on standard standing X-rays (Yazici et al, 2001; Rigo and Villagrasa, 2010). The Perdriolle torsiometer is a template, ruler, graded in five degree intervals (Pinheiro et al, 2009). A picture of this template, Figure 3.2 is presented on the next page. The template is placed on the apical vertebra, convex side of the curve on the AP X-ray (done in standing) view.

The template is placed in the way that the lateral edges of the vertebral body are located between the two lateral lines of the ruler. A third line, which passes through the axis of the pedicle, will indicate the degree of vertebral axial rotation.

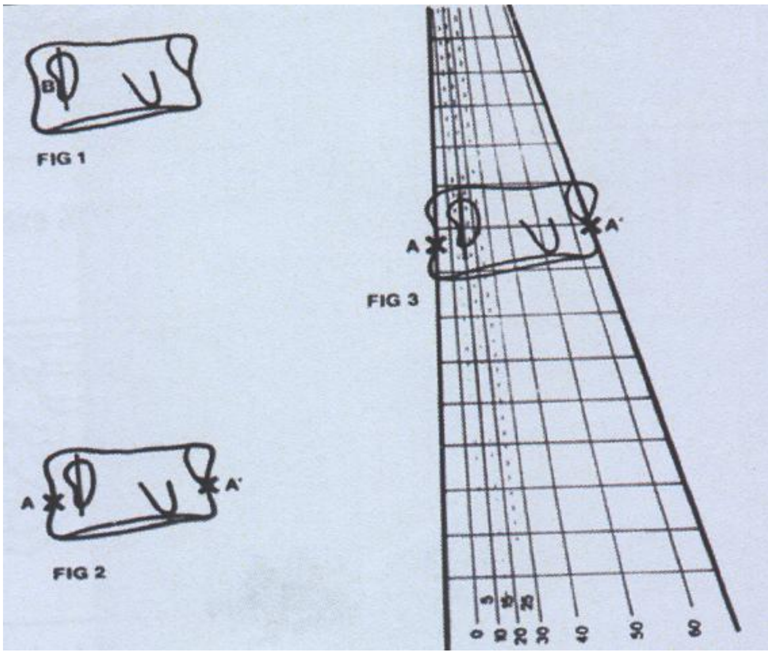

Figure 3.2 A Perdriolle Torsiometer placed on an apical vertebra (Perdriolle and Vidal, 1985) in 'Thoracic idiopathic scoliosis curve evaluation and prognosis.' Spine 10(9): 785-791.

The advantages of the Perdriolle method versus other methods such as the Nash-Moe method and Stokes method are that it's a simple procedure, it is affordable and non-invasive making it applicable in clinical settings (Lam et al, 2008). Another advantage is that vertebral rotation can be measured from a single X-ray limiting patient exposure to radiation (Barsanti et al, 1990). Most studies find intraobserver and interobserver measurement errors of ± five degrees (Barsanti et al, 1990; Omeroglu et al, 1996). Weiss (1995), however reported an intraobserver error of one degree and interobserver error of three degrees (Weiss, 1995). He suggested measuring a second vertebra as a reference, so as to reduce measurement error due to a rotated body position. A complication of marking the pedicles on X-ray is that a two millimeter error corresponds to five degrees of rotation (Richards, 1992). Errors can be made in identifying the apical vertebra (Capasso et al, 1992). The apical vertebra is the most rotated and wedged vertebra, and the most laterally deviated from the vertical axis, passing through the centre of the sacrum.

Several studies have found a poor relationship between pedicle rotation and angle of trunk rotation (ATR)(Weinstein, 1990). Burwell et al (1983), found a poor, however statiscally significant correlation between vertebral rotation and trunk asymmetry (Burwell et al, 1983). Although scoliosis is defined as a lateral curvature of the spine accompanied by trunk rotation, a rib hump can also be present in the absence of a lateral curvature (Weinstein, 1990). Thoracic cage deformation precedes the deformation of the spine (Grivas et al, 2002).

3.3 Angle of Trunk Rotation

The angle of trunk rotation (ATR) is measured using a scoliometer (Bunnell, 1984). The scoliometer is an inclinometer designed to measure trunk asymmetry, or axial trunk rotation also referred to as 'rib hump deformity'. This objective measurement can be used to determine whether or not further orthopaedic evaluation is needed. From an eight year prospective study on 1065 subjects referred for evaluation of scoliosis, Bunnell (1984), concluded that a minimum significant angle of trunk rotation (ATR) of five degrees was a good criterion for identifying curvatures of 20 degrees (Cobb angle) or more. Bunnell concluded that this method of measurement is simple, reliable and inexpensive and therefor it was used in this study. This measurement has a high degree of sensitivity and specificity, scoliosis screening in this manner has resulted in a false- negative rate of 0.1 per cent, when Cobb angles greater than 20° have an ATR less than five degrees. Bunnell (1984) also suggested that this method of measuring could be used on sequential clinical visits and data rather than additional X-rays and could serve to document curve progression. A change of three degees or more of a scoliometer measurement indicates possible curve progression. Curve progression (Cobb angle) can however occur without a change in ATR.

The scoliometer measurement is done on the patient in forward bending (Adams test) in both standing and sitting positions (Patias et al, 2010). Forward bending accentuates the asymmetry and is the standard method for detecting mild curvatures in mass screening examinations (Bunnell, 1984) (See Figure 3.3 on the next page). The patient is asked to bend forward looking down, feet are approximately 15cm apart, knees straight, shoulders loose and hands in front of knees or shins, elbows straight and palms opposed (Patias et al, 2010). The spine is viewed from behind the patient and the back must be viewed with the screener's eye at the horizontal level of the maximum deformity of the back (Bunnell, 1984). The patient bends forward about 45 degrees and the screener will view the outline of the thoracic spine. As the patient bends further down the outline of the rest of the spine will be viewed. The scoliometer is placed on the patient, with the zero mark over the tip of the spinous process at the level of the apex of the deformity. No pressure is placed on the scoliometer and the scoliometer can be moved up and down the spine to find the maximum ATR (See Figure 3.4 on the next page). There are three areas of interest: thoracic (T3-T4), main thoracic (T5-T12) and thoracolumbar (T12-L1 or L2-L3) (Patias et al, 2010). In the sitting forward bending position, the patient sitting on a chair, 45cm in height, is asked to bend forward, head between the knees, shoulders loose, elbows straight and hands positioned between the knees, palms opposed. A scoliometer measurement of zero degrees is defined as symmetry and any other value is asymmetry of the trunk. If a double curve is present, two distinct deformities at two different levels will appear and two scoliometer measurements must be made. The measurement of the ATR is affected by a non level pelvis, especially within the lumbar spine (Kotwicki et al, 2009). Different readings are obtained when putting in a heel lift for leg length discrepancy. The sitting position is the preferred screening position for examining ATR, as it demonstrates the best correlation with the spinal deformity, exposing the real trunk deformity (Grivas et al, 2006B). Therefor the sitting position was used in this study. Real trunk deformity is revealed due to the levelling of the pelvis and elimination of any effect of leg length inequality on back shape. The Adams Forward Bend Test in standing (Bunnell, 1984) is shown in Figure 3.3 on the next page.

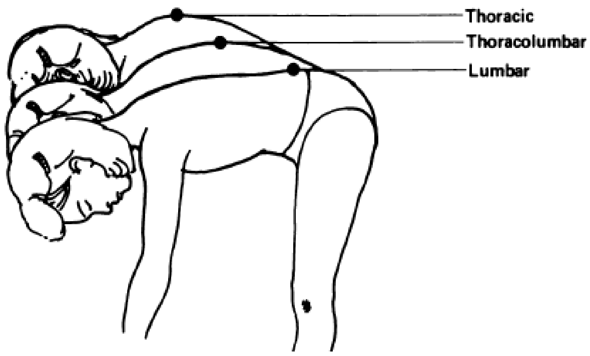

Figure 3.3 Adams Forward Bend Test (Bunnell, 1984) In 'An objective criterion for scoliosis screening.' Journal of Bone and Joint Surgery 66-A (9): 1381-1387.

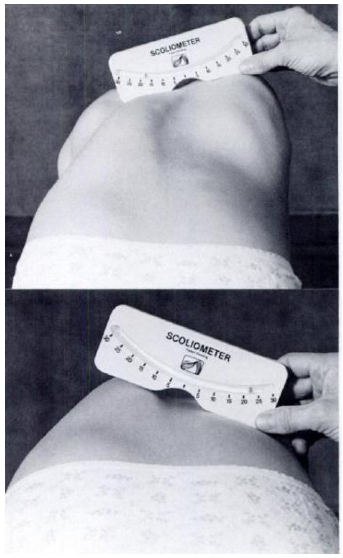

Figure 3.4 Measurement of ATR of Thoracic spine and Lumbar spine (Bunnell, 1984).

The ATR is a reliable measurement with good reproducibility (Amendt et al, 1990; Zaina et al, 2008). Intrarobserver and interobserverver measurements revealed high concordance of measurements (Weinstein, 1990; Kotwicki et al, 2006). Standard deviations of less than one degree have been reported on intraobserver reliability. A change of two degrees can be significant for intra-observer measurement (Grosso et al, 2002).

The Adams test actually demonstrates the rotational component of the scoliosis, since the rib prominence is the result of the rib cage rotating along the spine

(Grossman et al, 1995). The sensitivity and specificity of the test varies depending on the skills of the examiner, location of the curve and magnitude of the curve. Sensitivity and specificity is higher in thoracic curves and larger curves. The ATR measured with a scoliometer does not correspond to the Cobb angle measured on the X-ray and the ATR does not predict the Cobb angle (Amendt et al, 1990; Bunnell, 2005; Grivas et al, 2007). The Cobb angle alone cannot explain the whole of the surface deformity as the X-ray is two dimensional (Goldberg et al, 2001B). In younger children (7-13 years) the correlation between the surface and the spinal deformity is weak and it becomes stronger as the children (from 14 years) are growing up (Grivas et al, 2007). Goldberg et al (2001B) states that it is not possible to correlate surface asymmetry with X-rays as they both focus on different aspects of the deformity. Evaluation of the results of treatment for idiopathic scoliosis should consider parameters describing both clinical and radiological deformity (Kotwicki et al, 2007B). Although the relationship between Cobb angle and surface parameters is weak, it is noted that the more severe the Cobb angle the more the surface deformity is pronounced (Patias et al, 2010).

Angle of trunk rotation is almost always higher than expected for any degree of Cobb angle, rarely is the ATR less than expected (Bunnell, 1984). The ATR measurement is therefor a good screening tool, the rib hump reflects rib cage deformation. The minimum measurement of five degrees of ATR suggested by Bunnell (1984), justifies referral for an orthopaedic evaluation. Patients with a lesser degree of deformity should be rescreened in six to twelve months. There is a poor relationship between ATR and pedicle rotation and the scoliometer predicts pedicle rotation less accurately than the Cobb angle (Weinstein, 1990). Burwell et al (1983), however found a strong relationship between Cobb angle and vertebral rotation. Scoliometer measurements alone are not sufficient to use as a basis for treatment decisions such as bracing and surgical intervention (Weinstein, 1990).

3.4 Risser Sign

The diagnosis of skeletal maturity is based essentially on radiological investigations. There are various measures of skeletal maturity which are used for prognosis and treatment approaches for AIS patients (Risser, 1958). The Risser sign, which is observed on an X-ray of the iliac apophysis, is an accurate and reliable method of determining skeletal growth according to Risser (1958). The last ossification centres to appear and develop are the iliac crest apophyses (Risser, 2010). The ossification of the iliac apophysis across the iliac crest occurs simultaneously with the vertebral growth plates. Complete ossification of the iliac apophysis is a determinant of closure of the vertebral epiphysis, not easily visible on X-ray, and that skeletal maturity has been reached (Risser, 2010). The iliac apophysis appears anterolaterally on the crest of the ilium, called 'capping' and tracks posteromedially down to contact the ilium medially at its junction near the sacrum. The apophysis may develop in fragments, leaving spaces and can take between seven months to three years to complete (Risser, 2010). Risser sign is an exellent physiological sign that can be used to determine end of vertebral growth and when weaning from a brace for AIS can be started. Risser sign can be used to predict progression risk in a curve, as described in Chapter 2.4. Deformities are more likely to increase rapidly prior to capping of the iliac apophysis, with a decrease in rate of progression after completion (Risser, 1958). The incidence of curve progression decreases as the initial Risser sign increases (Lonstein and Carlson, 1984).

Risser Sign is a six point grading system used to evaluate the ossification of the iliac crest (Risser, 1958; Manring, 2010). It ranges from Risser 0 (completely immature) to Risser 5 (end of growth). A picture of the grading system appears below in Figure 3.5.

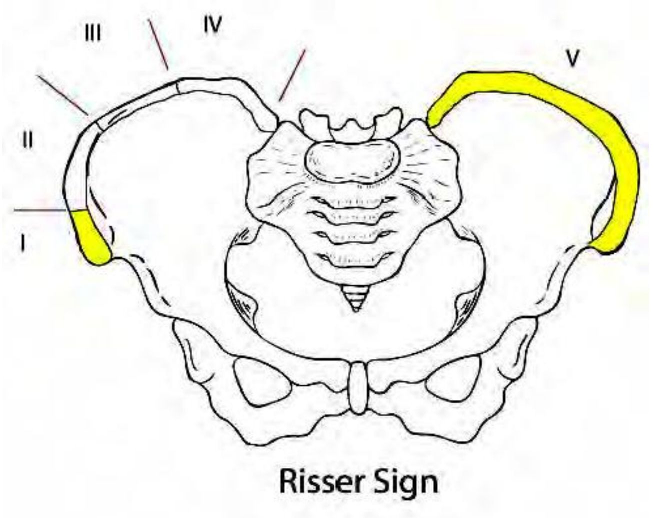

Figure 3.5 Risser Sign (Risser, 1958).

The iliac wing is divided into quarters, defining the grades (1, 2, 3, and 4) of ossification of the apophysis.

Risser 0 : No ossification.

Risser 1: 25% Iliac apophysis ossification anterior superior iliac spine. Seen in prepuberty or early puberty.

Risser 2: 50% Iliac apophysis ossification, which extends halfway across iliac wing.

Risser 3: 75% Iliac apophysis ossification. Indicates slowing of growth.

Risser 4: 100% ossification, with no fusion to iliac crest. Indicates slowing of growth.

Risser 5: Iliac apophysis fuses to iliac crest. Indicates cessation of growth.

Iliac crest apophysis maturation is significantly correlated with skeletal age assessment (Biondi et al, 1985). The Risser sign is a reliable staging system when used by trained physicians with experience in assessing pelvic radiographs for skeletal maturity (Reem et al, 2009). It provides substantial inter-observer and excellent intraobserver reliability when radiographic views of the full pelvis are used for grading. Reem et al (2009), conclude that the reliability of the Risser sign is acceptable and can be improved when other markers of skeletal maturity on the pelvis x-ray are used to assist in the grading. Most studies, not all however, are favourable for the reliability of the Risser sign (Izumi, 1995; Bull et al, 1999; Groell et al, 1999). As controversy has existed over the accuracy of the Risser Sign (Manring, 2010), Hoppenfield et al (2004), have suggested using the rib epiphysis and proximal humerus in combination with Risser sign when evaluating skeletal maturity (Hoppenfeld et al, 2004). The Risser sign can be used with direct serial height measurements, measuring height velocity, to provide a reasonable assessment of maturity (Hoppenfeld et al, 2004; Sanders, 2007). The Risser sign is one of the most commonly used skeletal maturity indicators as it is convenient to use, it can be evaluated immediately on the scoliosis AP X-ray without having to do a second x-ray (Manring, 2010).

The Risser sign is not reliable on a posteroanterior (PA) x-ray as this view produces a distorted image of the iliac apophysis and the medial and lateral aspects of the apophysis are superimposed on the ilium (Izumi, 1995). An anteroposterior (AP) view X-ray is more reliable for Risser sign. The drawback of this is increased gonadal irradiation (Sanders, 2007). Iliac apophysis fusion can be more accurately estimated when a lateral spinal x-ray is included and analyzed with Lateral Risser Modifiers (Kotwicki, 2008). The Posterior Superior Iliac Spine (PSIS) is seen neither on AP or PA X-rays of the pelvis (Kotwicki, 2008). A lateral spinal X-ray allows visualization of the full excursion of the iliac apophysis up to the PSIS. The Risser sign is a less reliable indicator in boys, with iliac ossification starting relatively early with respect to further growth potential. A common misperception that also occurs is that growth remains while physes are open, when actually a physis can be nongrowing, particularly towards the end of growth, despite an open appearance on X-ray (Sanders, 2007).

A study done to establish residual growth activity (Noordeen et al, 1999), found Risser 5 was the only indicator of cessation of vertebral growth in idiopathic scoliosis, on spinal surgery patients, from which vertebral endplates were harvested. Risser 4 showed significant growth activity in the vertebral endplates. Hoppenfeld et al (2004) showed that mean growth after Risser 4 in girls was 1.75cm and in boys 2.46cm (Hoppenfeld et al, 2004). No growth occurred after Risser 5. They recommended using serial height measurements as well as Risser sign, when making decisions on the management of the scoliosis patient. After termination of vertebral growth, Risser 5, scoliosis is commonly a progressive condition, where disc degeneration is the most important factor(Risser et al, 1977).

3.5 Height Measurement

Clinical height measurements can be used to determine height velocities in AIS patients and to document the peak growth period, and reliably predict cessation of growth (Little et al, 2000). Knowing the timing of peak growth is valuable in determining peak progression of curvatures. A rapid increase in height at the time of the pubertal growth spurt, causes an increase in spinal curvature (Busscher et al, 2010). The maximum growth rate is called the Peak Height Velocity (PHV)(Sanders, 2007). The timing of PHV is the most important skeletal maturity indicator in AIS. Growth hormone and sex steroids, mainly oestrogen are necessary for the normal growth spurt. Lower doses of oestrogen stimulate a growth spurt and higher doses in later puberty, lead to growth cessation. Oestrogen is the primary factor causing physeal closure at the end of skeletal growth (Sanders, 2007). PHV in girls occurs on average, between ages 10-14 years and in boys, PHV occurs at 12-16 years. Girls have a PHV of about eight cm, and, boys about nine cm per year. Height measurements should be measured at sequential visits to determine PHV and height measurements must be done at the same time for every visit. The reason being height has a diurnal variation of 1.4cm (Tillmann and Clayton, 2001). Diurnal variation in height is smallest between 18.00 and 21.00 hours. Height should be measured with the patient gently stretched by applying gentle upward pressure on the mastoids, while ensuring that the feet remain flat on the floor (Tillmann and Clayton, 2001; Sanders, 2007). Sitting height measurements allow a closer look at spinal growth, but the reliability of sitting height is less than standing height. PHV is a good maturity indicator, whereas menarche, which occurs after PHV and is variable, is therefor not a reliable maturity indicator (Sanders, 2007).

Standing height measurements can be taken using a Seca 206 Bodymeter Measuring Tape with a wall stop. This is a standiometer that rolls up out of the way in its own case and is permanently wall mounted, in the same place. The tape is pulled down to the patient’s head, while patient stands back to the wall and the reading is read instantly in centimeters, to the nearest 0,1cm, through the tape window. Interobserver and intraobserver measurements of this instrument are all within acceptable limits, below five percent difference (Geeta et al, 2009). Using the Bodymeter Measuring tape for height measurements is reliable and valid for its use (Geeta et al, 2009). The estimated standard deviation for a single height measurement is 0,2-0,3cm (Voss et al, 1990).

Trunk height loss in AIS is related to curvature progression (Gremeaux et al, 2009). Loss of height is a method of monitoring the natural history of scoliosis in adults and adolescents. The height of the body is very important in the analysis of pulmonary function (Durmala et al, 2008). In pulmonary function testing, observations in a patient are compared with predicted norms. Normal values depend on age, sex and height. In scoliosis, the spine is deformed and the height of the trunk is smaller than a normal spine. Actual height can be estimated by measuring the arm span, distance between the tips of the middle finger (Hibbert et al, 1988; Durmala et al, 2008).

3.6 Peak Flow

Pulmonary dysfunction occurs in thoracic scoliosis curvatures occurring above the attachment of the spine to the diaphragm as mentioned in Chapter 2.5.2. The three dimensional deformity of the spine and trunk result in reduced chest wall mobility and compliance and therefor restrictive lung function (Hawes, 2003; Weiss, 2003; Tsiligiannis and Grivas, 2012). Vital capacity and total lung volume are decreased as a result of a frozen rib cage. Resting lung function tests show reduced peak flow rates, lung volumes and maximum voluntary ventilation in AIS patients (Shneerson, 1980). Peak expiratory flow is significantly reduced in AIS patients with larger curves (Shneerson, 1980; Zatloukal et al, 1997; Zaba, 2003; Durmala et al, 2008). Reduced values of Total Lung Capacity (TLC), Vital Capacity (VC), Forced Vital Capacity (FVC), Intrathoracic Gas Volume and Residual Volume are found in AIS patients (Durmala et al, 2008). In a study comparing the physical fitness of girls with AIS, with smaller curvatures (Cobb< 60 degrees) to that of girls with large curvatures (Cobb > 60 degrees), the significant difference between the two groups was forced expiratory vital capacity in one second (FEV1)(Zatloukal et al, 1997). Girls with larger curvatures confirmed lower FEV1. There is an inverse relationship between Cobb angles and FVC. The larger the Cobb angle the smaller the FVC (Hawes, 2002).

The flow of air through the lungs can be measured using FEV1, which is normally 70-80 percent of forced vital capacity (FVC) (Gaskell and Webber, 1988). FVC is the maximum amount of gas the patient can exhale forcefully and quickly as possible. Alternatively the peak expiratory flow rate may be measured using a Mini-Wright peak flow meter. This device measures maximum flow over 10 milli-seconds at the beginning of expiration. The Mini-Wright peak flow meter is simple, portable, convenient, reproducible and practical to use clinically (Wright and McKerrow, 1959; Wright, 1978). This instrument has been shown to agree well with a standard flow meter (Oldham et al, 1979). Peak expiratory flow values measured with frequently used mini-Wright peak flow meters have been shown to still be reliable after five years of use, which is important for research purposes (Douma et al, 1997). The same type of flow meter should be used and the same meter should be used when monitoring children (Deng and Azizi, 1996). Mini-Wright meters give repeatable results (Miller et al, 1992). Intraobserver measurement agreement is 90-100 percent and interobserver agreement is 69-97 percent. However it has been found that the ‘original ’ Mini-Wright peak flow meter can over read up to 30l/min between 150-300l/min (Miller et al, 1992; Jackson, 1995). The Mini-Wright meter is found to be more accurate at high flow rates, greater than 400l/min and less accurate below 300l/min, overestimating flows in mid range (Shapiro et al, 1991; Gardner et al, 1992).

The original flowmeters in 1991 over read in the mid ranges of peak flow because their calibration was inaccurate (Miller, 2004). Improvements in the calibration methods for peak flow have led to the ability to produce very accurate flow profiles. Appropriate changes have been made to scales and calibration of these meters and were initiated at the end of 2004 (Miller, 2004). The new European Union (EU) standard for peak flow meters now exists and Clement Clarke International Ltd has developed mathematical equations that will allow conversion of peak flow readings from the Wright-McKerrow scale to the EU scale and vice versa. The conversion to the EU scale was used in this PhD thesis as an older peak flow meter was used.

3.7 Brace Questionnaire

The Brace Questionnaire (BrQ) was designed as a result of the controversy surrounding the HRQoL in scoliosis patients wearing braces mentioned in 2.11.4.4 (Vasiliadis et al, 2006B). Adolescent IS is a complex and progressive condition affecting patients’ QoL. The BrQ, designed specifically to test HRQoL, is the first questionnaire validated to measure clinical success in the management of AIS patients with a brace. Quality of life is defined by the World Health Organisation

(WHO) as an individual's perception of their position in life in the context of the culture and value systems in which they live and in relation to their goals, expectations, standards and concerns (WHOQOL, 1995). Evaluation of QoL is an important part of AIS treatment and should be carefully monitored over the course of treatment (Aulisa et al, 2010). Monitoring of stress levels allows for the possibility of modification of treatment in order to maintain good compliance (Kotwicki et al, 2007C).

The BrQ was validated only in its original Greek version, in Polish and Dutch languages, however an English translation is provided by its authors Vasiliadis et al (2006B). (See Appendix IV, page 208). They found the BrQ to be reliable, valid and responsive to change in AIS patients, who are treated conservatively using a brace. The BrQ overall score is able to distinguish between patients with mild and moderate scoliosis, moderate scoliosis having lower scores and poorer QoL. The BrQ possesses a higher discriminatory capacity compared with other questionnaires, such as Scoliosis Research Society 22 (SRS-22) and the Bad Sobernheim Stress Questionnaire (BSSQ) (Aulisa et al, 2010). The BrQ has a higher capacity to detect changes in QoL in relation to the patient gender, type of brace, curve severity at baseline and end of treatment, and curve type. The reason for this is the BrQ has more questions which enable it to explore more domains than the other questionnaires and is an effective tool in monitoring QoL (Aulisa et al, 2010). The BrQ therefor takes longer to complete than the other questionnaires.

The BrQ is developementally appropriate for ages 9-18 years and administration of the questionnaire takes 10-12 minutes (Vasiliadis et al, 2006B). The BrQ consists of 34 items and covers eight domains: general health perception, physical functioning, emotional functioning, self esteem and aesthetics, vitality, school activity, bodily pain and social functioning. Each item is scored, with scores ranging from 1 (best) to 5 (worst) and varies depending on the answer selected (ie. "always", "most of the time", "sometimes", "rarely", "never"). A summary score is calculated and ranges from 100 (optimal QoL) to 20 (very poor QoL). Higher scores mean better quality of life.(See BrQ Scoring Sheet, Appendix V, page 213).

Vasiliadis and Grivas (2008), found that patients with AIS scored lower in all the domains of the BrQ at the end of conservative treatment with a brace (Vasiliadis and Grivas, 2008). HRQoL was negatively affected immediately after the end of treatment. Therefor QoL must be closely monitored during brace treatment (Aulisa et al, 2010). Conservative treatment does not however severely impact on QoL of patients with AIS (Aulisa et al, 2010). The type of bracing utilized has an impact on patients' QoL, depending on design, dimensions, degree of physical restrain and visibility. Aulisa et al (2010), also found that girls experience a greater deterioration in QoL compared with boys.

3.8 Personality Questionnaire

The High School Personality Questionnaire (HSPQ) and the Sixteen Personality Factor Questionnaire (16PF) were developed in the USA by Raymond B. Cattell (University of Illinois) and Mary D.L. Cattell (Institute for Personality and Ability Testing) (Cattell and Cattell, 1975). Personality can be defined in various ways. Raymond Cattell regards personality as that which tells what a man will do when placed in a given situation (Cattell, 1965). Visser, Garbers-Strauss and Prinsloo (2003), define personality as the integrated and dynamic organisation of the individual's psychic, social, moral and physical characteristics, as it obtains expression in the person's interaction with the environment and with other people. The aim of developing the personality questionnaires was to create a questionnaire that would give a valid and reliable picture of the personality of a person aged 12-18 years (HSPQ) and persons 18 years and older (16PF) (Cattell and Cattell, 1975). These questionnaires include all the major dimension of personality that can be factorially analyzed, they have to be easy to administer and have to measure psychologically significant characteristics. These questionnaires have been adapted and translated for use in South Africa by the Institute for Psychometric Research of the Human Sciences Research Council and standardised for the various age groups (Visser et al, 2003). The questionnaires have been widely used internationally and have been translated into over 35 languages and are based on 70 years of research, and are used to predict behaviour (Cattel and Schuerger, 2003).

The HSPQ can be used to identify individuals with emotional and behavioural problems, to understand individuals and their problems better, to predict future school achievement, to promote pupils' self-knowledge and to monitor personality growth (Cattell and Cattell, 1975). The HSPQ and 16PF were included as instruments in this study based on the premise that one's personality plays a major role in every aspect of life and this instrument assists in understanding the functioning of adolescence and personality characteristics in AIS patients during brace wearing. The 14 personality traits have been shown to be good predictors of social, clinical, occupational and school behaviour (Cattell and Cattell, 1975). The HSPQ and 16PF may be used by psychologists to predict the effectiveness of any therapeutic treatment. Cattell and Cattell (1975) identified 14 primary personality factors which the HSPQ measures:

Factor:

A: Warmheartedness

B: Intelligence

C: Emotional stability

D: Excitability

E: Dominance

F: Carefreeness

G: Conscientiousness

H: Social Boldness

I: Tender-mindedness

J: Individualism

O: Guilt proness

Q_2: Self – sufficiency

Q_3: Self – control

Q_4: Tension

Secondary personality factors were identified from the primary factors and provided a broader more basic concept for describing personality. These secondary factors are:

Anxiety

Extraversion

In comparison the 16PF, designed for 18 years and older has 16 primary factors and five secondary factors scores. The factors in the 16PF are exactly the same as for the factors in HSPQ except for the following:

Primary factors in 16PF (not in HSPQ) include

L: Trusting / suspicious

M: Groundedness

N: Forthrightness

Q^1: Openness to change

Factors D and J, which are in the HSPQ are not in the 16PF.

Secondary factors in the 16PF are:

Anxiety

Extraversion

Emotional sensitivity

Independence

Compulsivity

The HSPQ and 16PF can only be administered and scored by a trained psychologist or psychiatrist, The HSPQ consists of 142 items (16PF has 187 items) for each form of the questionnaire. Four forms (Forms A, B, C, and D) of the HSPQ have been constructed of which Forms A and B have been standardised for South African groups (Visser et al, 2003). Form A was used in this study. The South African version of the 16PF form, the SA92 form, was used in the 16PF questionnaire. The HSPQ / 16PF takes about 40-50 minutes to complete, however there is no time limit. Copies of the questionnaires could not be provided for inclusion in this thesis as a result of copyright laws. A scanned copy of this copyright law appears in Appendix VI, page 214. The HSPQ measures the 14 independent personality dimensions and the 16PF, 16 personality dimensions. There are both primary and secondary factors within the questionnaire. Each primary factor is characterised as a bipolar continuum where two extreme poles are described. The left-hand pole represents a sten score of one to four and the right-hand pole represents a sten score of seven to ten. Scores falling within the extreme poles on each continuum may be regarded as being significant scores (Visser et al, 2003). The fourteen primary factors of the HSPQ (Visser et al, 2003), follow on the next page in Table 3.2.

Table 3.2. Fourteen primary factors of the High School Personality Questionnaire

Factor	Low Score Description	Standard Ten Score (Sten) Average 1 2 3 4 5 6 7 8 9 10	High Score Description
A	Critical, reserved, cool		Warm, soft-hearted, participating, outgoing
B	Dull, less intelligent, concreteness		More intelligent, bright, abstract, thinking
C	Emotionally immature, unstable		Emotionally mature, stable, realistic
D	Deliberate, stodgy, placid, phlegmatic temperament		Unrestrained, nervous, excitability
E	Obedient, mild, dependant		Assertive, aggressive, rebellious, dominance
F	Sober, silent, serious		Happy-go-lucky, enthusiastic
G	Casual, quitting, undependable, opportunistic		Conscientious, preserving
H	Timid, threat-sensitive, shy		Venturesome, thick-skinned, social boldness
I	Practical, tough-minded		Tender minded, sensitive, protected,
J	Vigorous, goes readily with group, zestfulness		Individualistic, obstructive, reflective
O	Secure, resilient, confident		Discouraged, worrying, self-reproaching, prone to guilt feelings
Q²	Group follower, values social approval		Make own decisions, resourceful, self sufficiency
Q³	Careless, ignores standards, lax		Self-controlled, self-respecting
Q⁴	Relaxed, composed		Tense, driven, irritable
		1 2 3 4 5 6 7 8 9 10	

The reliability of the HSPQ and 16PF can be described as the consistency with which the questionnaires measures from one occasion to the next and the reliability can be determined in different ways (Visser et al, 2003). The test – retest reliability of the HSPQ had reliability coefficients of 0.53 (for Form A) and 0,78 (Form B). The reliability coefficients are regarded as satisfactory for a questionnaire of this nature. The results of the tests are influenced by the testee’s circumstances. The Anxiety scale is influenced by the testee’s state of mind, and tension in the test situation may influence the scores. In contrast the Extroversion Scale, which has a strong hereditary component, seems to be more consistent. The retest reliability of the South African 16PF, SA92 has been shown to be highly satisfactory and the same as the original 16PF form (Cattell, 1992). ‘Parallel Forms Reliability’ was established by applying the A and B forms of the HSPQ on the same group of individuals. The HSPQ was found to be a reliable measurement of the characteristics concerned (Visser et al, 2003). The internal consistency of the scales of the HSPQ, is considered to be satisfactory.

The validity of the HSPQ consists of construct validity, content validity and criterion-related validity. There is convincing evidence produced by Cattel RB that the constructs have validity (Visser et al, 2003). The content validity of the HSPQ, developed by Cattell, indicates the content of the HSPQ is appropriate. The low inter-correlation between the different factors and the high equivalent coefficients calculated for the different factors (ranging between 0,50 and 0,84) indicate that the HSPQ does have a relatively high level of construct validity (Taljaard and Prinsloo, 1995). Criterion-related validity consists of concurrent validity (diagnosis of current behaviour can be made with the HSPQ), and predictive validity (prediction of future behaviour using the HSPQ). Cattell (1975) sets out in his manual the diagnostic and predictive ability of the HSPQ in respect of factors such as school achievement, creativity, delinquency, adjustment, behavioural problems, addiction, popularity, leadership and aspects of social status. Studies in countries including India, Italy, Finland, Brazil, France Germany, Belgium, Holland and Japan verify the intercultural stability of the personality dimensions that are measured in the HSPQ and 16PF questionnaire (Tsujioka and Cattel, 1965; Cattel et al, 1970). The High School Personality Questionnaire therefor appears to be a reliable, valid and unbiased test medium. The 16PF, SA92, Questionnaire corresponds well with the Cattell content as far as construct and content validity is concerned (Cattell, 1992) and is also a reliable, valid and unbiased questionnaire that can be used for assessment of personality in South Africans aged 18 years and above (Cattell, 1992).

Chapter 4

METHODOLOGY

The methodology for this study is presented in this chapter. The study design, subjects and study procedure will be described.

4.1 Study Design

A pre test /post test study design was used with a post study comparison between subjects who complied with the management and those who did not comply. Good compliance was defined as wearing the brace 20-23 hours a day and doing the prescribed exercises three or more times a week.

4.2 Ethical Considerations

Ethical clearance was obtained from the Committee for Research on Human Subjects at the University of the Witwatersrand. (See Appendix I). Subjects and parents signed informed consent before participating in the study. (See Appendix II and III). Subjects signed informed assent and parents informed consent.

Special ethical considerations:

Normal management procedures were followed ie: Subjective examination, physical examination, exercise prescription, brace fitting and a psychological questionnaire were administered as is normally done with these subjects.

A standard exercise programme for scoliosis was followed. The exercises are not physically very demanding. The RSC brace used is the most commonly used brace for scoliosis in Europe. The number and type of X-Rays done were no more than what is routinely done for these subjects, in this brace, while monitoring their progress. The administration of the psychological questionnaire was supervised, monitored and assessed by a psychologist. The information obtained from all assessments was kept confidential. Data collection forms were locked away and only a subjects' code was used. Only the researcher knew the names of the subjects. Subjects were free to withdraw at any time without prejudice.

4.3 Subjects

Subjects were drawn from a private physiotherapy practice in Randburg, South Africa. A number of different orthopaedic surgeons specialising in scoliosis, refer patients to this practice. All subjects who fitted the inclusion criteria were included in the study. Subjects were divided into two groups after the brace and exercise interventions were complete and when weaning out of the brace had begun. Subjects were allocated to the two groups according to their compliance, which was recorded in their diaries. The compliant group was defined as those subjects who wore the brace 20-23 hours a day and exercised three or more times per week. The non-compliant group were those subjects who wore the brace less than 20 hours a day and exercised for less than three times per week. The study was terminated the day the subjects started weaning out of the brace. The two study groups were compared with respect to the Cobb angle, rotation of apical vertebrae, peak flow, kyphotic, lordotic angles, quality of life and personality traits.

4.4 Sample Size

Of primary interest was the change in Cobb angle and therefor the power calculations were done for this parameter. A sample of 13 subjects per group had ninety percent power to detect a clinically relevant difference of seven percent change in Cobb angle between the groups at the 0.05 level of significance. A standard deviation of 5.12 degrees was calculated from a pilot study using a two group t-test. A mean change of 11.75 degrees was found in the worst curves in this pilot study. nQuery 6.0 software was used to determine the sample size of 13. According to these statistics a minimum of 13 subjects in each group was needed. As subjects might have dropped out of the study as many as possible were recruited.

Inclusion Criteria : - Idiopathic scoliosis

- Girls between the ages of 12 –16
- Cobb angle between 20-50 degrees
- No prior treatment

Exclusion Criteria : - Other types of scoliosis

- Curves greater than 50 degrees
- Surgical cases. ie. those subjects who have had previous surgery for scoliosis.
- Previous treatment

4.5 Measurement Devices

All measurements analyzed and presented in this study were taken and recorded by the research assistant, a prosthotist, at his rooms at the Sandton Clinic, Johannesburg. The research assistant was blinded to who was in the study and did not know the inclusion criteria. Measurement methods used in this study were and are standardised for all his subjects. At baseline measurements taken were the following: X – Rays, scoliometer readings, height, weight and peak flow.

(See Assessment Sheet- Research Assistant in Appendix VIII).

4.5.1 X-Rays

X-Rays were done pre-test (in and out the brace), at six weeks of wearing brace 23 hours a day (in the brace) and then every six months (in and out the brace) until the day the patient started weaning out of the brace. In and out brace views were taken to ensure a good in-brace correction was achieved compared to out of the brace. The last X-ray taken, before weaning was started, was taken after the subject had been out the brace for four hours. The research assistant saw the subjects after each X-ray and every 6-8 weeks for a brace check during the treatment period. X-Rays were done at the Sandton Clinic Radiology Department in Sandton. X-Rays were taken at the same time of day as the first X-Ray and subjects were barefoot.

X-rays at pretest and final X-ray before weaning included:

a) Three foot PA (Posterior Anterior), (C2 to S2) view, in standing, shielding the pelvis and exposing iliac crests for Risser sign.

b) Three foot sagittal view, C2 to S2.

X-rays done every six months only included a PA view not sagittal view.

c) A scanogram, an x-ray of the legs, was done in lying position, if actual leg length discrepancy was found in the pretest assessment. Discrepency in mm was recorded. A scanogram by definition is an X-ray technique used for showing true dimensions by moving a narrow orthogonal beam of x-rays along the length of the lower extremeties to determine leg length discrepecies (Sabharwal et al, 2006).

Measurements off the X-rays done by the research assistant included:

- Cobb angles (thoracic & lumbar). Method of measuring the Cobb angle is described in 3.1
- Kyphotic angle (taken T4 to T12) and the Lordotic angle (taken L1 to L5). Cobb angle method of measuring was used as described in 3.1.
- Rotation of apical vertebrae (most translated and rotated vertebra) measured by the Pedriolle method (degrees) described in 3.2.
- Risser sign (bone age, seen at the iliac crest, measured 1 to 5). Method of measuring is described in 3.4.

The research assistant adviced the subjects to wear the brace 23 hours per day.

4.5.2 Scoliometer

Scoliometer readings were taken pretest, at six weeks, thereafter every four months and just before weaning, by the research assistant. The researcher also took scoliometer readings at each visit of the patient for monitoring purposes. However the research assistant's measurements are the scoliometer readings presented in the results of this study. The scoliometer used was the OSI Scoliometer, which measures the degree of rotation of deformity of the trunk

(Bunnell, 1985). A change of three degrees or more indicates possible progression, two degrees or less indicates a variation in posture. Subjects sat on the same stool for all these measurements and this 45cm high stool was used throughout the study. The hips and knees were flexed to 90 degrees, with legs apart and subject facing the measurer. The subject flexed the trunk forward with palms facing each other, flexing until fingertips touched the floor. The measurer then ran the scoliometer from sacral base to C2, without any pressure on the trunk, slowly taking measurements of maximally rotated trunk inclination. Further details of the scoliometer measurements are described in 3.3. Measurements were recorded in degrees. Both the research assistant and the researcher followed the method described above.

4.5.3 Height

Height was measured at the same intervals as above. First appointment and follow-up assessments were scheduled at the same time of day, so that height readings were as accurate as possible. Height was measured using a standiometer, a 206 Bodymeter Tape with wall stop. This automatic metal tape measure is permanently mounted on the wall in the same place. The tape is pulled down to the subject's head and the measure is read instantly through the tape window. Height measurements were taken on flooring without a carpet and against a concrete flat wall. Subjects were instructed to remove shoes and socks, hair ornaments and undo ponytails, so that the head was flat against the wall. Subjects stood with their back against the wall facing the research assistant. Their feet were flat, together and against the wall. Legs were straight, arms loose at their sides and shoulders level. Head, shoulders, buttocks and heels touched the flat wall. The subject looked ahead, with line of site parallel with the floor, the corner of the eyes horizontal to the middle of the ear. The research assistant faced the subject. The headpiece was brought down until it touched the crown of the subject's head. The headpiece formed a right angle with the wall and measurer's eyes were in line with the bottom of the headpiece. The subject was asked to inhale and then the assistant applied upward pressure to the subjects' mastoid processes, and maintained this pressure while the subject exhaled. Feet and heels could not rise up from the ground. Once the patient had fully exhaled the measurement was read off the tape measure window at eyelevel and recorded to the last complete millimeter.

4.5.4 Weight

Weight was measured at the same intervals as above. Weight was measured in kilograms (kg) on a calibrated Pentasystems Digital scale, the same scale throughout the study. Calibration of the scale was checked monthly. The scale was placed on a concrete floor and remained in the same place throughout the study. Weight measurement was taken in standing, without shoes and wearing shorts and a t-shirt, all heavy clothing was removed. Body weight changes were monitored, with the fit and tightness of the brace, to ensure effective fitting of the brace. If loss of weight resulted in the brace not fitting properly, adjustments were then made to the brace. Weight was recorded in kilograms.

4.5.5 Peak Expiratory Flow

Peak Flow expiratory readings were taken at the same intervals as above by the research assistant. Peak flow (in ml per second) were taken in high sitting on the same chair as used throughout study. Hips and knees were at 90 degrees, with feet shoulder width apart and flat on the floor. The Mini-Wright Peak Flow meter was used and held in the dominant hand. The subject were given three chances to blow into the meter, with a 30 second break in between each blow. Each time the subject was asked to breathe in maximally and then exhale forcibly and as quickly as possible into the spirometer. The best result was taken and recorded in ml / second (Gaskell and Webber, 1988).

4.5.6 Brace Questionnaire (BrQ)

A Quality of Life Questionnare, the Brace Questionnaire was administered after a minimum of one year of wearing the brace (See Appendix IV). The researcher administered the questionnaire during a routine patient visit. Subjects sat in a cubicle on a chair in front of a table. They were given the questionnaire on a clip board with an HB pencil and an eraser. Instructions were given to subjects on how to fill out the questionnaire. The researcher was available throughout for any explanation or clarification required by the subjects. The English version of the questionnaire provided by the authors, Vasiliadis et al (2006), was administered (Vasiliadis et al, 2006B). The researcher stressed there were no right or wrong answers and that questions referred to when the brace was being worn. Subjects took 10-12 minutes to complete the questionnaire. The researcher then scored all the answer sheets. Each question was scored, domain subscores were calculated and a total BrQ score was obtained. (See Appendix V for a scoring sheet). The individual BrQ scores of the compliant and non-compliant groups were then analysed.

4.5.7 High School Personality Questionnaire and 16PF

A psychological test was done in the last year of fulltime brace wearing, before weaning was started. The HSPQ and 16PF were administered and scored by a psychologist (See Chapter 3.8). The psychologist administered the questionnaires, and assessed and scored the questionnaires. Each subject sat in a physiotherapy cubicle on a chair, at a table. The psychologist provided the subjects with the questionnaire, an answer sheet on a clipboard, an HB pencil and an eraser. Form A (HSPQ) and the SA92 (16PF) forms were used in this study and the answer sheet (456) for hand scoring the HSPQ and answer sheet (3351) for the 16PF was used. The instructions were read according to the HSPQ and 16PF Manual and if there were questions from the subjects, the psychologist discussed them. Most subjects (36) completed the HSPQ and five subjects completed the 16PF. The psychologist stressed that there were no correct or incorrect answers, but rather a correct response for each unique and individual subject. The questionnaires took 35-45 minutes to complete. The scoring and interpretation was done as stipulated by the HSPQ Manual (2936/E) and the 16PF/SA92 Manual (3352/E). In the HSPQ, Scoring stencils 1(679) for Factors A, C, E, G, I , O and Q_3 were used and Scoring Stencil 2 (680) for Factors B, D, F, H, J, Q_2 and Q_4. In the 16PF scoring stencils 1 and 2 (3353N) were used. Factors were compared in the compliant and non-compliant groups.

4.5.8 Diary

A diary was completed by the subject to monitor hours of brace wearing during the day and days that physiotherapy exercises were done. Diary was completed by the subject daily, recording total number of hours brace was worn for the day and an 'E' for exercise was recorded when exercise was done. (See Appendix VII). Contents of the diary were checked once a month by the researcher, once a week by the parents and contents were confirmed and validated with the parent.

4.6 Procedure

At Baseline.

4.6.1 Assessment

After the subjects had seen the research assistant, they were assessed by the researcher for the purposes of implementing the management programme. This assessment included a Subjective and Objective examination. (See Appendix IX for Assessment Sheet (Researcher)).

The Subjective examination included :

- Date of birth
- Age of onset of scoliosis
- Age at Menarchy
- History (to confirm that it was an idiopathic scoliosis)
- Family history
- Other medical conditions
- Medication
- Involvement in sport
- Pain presentation, if so: type of pain, depth, irritability, severity
- The researcher then examined the X-rays and recorded the measurements, done by the assistant, and the type and nature of the curvature. These measurements dictated the exercises the researcher gave the subject. Risk of curve progression was calculated using the Lonstein Progression Risk Factor described in 2.4.

A physical examination was then done to assess the following:

- Posture (frontal & sagittal alignment), in sitting and standing
- Anterior & posterior rib symmetry, waist and shoulder asymmetry
- Adams Forward Flexion test, in sitting
- Side shift range of movement of pelvis, comparing left & right range of movement in standing against the wall. The researcher confirmed this, by asking the subject, which leg they preferred to stand on.
- Scoliosis measurements using the scoliometer were taken in sitting by the researcher to monitor the trunk inclination and check that no exercise made the rotation of the trunk worse and to measure improvements in the rotation. This was an adjunct to the management.
- Straight leg raise, range of movement.
- Gluteal maximus strength (Tested with bridging and one leg bridge, to determine if one gluteal muscle was stronger than the other).
- Sacro Iliac Joint (SIJ) alignment using Standing Flexion test, to determine which SIJ was hypomobile and stiff. Reliability of this test was improved by confirming findings using a Stork/Gillet Test and a Supine to Long Sitting test.
- The Piriformis muscle was checked for range of movement in supine to determine which side was tighter. Hip joint was at 90 degrees, adducted and externally rotated.
- Leg length discrepancy in supine. Supine to Long Sitting test. Actual or apparent leg length discrepancy was established. ie supine to long sitting with hands behind subject resting on the bed. If actual leg length discrepancy was found and this was confirmed by scanogram, a complete foot raise, for inside the shoe (from the orthotist) for the subject was obtained, if the discrepancy aggravated the lumbar or thoracolumbar curves. In the double curve types only if there was a thoracic curve and it was smaller or equal to the lumbar curve was a heel raise used for the lumbar curve. The raise equalled the mm deficit of the short leg and was worn in all subjects' shoes. These

shoe lifts were not worn during X-rays. If the discrepancy did not aggravate the curvature, no shoe raise was used.

- Height was taken for monitoring the curve changes. Weight was measured.
- If the subject complained of pain in a local area, that joint/area was examined.

4.6.2. Treatment Aims, Management Programme

The treatment aims in the specific management programme included:

- Autocorrection of the spine in a three dimensional plane, including restoration of sagittal profile
- Autoelongation – self elongation of the spine
- Deflection- Correction of body parts in the frontal plane
- Derotation- Better alignment of spine in frontal and sagittal plane
- Stabilising the corrected posture
- Ergonomy- training in active daily living, taught in sitting, standing postures
- Respiratory function and education
- Patient and family education on scoliosis theory:
  Decreasing curve progression, improving cosmesis, decreasing functional limitations, coping with treatment and deformity and psychological support.

Other aims were to improve:

- Coordination
- Equilibrium
- General motor capacity
- Muscle endurance
- Muscular strength
- Neuromotor control of spine
- Correct side shift of the pelvis, if the pelvis was translated

4.6.3 Home Programme of Exercises

- An explanation to the subjects of the principles of the specific scoliosis home programme of exercises was then given ie. elongation, breathing, frontal and sagittal alignment. Subjects were asked to do the exercises 4-5 days a week. The researcher then demonstrated the exercises and the subject did the exercises under correction. The exercises were written down. (See Home Programme of Exercises given, in Appendix XI, page 228). Justification for these exercises is presented in Appendix X, page 218. A description of the exercises were put in a file which the subjects kept and brought with them every time they came to physiotherapy. A picture of the curve was also drawn in the file to show them the curve and how to shift the pelvis in order to correct the curve.

- Included in the file was a diary, which subjects had to complete, when they did their exercises and how many hours they had worn their brace each day. They were asked to wear the brace 23 hours per day. They could take the brace off for bathing and doing the exercises. They could also take it off once a week for three hours in the evening, when they were going out to a function. The researcher felt the subjects were teenage girls that at least once a week could go out and wear nice clothes, that they could not normally wear with the brace on.

- The researcher then asked the subject's parent/guardian to take a photograph of the subject in her costume front, back and sagittal view at home and to keep these pictures in her file. These were to show the subject the appearance of scoliosis from behind and to refer to in later treatments to observe any cosmetic improvements.

- The researcher saw the subject after one week, and checked the exercises given, that the exercises were being done correctly and gave more exercises, as appropriate. The exercises were to be done four to five times a week and did not take longer than half an hour to do. The subjects were seen again by the researcher after two weeks, during which time they would have been weaning into the brace.

- The researcher then saw the subject once a month, when the researcher would: reassess the subject, check the previous exercises, add new exercises and replace some exercises, check hours of brace wearing and the amount of exercise done. The comfort and fit of the brace, including pressure areas was checked and any brace wearing difficulties were addressed. If subjects were not being compliant, the consequences of not being compliant were explained to them to encourage them to do the exercises and wear the brace full time. This explanation was however given to every patient, explaining that their curves were at high risk to progress, that their deformities could get worse and the natural history of scoliosis throughout life was described.

4.6.4 Follow up appointments

- The Quality of Life Questionnaire, BrQ, was administered, after a minimum of one year of wearing the brace, at one of the monthly visits to the researcher.

- In the last year of wearing the brace full time, the psychologist came to one of the subjects' monthly visits to the researcher. The psychologist administered the psychological questionnaire, HSPQ or the SA92/16PF on her own in a quiet cubicle. Questionnaire was kept confidential and taken by the psychologist for assessment.

- Monthly follow-up appointments with the researcher continued until skeletal maturity was reached. This was defined by reaching Risser 5 on X-ray, or as close to Risser 5 as possible ie. Risser 4,5 and the subject's height measurements must have been static for at least six months. Once skeletal maturity had been reached weaning out the brace was started, which is when the study ended. The reason for this, is described in 2.11.6. The Risser sign at the end of the study was confirmed on X-ray with a coned anterior posterior view of the iliac crests. Subjects however continued to see the researcher once a month during the weaning process.

4.6.5 The Weaning process

The study ended the day the weaning process started. Eight subjects in the compliant group were however followed up to the end of the weaning process. The weaning process used and the results of these eight subjects at the end of the weaning process are presented in Appendix XV, page 240, and Appendix XVI, page 241. The rest of the compliant subjects had not completed the weaning process and their results will be presented in a future study.

4.7 Data Analysis

Subjects were divided into two groups after assessing the compliance of the subjects according to what they had recorded in their diaries. Diaries were checked by the researcher monthly, with the parents to confirm the contents. Parents checked subject's diaries weekly. Groups were compared with respect to Cobb angle, rotation of apical vertebrae, kyphosis and lordosis angle, scoliometer readings, peak flow, height, age , QoL and personality traits.

At baseline and endpoint respectively the two groups were compared using student's two- sample t- test with equal variance. The latter results were confirmed with the Welch t- test taking into account that the groups may have different variance and also with the Wilcoxon rank-sum test (Mann- Whitney test). The groups were compared with respect to change from baseline to endpoint using analysis of covariance (Ancova) with baseline as covariate (change adjusted for baseline). Also of interest were the change from baseline to end, within a group (compliant or non compliant) and testing was done using students paired t- test. Lastly, in subjects with two curves the observation vector (thoracic cobb angle; lumbar cobb angle) was compared in the two groups using Hotelling's T^2-test, with univariate t- tests for thoracic Cobb angle and lumbar Cobb angle respectively, at baseline, end of treatment and change from baseline to end of treatment. The reason for using Hotelling's T^2-test was that in some Thoracic Type curves, there are two curves, one major and one very minor curve, therefor all subjects with two curves were compared. Testing was done at the 0,05 level of significance.

p value ≤ 0.05 is significant,

p value $0.05 < p \leq 0.10$ is marginally significant

p value $p > 0.1$ is not significant (Motulsky, 1995)

Data analysis was be done using the software: StataCorp. 2009. Stata: Release 11. Statistical Software. College Station. TX: StataCorp LP.

4.7.1 Brace Questionnaire

The individual BrQ scores of the compliant and non compliant groups were analysed and compared. Two- sample t- test with equal variance was used.

Outcome was confirmed with both the Welch t-test and the Wilcoxon rank-sum test, when group standard deviations were very dissimilar.

4.7.2 Personality Questionnaire

The HSPQ and 16PF were analysed through scoring and interpretation as allocated and stipulated in the questionnaire HSPQ and 16PF/SA92 manuals and according to the normal hand scoring method used by the psychologist. South African norms and a sten scale were applied during interpretation of the scores and interpretation according to the guidelines set out in the manuals. Scores in the two groups were compared using the two– sample t- test with equal variance. Outcome was confirmed with both the Welch t- test and the Wilcoxon rank-sum test, when group standard deviations were very dissimilar. As a result of the personality factor traits being marginally significantly different between the compliant and non compliant groups, the groups were then compared using Pearson's chi-square test after categorizing the trait scores into low, average and high sten scores.

4.8 Time Scale

The study started when subjects went into the brace, which was between ages of 12-16, till the day the subjects started weaning out the brace. The youngest subjects going into the brace were in the brace for four to five years and then they spent 11 months weaning out the brace. This study thus took five years.

Chapter 5

RESULTS

The results of this study are presented in this chapter. Baseline data for the measurements in each group are presented and compared, followed by the end point of study data collection and the change from baseline to end point in the two groups is presented and compared. The results will be discussed in detail in Chapter Six.

5.1 Subjects Divided into Groups and Dropouts.

At the start of the study there were 51 subjects, however four subjects dropped out very early on in the study. These four subjects had the brace fitting with the orthotist and the physiotherapy assessment, during which time they were given their exercise programme. The subjects did not visit the orthotist again, had no further X-rays, however they had three to six visits to physiotherapy and then did not return. Results will therefor be presented on the 47 remaining subjects.

These 47 subjects, who fitted the inclusion criteria were drawn from a private physiotherapy practice. Subjects were divided into two groups after the brace and exercise interventions were complete and when weaning out of the brace had begun. Twenty six subjects were allocated into the compliant group and 21 subjects into the non-compliant group. The compliant group were those subjects who wore the brace 20-23 hours a day and exercised three or more times per week. The non-compliant group were those subjects who wore the brace less than 20 hours a day and exercised less than three times per week.

There were three different curve types in the group of 47 subjects. The curve types and numbers in the whole group are shown in Table 5.1 below. This is a simplified description of curve type according to the Rigo Classification (Rigo, 2005).

Table 5.1 Curve types in the study.(n=47)

Curve Type	Description of curve type	Number of subjects
Double Major Curves	Two Cobb angles: one in thoracic area (T) and one in lumbar (L) or thoracolumbar (TL) region. Similar Cobb angle size. (T + L) or (T + TL)	31 (22 were thoracic and lumbar: 9 were thoracic and thoracolumbar)
Thoracic Curves	Main curve, apical vertebra in thoracic region. There could be a minor (smaller) lumbar curve.	13
Thoracolumbar Curves	A single curve, apical vertebra at the thoracolumbar junction, T12 or L1.	3
	TOTAL	47

5.2 Baseline Data

Inclusion criteria for this study were Cobb angles 20 – 50 degrees. The Cobb angle size distribution in the two groups is presented in Table 5.2 below. The Cobb angles presented here are those for the worst curve in a subject.

Table 5.2 The Cobb angle distribution of the worst curve (in a subject) in each group at baseline. (n=47)

Cobb angle	Total	**Compliant** n (%)	**Non Compliant** n (%)
20 - 29°	12	3 (25)	9 (75)
30 - 39°	23	16 (70)	7 (30)
40 - 50°	12	7 (58)	5 (42)
	47	26 (55)	21 (45)

An observational analysis on the above indicates that the non compliant group had more Cobb angles in the lower ranges 20-29 degrees than the compliant group. The compliant group had more Cobb angles in the higher ranges 30-39 and 40-50 degrees than the non compliant group. Baseline data for the two groups are presented in Table 5.3 below. In Tables 5.6 and 5.7 the comparison of different curve types is presented, with respect to Cobb angles and their apical rotations.

Table 5.3 Baseline Data. (n=47)

Measure	**Group**	**n (%)**	**Mean (±SD)**	**p Value**
All Thoracic Cobb angles (degrees)	Compliant **(n=26)** Non Compliant **(n=21)**	25 (96) 21 (100)	34.36 (± 7.86) 28.76 (± 9.61)	**0.04** *****
All Lumbar Cobb angles (degrees)	Compliant Non compliant	19 (73) 19 (90)	28.21 (± 9.70) 26.05 (± 8.16)	0.46
Worst Cobb angle (degrees)	Compliant Non compliant	26 (100) 21 (100)	35.58 (± 7.79) 31.19 (± 8.02)	0.06
Worst Apical Rotation (degrees)	Compliant Non compliant	26 (100) 21 (100)	18.96 (± 10.32) 14.29 (± 8.11)	0.09
All (Thoracic) Rotation Apical Vertebra	Compliant Non compliant	26 (100) 21 (100)	16.27 (± 10.82) 10.24 (± 8.47)	**0.04** *****
All (Lumbar) Rotation Apical Vertebra	Compliant Non compliant	26 (100) 21 (100)	8.46 (± 9.88) 10.47 (± 8.20)	0.46
Kyphosis angle (degrees)	Compliant Non compliant	16 (62) 11 (52)	22.50 (±10.75) 28.00 (± 12.94)	0.24
Lordosis angle (degrees)	Compliant Non compliant	14 (54) 8 (38)	41.64 (± 13.66) 35.25 (± 7.89)	0.24
Thoracic, Scoliometer Reading (degrees)	Compliant Non compliant	26 (100) 21 (100)	9.96 (± 3.58) 9.00 (± 5.89)	0.49
Lumbar, Scoliometer Reading (degrees)	Compliant Non compliant	26 (100) 21 (100)	5.04 (± 4.85) 4.48 (± 3.52)	0.66
Peak Flow (l/min)	Compliant Non compliant	26 (100) 20 (95)	314.15 (± 59.78) 347.1 (± 67.36)	0.09
Height (centimeters)	Compliant Non compliant	26 (100) 21 (100)	159.35 (± 7.05) 161.75 (± 7.68)	0.27
Age (years)	Compliant Non compliant	26 (100) 21 (100)	14.34 (± 1.06) 13.91 (± 1.24)	0.21

***** significant p values

The two groups were well matched for all variables measured as there were no significant differences between the two groups, except for the thoracic Cobb angles (p=0.04) and their apical rotations (p=0.04). The mean thoracic Cobb angles were significantly larger (34.36°±7.9) in the compliant group compared with the non compliant group (28.76°±9.1)(p=0.04). The corresponding apical rotation in the compliant group (mean 16.27°±10.8) is significantly larger than the non compliant group (10.24°±8.5) (p=0.04). These differences were adjusted by using an analysis of covariance (Ancova) with baseline as covariate when comparing change in data in both groups. The number of subjects with lordosis and kyphosis measurements was lower than the total number of subjects, as sagittal view X-rays were not done by individual surgeons referring some of these subjects.

The normal values of peak flow for an adolescent female of height 160 cm is 400 litres per minute (Polgar and Promhadt, 1971; Harkinson et al, 1999). In this study mean peak flows were 314 l/min (compliant group) and 347 l/min in the non compliant group and therefor below normal values, bearing in mind that the heights measured are not true heights as a result of the deformity. The Risser sign, was observed on the X-ray of the iliac apophysis in each group. The Risser sign, which is an accurate and reliable method of determining skeletal growth (Risser, 1958) is presented for each group in Table 5.4 below. The number of subjects within a Risser sign are indicated in each group.

Table 5.4 Risser sign in groups at baseline.(n=47)

Risser Sign	**Compliant Group n (%)**	**Non Compliant Group n (%)**	Total
0	2 (50)	2 (50)	4
1	4 (57)	3 (43)	7
2	8 (47)	9 (53)	17
3	10 (59)	7 (41)	17
4	2 (100)	0 (0)	2
Total	26	21	47

Most of the subjects were Risser 2 and 3 at baseline. The two subjects at Risser 4 in the compliant group had curves greater than 40 degrees. At baseline the progression risk for each subject's curvature was calculated using the Lonstein Progression Risk Factor described in Chapter 2.4 and presented on the next page.

$$\text{Lonstein Progression Factor} = \frac{\text{Cobb} < -3 \times \text{Risser Sign}}{\text{Chronological Age}}$$

The progression risk for each group, with means and standard deviations is presented below in Table 5.5. Included in this table is the percentage of in-brace correction a subject had in their brace at baseline in each group. This was seen on the initial X-ray in the brace. The percentage that the curve was corrected by the brace is the “in-brace correction”.

Table 5.5 Progression risk and in-brace correction for groups at baseline.(n=47)

Measure	Group	n (%)	Mean (± SD)	p Value
Progression Risk (percentage)	Compliant (n=26) Non Compliant (n=21)	26 (100) 21 (100)	78.46 (± 28.1) 70.48 (± 28.94)	0.34
In Brace Correction (percentage)	Compliant Non Compliant	21 (81) 16 (76)	44.52 (± 16.95) 35.75 (± 18.81)	0.15

There was no significant difference between the two groups for progression risk of the curvatures and the in-brace corrections. The risk of progression in both groups was high, over 70 percent, and slightly higher in the compliant group. The numbers of subjects having in-brace X-rays in both groups is lower than the total number in each group, as not all subjects were sent for this X-ray at baseline.

Two curve types were compared in the two groups at baseline, “Double Major curves” and “Thoracic curves”. These are shown in Table 5.6 and 5.7 on the next page. The Cobb angles and apical rotations were compared. There were only three Thoracolumbar curves and therefor these curves were not compared in the two groups. In the Double Major group of curves, the two curves within that group, those with lumbar curves (T + L) and those with thoracolumbar curves (T + TL) could not be separated as the numbers were too low in the compliant or non compliant groups. Therefor the whole group of Double Major curves (all 31) was compared in the two groups.

Table 5.6 Comparison of Double Major curves in compliant and non compliant groups at baseline. (T + L) and (T + TL) curves.(n=47)

Measure	Group	n (%)	Mean (±SD)	p Value
All Thoracic Cobb angles (degrees)	Compliant **(n=26)** Non Compliant **(n=21)**	14 (54) 17 (81)	32.64 (± 9.13) 28.12 (± 9.78)	0.20
All Lumbar Cobb angles (degrees)	Compliant Non compliant	14 (54) 17 (81)	30.64 (± 9.44) 27.82 (± 6.42)	0.33
All (Thoracic) Rotation Apical Vertebra	Compliant Non compliant	14 (54) 17 (81)	13.21 (± 7.75) 8 (± 8.57)	0.15
All (Lumbar) Rotation Apical Vertebra	Compliant Non compliant	14 (54) 17 (81)	13.57 (± 9.08) 12.06 (± 7.72)	0.62

There was no significant difference between the groups, at baseline.

Table 5.7 Comparison of Thoracic Curve Types in compliant and non compliant groups at baseline.(n=47)

Measure	Group	n (%)	Mean (±SD)	p Value
All Thoracic Cobb angles (degrees)	Compliant **(n=26)** Non Compliant **(n=21)**	9 (35) 4 (19)	37.11 (± 5.69) 31.5 (± 9.68)	0.21
All (Thoracic) Rotation Apical Vertebra	Compliant Non Compliant	9 (35) 4 (19)	20.89 (±13.02) 16.25 (± 4.79)	0.51

Although there were only 13 thoracic curves, there was no significant difference between the two groups, with respect to Cobb angle and apical rotation at baseline.

For all subjects who had two curves, compliant and non compliant groups were compared with respect to the observation vector (thoracic Cobb angle; lumbar Cobb angle) at baseline. Therefor subjects with a single curvature were not included in this comparison and only those with the combination of a thoracic and lumbar Cobb angle were included. Included are a few thoracic type curves, which have a major thoracic Cobb angle and a minor lumbar Cobb angle, however by definition are called Thoracic type curves (Rigo, 2005). The comparison of subjects with two curves are presented in Table 5.8 on the next page. Thoracic apical rotations and lumbar apical rotations are included.

Table 5.8 At baseline, subjects with two curves, were compared between groups with respect to vector (thoracic Cobb angle; lumbar Cobb angle).(n=47)

Measure	Group	n (%)	Thoracic mean (±SD)	p-value	Lumbar mean (±SD)	p-value t-test	Hotelling T^2 p-value
Cobb angle -degrees	Compliant (n=26) Non compliant (n=21)	18 (69) 19 (90)	33.39 (± 8.43) 28.95 (± 9.91)	0.15	28.11 (± 9.98) 26.10 (± 8.16)	0.49	0.31
Apical Rotation -degrees	Compliant Non compliant	18 (69) 19 (90)	15.72 (±11.66) 9.21 (± 8.21)	0.06	10.83 (±11.66) 11.58 (±7.82)	0.80	0.14

There were no significant differences between compliant and non compliant subjects with two curves at baseline. Mean thoracic Cobb angles and mean lumbar Cobb angles were not significantly different in the two groups.

5.3 End of Study Data

These data were collected when full time bracing and exercise interventions were complete and when weaning out of the brace had begun. This occurred when skeletal maturity had been reached, either Risser 5 was seen on X-ray or as close to Risser 5 as possible and the height had been static for at least the last six months. The Cobb angle size distribution at the end of the study in the two groups is presented in Table 5.9 below. The Cobb angles presented here are those for the worst curve in a subject.

Table 5.9 The Cobb angle distribution of the worst curve (in a subject) in each group at the end of the study. (n=47)

Cobb angle	Total (@ Baseline) End	**Compliant n (%)** (@ Baseline) **End** (%)	**Non Compliant n (%)** (@ Baseline) **End** (%)
< 20°	(0) 5	(0) **5** (100)	(0) **0** (0)
20 - 29°	(12) 19	(3) **14** (74)	(9) **5** (26)
30 - 39°	(23) 14	(16) **6** (43)	(7) **8** (57)
40 - 50°	(12) 9	(7) **1** (11)	(5) **8** (89)
Total	(47) 47	(26) **26**	(21) **21**

(Number at baseline of study is in the first set of brackets).

In the compliant group, five subjects dropped below 20° at the end of the study. and the number of subjects in the 20-29° range increased from three to 14, The number of subjects in the 30-39° and 40-50° range, decreased from 16 to six subjects and from seven down to one subject. With one subject only in the 40-50° range the risk of going to surgery was reduced in these subjects as surgery is indicated at 50° (Hopf, 2000; Hawes, 2006). In the non compliant group the numbers in the 20-29° range decreased from nine to five, and in the 30-39° and 40-50° ranges, increased from seven to eight, and five to eight subjects. With eight subjects in the 40-50° the risk of surgery was increased in the subjects in the non compliant group. However looking at the whole group of 47, the risk of surgery was decreased, as the total number of larger curves were decreased.

Three subjects in the non compliant group did have surgery as their curvatures were too large (Cobb angle > 45 °) and they had not yet reached skeletal maturity One of these subjects stopped wearing the brace and did not wear it at all in the last eight months of the study. Measurements were taken just before their surgery.

The average hours of brace wearing per day per subject and the number of exercise sessions done per week per subject were compared in the compliant and non compliant groups and are presented below in Table 5.10.

Table 5.10 Brace Hours and Exercise Sessions at end of study in compliant and non compliant groups.(n=47)

Measure	**Group**	**n (%)**	**Mean (±SD)**	**p Value ***
Average hours of brace Wearing per day (hours)	Compliant (n=26) Non Compliant (n=21)	26 (100) 21 (100)	21.5 (±1.17) 12.19(±7.05)	**<0.0001**
Average exercise Sessions per week	Compliant Non Compliant	26 (100) 21 (100)	3.92 (±0.63) 1.71 (±1.06)	**<0.0001**

There was a significant difference in brace wearing hours between the two groups, significantly more hours in the compliant group. Four to five times a week of exercise was prescribed to all subjects. In the non compliant group two of the subjects stopped wearing the brace eight months before skeletal maturity was reached as they did not wish to wear the brace anymore. One of these subjects did however continue with her exercises.

End of study data are presented in Table 5.11 below.

Table 5.11 End of study data.(n=47)

Measure	Group	n (%)	Mean (±SD)	p Value
All Thoracic Cobb angles (degrees)	Compliant (n=26) Non Compliant (n=21)	25 (96) 21 (100))	25.4 (±8.67) 34 (±9.71)	**0.002** *
All Lumbar Cobb angles (degrees)	Compliant Non compliant	19 (73) 19 (90)	21.10 (±7.80) 29.74 (±10.0)	**0.005** *
Worst Cobb angle (degrees)	Compliant Non compliant	26 (100) 21 (100)	25.38 (±8.33) 36.71 (±9.30)	**0.0001** *
Worst Apical Rotation (degrees)	Compliant Non compliant	26 (100) 21 (100)	11.54 (±7.97) 17.95 (±9.03)	**0.01** *
All (Thoracic) Rotation Apical Vertebra	Compliant Non compliant	26 (100) 21 (100)	11.35 (±7.28) 14.05 (±9.03)	0.26
All (Lumbar) Rotation Apical Vertebra	Compliant Non compliant	26 (100) 21 (100)	4.81 (±6.55) 11.52(±10.09)	**0.009** *
Kyphosis angle (degrees)	Compliant Non compliant	6 (23) 4 (19)	34.33 (±6.44) 21.5 (±6.85)	**0.02** *
Lordosis angle (degrees)	Compliant Non compliant	6 (23) 4 (19)	41 (±10.59) 39 (±14.36)	0.82
Thoracic, Scoliometer Reading (degrees)	Compliant Non compliant	26 (100) 21 (100)	7.5 (±3.73) 8.67 (±5.12)	0.37
Lumbar, Scoliometer Reading (degrees)	Compliant Non compliant	26 (100) 21 (100)	1.38 (±2.47) 4.67 (±4.04)	**0.001** *
Peak Flow (l/min)	Compliant Non compliant	26 (100) 20 (95)	377.46(±10.51) 378.25(±13.21)	0.96
Height (meters)	Compliant Non compliant	26 (100) 21 (100)	163.00 (±5.87) 165.36 (±5.82)	0.18
Age (years)	Compliant Non compliant	26 (100) 21 (100)	17.14 (±0.63) 16.18 (±1.06)	**0.0004** *

***** Significant p values in bold.

At the end of the study most of the measures were significantly different in the two groups. All Cobb angles were significantly lower in the compliant group compared to the non compliant group. The worst cobb angle, in the compliant group (25.38°±8.3) was significantly lower than in the non compliant group (36.71°±9.3)(p=0.0001). The associated worst apical rotation was also significantly lower in the compliant group (11.54°±7.9) compared to the non compliant group (17.95°±9)(p=0.01). The kyphosis Cobb angle was significantly higher in the compliant group (34.33°±6.4) and well within normal limits compared to the non compliant group (21.5°±6.9), which was below normal limits, being 25-50° (Durmala et al, 2009). The number of subjects with lordosis and kyphosis measurements was however small and lower than the total number of subjects, as sagittal view X-rays were not done by individual surgeons referring some of these subjects. The scoliometer readings in the lumbar area were significantly lower in the compliant group (1.38°±2.5) compared to the non compliant group (4.67°±4).

At the end of the study there were no significant differences in peak flow and height between the compliant and non compliant groups. However normal peak flow values are 412 l/min (compliant) and 424 l/min (non compliant) for these respective heights (Polgar and Promhadt, 1971; Harkinson et al, 1999) and therefor the peak flows were below normal. The compliant group (17.14 years) was significantly older than the non compliant group (16.18 years)(p=0.0004). Contributing to this difference was the fact that in the non compliant group, three subjects went to surgery before they reached skeletal maturity.
The number of subjects within a Risser sign at the end of the study, are indicated in Table 5.12 below for each group.

Table 5.12 Risser sign in each group at the end of the study. (n=47)

Risser Sign	**Compliant n (%)**	**Non Compliant n (%)**	Total
3.5		2 (100)	2
4		2 (100)	2
4.5	6 (40)	9 (60)	15
5	20 (71)	8 (29)	28
Total	26	21	47

Most subjects were at Risser 4.5 and Risser 5 at the end of the study except four subjects in the non compliant group, who were Risser 3.5 and 4. Two had surgery at Risser 3.5, one at Risser 4. The decision for surgery was made by the orthopaedic surgeons and the subjects. There was another subject who stopped wearing the brace at Risser 4, eight months before skeletal maturity had been reached, as the height was not yet static.

At the end of the study different curve types were compared. The whole group of Double Major curves (all 31) and Thoracic curve types was compared in the compliant and non compliant groups, with respect to Cobb angles and apical rotation. These curves are presented below in Table 5.13 and 5.14.

Table 5.13 Comparison of Double Major curves in compliant and non compliant groups at the end of the study. (T + L) and (T + TL) curves.(n=47)

Measure	Group	n (%)	Mean (±SD)	p Value
All Thoracic Cobb angles (degrees)	Compliant (n=26) Non Compliant (n=21)	14 (54) 17 (81)	26 (±11.08) 33.88 (±8.54)	**0.03** *****
All Lumbar Cobb angles (degrees)	Compliant Non compliant	14 (54) 17 (81)	23.21 (±7.92) 31.64 (±8.59)	**0.009** *****
All (Thoracic) Rotation Apical Vertebra	Compliant Non compliant	14 (54) 17 (81)	10.35 (±6.64) 12.05 (±7.92)	0.53
All (Lumbar) Rotation Apical Vertebra	Compliant Non compliant	14 (54) 17 (81)	7.14 (±6.42) 13.35 (±9.90)	**0.05** *****

***** Significant p values in bold.

The thoracic and lumbar Cobb angles, with their apical rotations, were significantly smaller in size in the compliant group compared to the non compliant group .

Table 5.14 Comparison of Thoracic Curve Types in compliant and non compliant groups at end of the study.(n=47)

Measure	Group	n (%)	Mean (±SD)	p Value
All Thoracic Cobb angles (degrees)	Compliant (n=26) Non Compliant (n=21)	9 (35) 4 (19)	24.56 (±4.98) 37.5 (±15.02)	**0.03**
All (Thoracic) Rotation Apical Vertebra	Compliant Non Compliant	9 (36) 4 (19)	12.2 (±7.12) 22.5 (±9.57)	**0.05**

The thoracic Cobb angles and the apical rotations were significantly smaller in the compliant group compared to the non compliant group.

For all subjects who had two curves, compliant and non compliant groups were compared with respect to the observation vector (thoracic Cobb angle; lumbar Cobb angle) at the end point of the study. The between group comparison of subjects with two curves are presented in Table 5.15 below. Thoracic apical rotations and lumbar apical rotations are included.

Table 5.15 At endpoint, subjects with two curves, were compared between groups with respect to vector (thoracic Cobb angle; lumbar Cobb angle).(n=47)

Measure	Group	n (%)	Thoracic mean (±sd)	p-value	Lumbar mean (±sd)	p-value t-test	Hotelling T^2 p-value
Cobb angle -degrees	Compliant(n=26) Non compliant (n=21)	18 (69) 19 (90)	26.56 (±9.85) 34.58 (±9.62)	**0.02**	21.17 (±8.02) 29.74 (±10.03)	**0.007**	**0.005**
Apical Rotation -degrees	Compliant Non compliant	18 (69) 19 (90)	11.39 (±6.82) 12.89 (±8.55)	0.56	5.83 (±6.24) 12.74 (±9.84)	**0.02**	**0.03**

Subjects with two curves had significantly smaller Cobb angles and apical rotations in the compliant group at the end of the study.

During the study, the age of menarche was noted in subjects and compared in the two groups. These data are presented in Table 5.16 below. Skeletal maturity (end of the study) in years after menarche was also noted and compared in the two groups.

Table 5.16 Age at menarche during the study and skeletal maturity in years after menarche.(n=47)

Measure	Group	n (%)	Mean (±SD)	p Value
Age at Menarchy (years)	Compliant (n=26) Non Compliant (n=21)	13 (50) 5 (24)	12.9 (±0.8) 13.06 (±1.37)	0.83
Skeletal Maturity, in Years after menarchy	Compliant Non Compliant	13 (50) 5 (24)	4.03 (±0.56) 3.46 (±0.46)	0.11

Skeletal maturity, was between 3.46 (±0.5) to 4.03 (±0.6) years after menarche in the two groups. Age at menarche data could not be obtained accurately on all subjects and therefore only 18 subjects were included. The subjects' heights were static 3.46 - 4.03 years after menarche, when weaning was started.

5.4 Change in Curve Data from Baseline to Endpoint

The change in measurements during the study, from baseline to endpoint is presented in Table 5.17 below.

Table 5.17 Change in study data, baseline to end. (n=47)

Measure	Group	n (%)	Mean (±SD)	p Value
All Thoracic Cobb angles (degrees)	Compliant (n=26) Non Compliant (n=21)	25 (96) 21 (100)	8.96 (±6.10) - 5.81 (±6.87)	**<0.0001**
All Lumbar Cobb angles (degrees)	Compliant Non compliant	19 (73) 19 (90)	7.11 (±4.99) - 3.11 (±4.98)	**<0.0001**
Worst Cobb angle (degrees)	Compliant Non compliant	26 (100) 21 (100)	10.19 (±5.46) - 5.52 (±4.31)	**<0.0001**
Worst Apical Rotation (degrees)	Compliant Non compliant	26 (100) 21 (100)	7.42 (±7.15) - 3.67 (±6.51)	**<0.0001**
All (Thoracic) Rotation Apical Vertebra	Compliant Non compliant	26 (100) 21 (100)	4.92 (±6.94) - 3.81 (±7.23)	**0.001**
All (Lumbar) Rotation Apical Vertebra	Compliant Non compliant	26 (100) 21 (100)	3.65 (±6.09) - 1.05 (±3.75)	**0.0005**
Kyphosis angle (degrees)	Compliant Non compliant	5 (19) 2 (10)	3.60 (±6.88) - 1.00 (±8.49)	0.24
Lordosis angle (degrees)	Compliant Non compliant	4 (15) 2 (10)	1.50 (±8.70) - 3.00 (±25.46)	0.73
Thoracic, scoliometer Reading (degrees)	Compliant Non compliant	26 (100) 21 (100)	2.46 (±2.34) 0.33 (±3.99)	**0.04**
Lumbar, scoliometer Reading (degrees)	Compliant Non compliant	26 (100) 21 (100)	3.65 (±3.61) - 0.19 (±2.77)	**<0.0001**
Peak Flow (l/min)	Compliant Non compliant	26 (100) 20 (95)	63.31 (±35.39) 31.15 (±49.92)	**0.04**
Height (meters)	Compliant Non compliant	26 (100) 21 (100)	3.64 (±2.80) 3.61 (±5.13)	0.43
Time spent in brace (years)	Compliant Non compliant	26 (100) 21 (100)	2.80 (±1.18) 2.27 (±1.00)	**0.0009**

Most of the measures were significantly different in the two groups. In the compliant group the mean thoracic Cobb angle, lumbar Cobb angle, worst Cobb angle, all apical rotations and scoliometer readings, all improved, whereas in the non compliant group these measures all deteriorated (p<0.0001). The worst Cobb angles in the compliant group improved 10.19° (±5.5) and deteriorated 5.52° (±4.3) in the non compliant group. Scoliometer readings show that the compliant group significantly improved cosmetically, compared to the non compliant group. The compliant group improved their peak flow significantly, by a mean of 20 percent, compared to the non compliant group, which improved by nine percent (p=0.04). The compliant group wore the brace for a significantly longer period than the non compliant group, in which three went to surgery before skeletal maturity was reached.

Compliant and non compliant groups were compared in the change from baseline to end point measures in the two different curve types, Double Major curves (31) and Thoracic Curve Types, with respect to Cobb angles and apical rotation. These curve types are presented below in Table 5.18 and 5.19.

Table 5.18 Change in data, baseline to end, in Double Major Curves in compliant and non compliant groups (T + L and T + TL). (n=47)

Measure	Group	n (%)	Mean (±SD)	p Value
All Thoracic Cobb angles (degrees)	Compliant (n=26) Non Compliant (n=21)	14 (54) 17 (81)	6.64 (±4.55) -5.77 (±7.12)	<0.0001
All Lumbar Cobb angles (degrees)	Compliant Non compliant	14 (54) 17 (81)	7.43 (±5.09) -3.18 (±5.28)	<0.0001
All (Thoracic) Rotation Apical Vertebra	Compliant Non compliant	14 (54) 17 (81)	2.86 (±5.08) - 3.24 (±7.28)	0.04
All (Lumbar) Rotation Apical Vertebra	Compliant Non compliant	14 (54) 17 (81)	6.42 (±7.19) - 1.29 (±4.15)	0.0009

Mean thoracic and lumbar Cobb angles, and their respective apical rotations all significantly improved from baseline to endpoint in the compliant group and all deteriorated in the non compliant group.

Table 5.19 Change in data, baseline to end, in Thoracic Type Curves in compliant and non compliant groups.(n=47)

Measure	Group	n (%)	Mean (±SD)	p Value
All Thoracic Cobb angles (degrees)	Compliant (n=26) Non Compliant (n=21)	9 (35) 4 (19)	12.56 (±7.07) -6.00 (±6.68)	**0.004**
All (Thoracic) Rotation Apical Vertebra	Compliant Non Compliant	9 (35) 4 (19)	8.67 (±9.07) -6.25 (±7.50)	**0.01**

There was a significant improvement in thoracic Cobb angle change of 12.56° in the compliant group compared to the non compliant group which deteriorated six degrees in Thoracic type curves. Apical rotation improved in the compliant group and deteriorated in the non compliant group.

For all subjects who had two curves, compliant and non compliant groups were compared with respect to the observation vector (thoracic Cobb angle; lumbar Cobb angle) change from baseline to the endpoint of the study. The between group comparison of subjects with two curves are presented in Table 5.20 below. Thoracic apical rotations and lumbar apical rotations are included.

Table 5.20 Change from baseline to end point, subjects with two curves, were compared between groups with respect to vector (thoracic Cobb angle; lumbar Cobb angle).(n=47)

Measure	Group	n (%)	Thoracic mean (±sd)	p- value t-test	Lumbar mean (±sd)	p-value t-test	Hotelling T^2 p-value
Cobb angle (degrees)	Compliant (n=26) Non-compliant (n=21)	18 (69) 19 (90)	6.83 (±4.35) - 5.63 (±7.06)	0.0000	6.94 (±5.09) -3.10 (±4.98)	0.0000	**<0.0001**
Apical Rotation (degrees)	Compliant Non-compliant	18 (69) 19 (90)	4.33 (±7.65) -3.68 (±7.42)	0.02	5.00 (±6.86) -1.00 (±3.93)	0.001	**<0.0001**

There were significant differences between compliant and non compliant subjects with two curves at the end of the study. Mean thoracic and lumbar Cobb angles, and their apical rotations, improved significantly in the compliant group and deteriorated in the non compliant group, when adjusted for baseline. Hotelling's T^2 p value for the vector (thoracic Cobb angle; lumbar Cobb angle) showed a significant improvement in the compliant group compared to the non compliant group for mean Cobb angles ($p<0.0001$) and apical rotations ($p<0.0001$).

5.5 Change in Curve Data from Baseline to Endpoint Within a Group

The difference between baseline (0) and endpoint (1) measurements within groups (compliant and non compliant) respectively was compared. The measurements within the groups are presented on the next page in Table 5.21A and Table 5.21B, on page 125.

Table 5.21A Difference between baseline (0) and end (1) within groups (compliant and non compliant) respectively. (n=47)

Measure	Group	n (%) (0)= baseline (1) = at end	Mean (±SD)	p Value
All Thoracic Cobb angles (degrees)	**Compliant (n=26)**	(0) 25 (96) (1) 25 (96)	34.36 (±9.61) 25.4 (±8.67) **= +8.96**	**<0.0001**
All Thoracic Cobb angles (degrees)	**Non compliant (n=21)**	(0) 21 (100) (1) 21 (100)	28.76 (±9.61) 34.57 (±9.71) **= - 5.81**	**0.0009**
All Lumbar Cobb angles (degrees)	**Compliant**	(0) 19 (73) (1) 19 (73)	28.21 (±9.70) 21.10 (±7.80) **= +7.11**	**<0.0001**
All Lumbar Cobb angles (degrees)	**Non compliant**	(0) 19 (90) (1) 19 (90)	26.05 (±8.16) 29.73 (±10.03) **= -3.68**	**0.006**
All (Thoracic) Rotation Apical Vertebra	**Compliant**	(0) 26 (100) (1) 26 (100)	16.27 (±10.82) 11.34 (±7.29) **= +4.93**	**0.001**
All (Thoracic) Rotation Apical Vertebra	**Non compliant**	(0) 21 (100) (1) 21 (100)	10.24 (±8.44) 14.05 (±9.03) **= -3.81**	**0.03**
All (Lumbar) Rotation Apical Vertebra	**Compliant**	(0) 26 (100) (1) 26 (100)	8.46 (±9.88) 4.81 (±6.55) **= +3.65**	**0.005**
All (Lumbar) Rotation Apical Vertebra	**Non compliant**	(0) 21 (100) (1) 21 (100)	10.47 (±8.20) 11.52 (±10.09) **= -1.05**	0.21
Worst Cobb angle (degrees)	**Compliant**	(0) 26 (100) (1) 26 (100)	35.58 (±7.69) 25.38 (±8.33) **= +10.19**	**<0.0001**
Worst Cobb angle (degrees)	**Non compliant**	(0) 21 (100) (1) 21 (100)	31.19 (±8.02) 36.71 (±9.30) **= -5.52**	**<0.0001**
Worst Apical Rotation (degrees)	**Compliant**	(0) 26 (100) (1) 26 (100)	18.96 (±10.31) 11.54 (±7.97) **= +7.42**	**<0.0001**
Worst Apical Rotation (degrees)	**Non compliant**	(0) 21 (100) (1) 21 (100)	14.29 (±8.11) 17.95 (±9.03) **= -3.67**	**0.02**

Within the compliant group, the difference between baseline and the end of the study was that all the mean Cobb angles, apical rotations and worst Cobb angles all improved significantly and decreased in size. In the non compliant group, the Cobb angles, apical rotations and worst Cobb angle almost all deteriorated significantly and increased in size. The worst Cobb angle decreased significantly in size by 10.19° within the compliant group and increased significantly in size by 5.52° within the non compliant group.

Table 5.21B Difference between baseline (0) and end (1) curve data within groups (compliant and non compliant) respectively. (n=47)

Measure	Group	n (%) (0) = at baseline (1) = at end	Mean (±SD)	p Value
Kyphosis angle (degrees)	**Compliant (n=26)**	(0) 5 (19) (1) 5 (19)	30.4 (±11.33) 34 (±7.14) **= +3.6**	0.31
Kyphosis angle (degrees)	**Non compliant (n=21)**	(0) 2 (10) (1) 2 (10)	23.5 (±2.12) 22.5 (±10.61) **= - 1**	0.89
Lordosis angle (degrees)	**Compliant**	(0) 4 (15) (1) 4 (15)	46.25 (±13.15) 44.75 (±11.84) **= 1.5**	0.75
Lordosis angle (degrees)	**Non compliant**	(0) 2 (10) (1) 2 (10)	31 (±9.90) 34 (±15.56) **= -3**	0.89
Thoracic, scoliometer Reading (degrees)	**Compliant**	(0) 26 (100) (1) 26 (100)	9.96 (±3.58) 7.5 (±3.73) **= + 2.46**	**<0.0001**
Thoracic, scoliometer Reading (degrees)	**Non compliant**	(0) 21 (100) (1) 21 (100)	9 (±5.89) 8.67 (±5.12) **= 0.33**	0.71
Lumbar, scoliometer Reading (degrees)	**Compliant**	(0) 26 (100) (1) 26 (100)	5.04 (±4.85) 1.38 (±2.47) **= + 3.65**	**<0.0001**
Lumbar, scoliometer Reading (degrees)	**Non compliant**	(0) 21 (100) (1) 21 (100)	4.48 (±3.52) 4.67 (±4.04) **= - 0.19**	0.76
Peak Flow (l/min)	**Compliant**	(0) 26 (100) (1) 26 (100)	314.15 (±59.78) 377.46 (±53.59) **= + 63.31**	**<0.0001**
Peak Flow (l/min)	**Non compliant**	(0) 20 (95) (1) 20 (95)	347.1 (±67.36) 378.25 (±59.07) **= + 31.15**	**0.007**

Kyphosis and lordosis angles did not change significantly within either group from baseline to the end of the study. Within the compliant group the thoracic and lumbar scoliometer readings improved significantly from baseline to endpoint, however not within the non compliant group. The peak flow improved significantly within both the compliant group and non compliant groups.

5.6 Brace Questionnaire

A quality of life questionnare, the Brace Questionnaire (BQ), was administered after a minimum of one year of wearing the brace. The results of the questionnaire comparing compliant and non compliant groups are presented in Table 5.22 below and also in a figure in Appendix XIV, page 239.

Table 5.22 Brace Questionnaire results.(n=45)

Measure	Group	n (%)	Mean (±SD)	p Value
Total Brace Questionnaire Score	Compliant (n=26) Non Compliant (n=19)	26 (100) 19 (100)	81.65 (±10.65) 69.52 (±12.25)	0.001
Domains				
General Health Perception	Compliant Non Compliant	26 (100) 19 (100)	8.12 (±1.73) 6.89 (±2.26)	0.04
Physical Function	Compliant Non Compliant	26 (100) 19 (100)	29.85 (±3.18) 25.95 (±5.05)	0.003
Emotional Function	Compliant Non compliant	26 (100) 19 (100)	18.58 (±3.84) 15.89 (±5.37)	0.05
Self Esteem	Compliant Non compliant	26 (100) 19 (100)	7.85 (±1.38) 6.26 (±2.02)	0.003
Vitality	Compliant Non compliant	26 (100) 19 (100)	7.92 (±1.26) 6.00 (±2.08)	0.0004
School Activity	Compliant Non compliant	26 (100) 19 (100)	13.42 (±1.77) 12.11 (±2.23)	0.03
Bodily Pain	Compliant Non compliant	26 (100) 19 (100)	25.57 (±3.75) 22.52 (±3.96)	0.01
Social Function	Compliant Non compliant	26 (100) 19 (100)	26.34 (±5.15) 23.16 (±6.42)	0.07

Two subjects in the non compliant group did not complete the BQ, due to lack of interest and thus there are 19 subjects in the non compliant group. Higher scores in the BQ mean a better quality of life. The compliant group had significantly higher scores and therefor had a significantly better quality of life than the non compliant group. These results are also shown in Appendix XIV, Figure 7.17.

The compliant group had significantly more energy and vitality than the non compliant group (p=0.0004) and they had better physical functioning in the brace during normal daily activities. The compliant group had significantly better self esteem than the non compliant group. The questions in this domain indicate that the compliant group were more satisfied with their bodies than the non compliant group. The non compliant group had significantly more pain with wearing the brace. School activity in the compliant group was significantly higher than the non compliant group (p= 0.03) and the questions in this domain indicate that in the non compliant group, wearing the brace affected paying attention in the classroom and they had difficulties in lessons. The compliant group had a significantly better general health perception than the non compliant group (p=0.04). The non compliant group had seen themselves as being more sickly than the compliant group. The compliant group's emotional functioning was better than in the non compliant group, therefor according to the questions in this domain, the compliant group was happier than the non compliant group and believed the brace to be beneficial. In the Social Function domain, however the scores were marginally significantly higher in the compliant group. Higher scores in this domain indicate subjects could always go out with their friends, did not feel different to their peers and had few problems with their family. All subjects in both groups of this domain said that special clothes had to be worn to cover the brace.

5.7 High School Personality Questionnaire and 16 PF

The HSPQ and 16 PF, psychological tests, were done in the last year of fulltime brace wearing, before weaning was started. Questionnaires were administered and scored by a psychologist. The scores for the different factors are compared in the compliant and non compliant groups and are presented in Table 5.23, on the page below.

Table 5.23 HSPQ and 16 PF scores for Factors in the compliant and non compliant groups. (n=41)

Measure	Group	n (%)	Mean (±SD)	p Value
Factor A	Compliant (n=23) Non Compliant (n=18)	23 (100) 18 (100)	5.91 (±2.52) 6.78 (±2.65)	0.29
Factor B	Compliant Non Compliant	23 (100) 18 (100)	6 (±1.95) 5.72 (±1.99)	0.66
Factor C	Compliant Non Compliant	23 (100) 18 (100)	6 (±1.81) 5.22 (±2.10)	**0.098**
Factor D	Compliant Non compliant	21 (91) 15 (83)	4.42 (±2.04) 4.73 (±2.02)	0.66
Factor E	Compliant Non compliant	23 (100) 18 (100)	5.86 (±1.94) 6.94 (±2.87)	**0.07**
Factor F	Compliant Non compliant	23 (100) 18 (100)	5.86 (±2.56) 6.88 (±1.88)	0.17
Factor G	Compliant Non compliant	23 (100) 18 (100)	5.26 (±1.98) 4.56 (±2.31)	0.30
Factor H	Compliant Non compliant	23 (100) 18 (100)	5.87 (±2.28) 6.83 (±1.79)	0.15
Factor I	Compliant Non compliant	23 (100) 18 (100)	5.48 (±1.68) 4.61 (±1.61)	**0.06**
Factor J	Compliant Non compliant	21 (91) 15 (83)	5.66 (±1.71) 5.86 (±2.61)	0.78
Factor O	Compliant Non compliant	23 (100) 18 (100)	4.78 (±2.24) 4.67 (±1.81)	0.86
Factor Q_2	Compliant Non compliant	23 (100) 18 (100)	5.52 (±1.88) 5.56 (±2.09)	0.84
Factor Q_3	Compliant Non compliant	23 (100) 18 (100)	4.74 (±1.96) 4.22 (±1.96)	0.41
Factor Q_4	Compliant Non compliant	23 (100) 18 (100)	4.57 (±1.99) 5.5 (±1.76)	**0.099**
Extraversion	Compliant Non compliant	23 (100) 18 (100)	5.68 (±1.65) 6.31 (±1.71)	0.24
Anxiety	Compliant Non compliant	23 (100) 18 (100)	5.15 (±1.28) 5.50 (±1.15)	0.36

The questionnaires were completed by 23 subjects in the compliant group and 18 in the non compliant group. The majority of subjects (36) completed the HSPQ. Two subjects in the compliant group completed the 16PF and three subjects in the non compliant group completed the 16PF as they were 18 years when completing the questionnaire. In Factor D and J there are only 21 subjects in the compliant group and 15 in the non compliant group as these factors were not in the 16PF questionnaire (for those 18 years and over). There was only a marginally significant difference (p value is in bold in Table 5.23) between compliant and non compliant groups in Factors C, E, I and Q_4.

Factor C in the compliant group had a marginally significantly higher score than the non compliant group (p=0.098). The higher score description in the questionnaire reflects that the compliant group was marginally more 'emotionally mature, stable and realistic' than the non compliant group, who were more towards the 'emotionally immature and unstable' scores, but the difference is minimal.

Factor E in the compliant group had a marginally significantly lower score than the non compliant group (p = 0.07). The lower score reflects that the compliant group was marginally more 'obedient, mild and dependant' than the non compliant group, who were more towards the 'assertive, aggressive, rebellious, dominance' score.

Factor I in the compliant group had a marginally significantly higher score than the non compliant group (p = 0.06). The higher score reflects that the compliant group was marginally more 'tender minded, sensitive, protected' than the non compliant group, who were more towards the 'practical, tough minded' score.

Factor Q_4 in the compliant group had a marginally significantly lower score than the non compliant group (p=0.099). The lower score reflects that the compliant group were marginally more 'relaxed, composed' than the non compliant group, who were more towards the 'tense, driven, irritable' score, but the difference is minimal.

Therefor in summary:

Compliant Group were marginally more: emotionally mature, stable and realistic; obedient, mild and dependant; tender minded, sensitive, protected and relaxed, composed.

Non Compliant Group were marginally more: emotionally immature and assertive; aggressive, rebellious, dominance; practical, tough minded and tense, driven, irritable.

As a result of the personality factor traits being marginally significantly different between the compliant and non compliant groups, the groups were then compared after categorizing the trait scores as:

Low sten scores (1,2 &3) = Category 1

Average sten scores (4,5,6,7) = Category 2

High sten values (8,9 &10)= Category 3

The only significant difference was found in Factor C. The results comparing compliant and non compliant groups in the different categories are shown below in Table 5.24.

Table 5.24 Factor C, category differences in compliant and non compliant groups. (n=41)

Factor Category	Compliant n (%)	Non Compliant n (%)	Total	p Value
1 Low score	0 (0.00%)	3 (16.67%)	3 (7.32%)	**0.03**
2 Average Score	14 (60.87%)	13 (72.22%)	27 (65.85%)	
3 High score	9 (39.13%)	2 (11.11%)	11 (26.83%)	
Total	23 (100.00%)	18 (100.00%)	41 (100.00%)	

There was a significant difference between compliant and non compliant groups (p=0.03) for Factor C only after categorizing the trait scores. The compliant group had no subjects in the low sten score category, but had significantly more in the average and high sten scores, compared to the non compliant group where most of the subjects were in the low and average sten score category. After categorizing the trait scores the compliant group was significantly more emotionally mature, stable and realistic than the non compliant group. The non compliant group was significantly more emotionally immature and unstable.

5.8 Conclusion

The intervention of a specific set of exercises and an RSC brace was used on AIS subjects with a high risk of curve progression. After dividing the subjects into those who were compliant and those who were non compliant at the end of the study, the groups were found to be well matched at baseline. The compliant group had significantly reduced curves, reducing the risk of going to surgery, whereas in the non compliant group the curves significantly increased, increasing the risk of surgery. Three subjects in the non compliant group had to have surgery, as the curves became too large. The sagittal profile, kyphosis Cobb angles, were significantly larger and within normal limits in the compliant group compared to the non compliant group, which were smaller and below normal limits at the end of the study.

During the study the Cobb angles, apical rotations and scoliometer readings all significantly improved in the compliant group compared to the non compliant group, which significantly deteriorated. The scoliometer readings, rib hump deformity (cosmetic), improved significantly in the compliant group compared to the non compliant group. Lung function, peak flow readings improved significantly in the compliant group compared to the non compliant group during the study.

The Brace Questionnaire, revealed that the compliant group had a significantly better QoL than the non compliant group. The personality questionnaire, HSPQ and 16 PF, a psychological test, was administered and showed that the compliant group were significantly more emotionally mature, stable and realistic than the non compliant group after categorizing the personality trait scores.

All findings will be discussed in more detail in the following chapter.

Chapter 6

DISCUSSION

The results of this study will be discussed in detail in this chapter. The main outcomes will be discussed, with possible reasons for the results. Clinical implications and research implications will be presented. Factors affecting compliance and the exercises that were given to subjects will be discussed. Challenges occurring during the research will also be included.

6.1 Significance of this Study

With treating IS conservatively the outcome can be altered with appropriate intervention. There is some evidence in the literature that scoliosis is reversible (Harrington, 1976; Mehta, 1984; Hawes and O'Brien, 2006). The results of this study indicate that compliance to a specific exercise programme and wearing the RSC brace can significantly improve AIS curvatures and signs and symptoms of AIS, thus supporting the hypothesis of this study. The natural history of scoliosis was altered in the compliant subjects. Non-compliance resulted in significant progression of the curvatures. This result possibly explains the controversy in the past, when some studies showed that conservative management of bracing and exercise had no effect on the natural history of scoliosis and some studies showed that conservative management was effective (Hawes, 2002). Compliance was not reported on in these studies. Some studies could possibly have had more compliant subjects than others and therefor future studies should monitor and present compliance achieved. The importance of compliance is supported by Landauer et al (2003). The type of brace used in previous studies and the nature of the exercises also would have affected the results. Different braces and different exercises have different results, as presented in chapter 2.9.3 and 2.11.3. The conservative programme presented in this thesis can be offered to patients all over South Africa and is suitable for those who cannot attend regular therapy, as patients only have to see the physiotherapist and brace technician once a month and sometimes only every three months.

6.2 Outcome Measures: Progression Risk and In- Brace Correction

The risk of progression of the curvatures in both groups of subjects was high, 70-78 percent, according to the Lonstein progression factor (Lonstein, 1988) presented in Chapter 2.4. The larger the curve and the younger the child the greater the risk of progression of the curve. According to the natural history of scoliosis these curvatures could have progressed to large curvatures, with large deformities, which come with pain later in life. In the compliant group the mean in-brace correction was 44.5 percent and the non compliant group was 35.8 percent, not statistically different however, but better in the compliant group. Compliance and initial correction effect in the brace are the two most important variables associated with good brace outcomes (Landauer et al, 2003; Weiss, 2003; Weiss and Rigo, 2008B). When the in-brace correction is good, the results of bracing are successful (Hopf and Heine, 1985; Kessler and Bowman, 2007; Weiss and Rigo, 2011). In-brace correction is multifactorial and dependant on curve pattern, age, sex, Cobb angle, stiffness of the curve and input of the brace technician (Landauer and Hofstadter, 2007; Weiss et al, 2007). The Cobb angle sizes at baseline were different, presented in Table 5.2. on page 109. The compliant group had larger curves at baseline, therefor higher risk of progression and better in-brace correction.

Rigo has reported in-brace corrections of 41.5%, similar to this study, and this was improved on by technical intervention (Rigo, 2007). He later reported corrections of greater than 45% (Rigo et al, 2009) and after a year, correction of vertebral wedging in the apex was ≥ 50%. The largest in-brace correction was reported, by Rigo and Gallo (2009). This was 76.7% in the study group, however no long term results of this study were presented, only good outcomes were predicted. Kotwicki et al (2002), have also reported a high in-brace correction of 67 percent in the Cheneau brace, with a 52 percent correction of apical rotation. These studies are presented in Table 2.7. on page 52. The reason for the good in-brace correction in this study (44.5 and 35.8 percent) is probably the good three dimensional design of the RSC brace (Wood, 2003). The strategically placed pressure points with the large expansion rooms provide space for correction of many aspects of the deformity.

A study by Landauer et al (2003), with tight inclusion criteria, namely female subjects with right thoracic scoliosis of 20-40 degrees, supports the results of this study. They advised full time Cheneau bracing, 23 hours per day and weaned the subjects at Risser 5 over a six month period, which was shorter than the weaning process of this study. At a six month follow-up of being out the brace they found, that girls with high early in-brace correction (40% or more) and good compliance achieved a correction of seven degrees in the Cobb angle. These results compare with this study's in-brace correction in the compliant group of 44.5 percent and a mean improvement of 12.56 degrees Cobb angle in Thoracic type curves. Landauer et al (2003) also showed that a low early correction (less than 40 %) and good compliance resulted in stabilisation of the curvatures. They also showed that poor compliance with a high or a low initial correction resulted in progression of the Cobb angle, close to the natural history of IS. This compares with this study's results in the non-compliant group, which had an in-brace correction of 35.8 percent and the thoracic curves progressed six degrees. The in-brace correction in the non-compliant group was only measured on 16 subjects, (there were 21 in the group). Therefor the in-brace correction could have been higher in this group, had all the subjects had an in-brace X-ray initially. The study by Landauer et al (2003) shows the final overall outcome of their study, including all subjects, was that the thoracic curve improved three degrees. This was not a successful result, however when the subjects in their study were divided into compliant and not compliant groups, then the study was very successful as the compliant group improved seven degrees (Landauer et al, 2003). The importance of evaluating compliance is emphasised in their study and it is more important than in-brace correction. In-brace correction is an indicator for brace action, but not always the most important factor (Weiss and Rigo, 2008B).

The in-brace correction of the non compliant group in this study is similar to a study by Maruyama et al (2011) on the RSC brace. Their early results showed an in-brace correction of 36 percent, however their subjects had not completed wearing the brace at the end of the study. Rigo et al (2002) have shown however, that a low in-brace correction of 31 percent and a large Cobb angle, with a bad prognosis can result in favourable results, and reduction in progression of the curves. Weiss and Rigo (2011) recommend that one should aim at an in-brace correction of more than 40 percent, however not all curves can be corrected to the same extent. The Boston brace has shown an in-brace correction of 30 percent (Willers et al, 1993).

Clinical Implications.

- In-brace X-rays should be done initially in the treatment programme to assess the in-brace correction. The technician's input is important to achieve a good in-brace correction. A good in-brace correction has been shown to have good results.
- An in-brace correction of 44 percent, which is a good correction, in the compliant group had favourable results at the end of this study.

Research Implications.

- All future studies on conservative management of AIS should include measures of compliance to improve the quality of studies.

6.3 Hours of Brace Wearing

The compliant group wore the brace 21.5 hours per day, significantly more than the non compliant group, who wore the brace 12.2 hours per day. Initially at the first visit, 23 hours of brace wearing was recommended to all subjects. The most commonly recommended wear time is 23 hours, however this is based on intuition and not on any objective data (Lou et al, 2008). Cheneau brace principles are to wear the brace 20 hours per day (Cheneau, 2003). Many Cheneau brace studies do not mention the number of hours the brace was worn (Rigo, 1999; Kotwicki et al, 2002; Wood, 2003; Gallo et al, 2011). Good brace compliance has been shown by a few studies to have good outcomes (Edgar, 1998; Goldberg et al, 2001; Landauer et al, 2003; Rahman et al, 2005). The compliant group in this study had a significant improvement in Cobb angles, angle of rotation and ATR, by wearing the brace 21.5 hours per day. Wearing the brace for 12 hours in the non compliant group resulted in progression of the curvatures. This study's results compare with the study by Landauer et al (2003) using the Cheneau brace, in which they also prescribed wearing the brace 23 hours and compliant subjects' Cobb angles improved seven degrees. They did not state in their study how many hours the brace was actually worn, however, they did use a compliance score. The score (1-5) consisted of five items, which indicated the level of compliance, ranging from 0 (worst compliance) to 5 (best compliance). Another Cheneau brace study prescribed 20 hours of brace wearing and resulted in preventing progression, and so stabilisation of 48 percent of subjects (Zaborowska-Sapeta et al, 2011). The actual brace hours were not measured. Kinel et al (2007) showed wearing the Cheneau brace a minimum of 16 hours per day, resulted in less clinical deformity than in an untreated group (Kinel et al, 2007A). Wearing the Cheneau brace 11.9± 5.5 hours per day, which is a lot less than this study, however similar to the non compliant group, resulted in a stabilisation of 56 percent of subjects in a study by Durmala et al (2010).

Actual brace wearing hours were measured by a temperature sensor in the Wilmington scoliosis brace and compared to progression of curves by Rahman et al (2005). They found that the compliance rate was 62 percent in those curves that progressed more than five degrees and compliance was 85 percent in those curves that did not progress. Some Boston brace studies have stated that the number of hours the brace is worn significantly influences the outcome (Wiley et al, 2000; Katz and Durrani, 2001; Katz et al, 2010). They found that wearing the brace over 18 hours per day increased the likelihood of success, which supports this study, and halted long term progression for 9.8 years after bracing had been discontinued. Another Boston brace study by Edgar (1998) however, stated that 16 hours per day was the optimum value as there needs to be a balance between effectiveness of brace correction and tolerance to bracewear, and that best curve corrections occur in those who wear the brace for the greatest time each day.

Recording the brace wearing hours was one of the challenges of this study. Parents checked the subjects' diaries once a week to see if recordings matched what the parents observed, and therefor recording of hours was also dependant on parents' input. Subjects had an appointment with the researcher once a month, when diaries were checked and subjects were asked about brace wearing hours. The researcher also then checked with the parents that the contents of the diaries were correct. If the subjects were not compliant about wearing the brace, the researcher was gentle in finding out what was affecting their compliance. The researcher wanted them to be honest about their brace wearing hours and to assist them improve their compliance. The brace hours recorded, and reported were therefor not physically measured.

A study by Takemitsu et al (2004) showed that patients complied with 75 percent of a prescribed routine and on average overreported their hours of brace wear to their physician (Takemitsu et al, 2004). Actual brace hours were measured using a compliance monitor. Contrasting this study is a study by Donzelli et al (2011) in which they used a temperature sensor (Thermobrace) and showed compliance to be higher than previously reported (Donzelli et al, 2011). Brace prescription was 16-23 hours per day and more than half the patients had 90 percent compliance. The researcher tried to get accurate recordings by seeing the subjects and parents as often as, once a month, and taking scoliometer readings at each visit. If they had been out the brace more than usual, then this could be seen with the scoliometer readings. This occurred for instance when they went on holiday or were sick and brace hours were decreased, scoliometer readings were then increased. Subjects were informed that non compliance could be ascertained by the scoliometer readings. Some parents informed the researcher that the subjects were very aware of this fact and it motivated them not to allow the readings to get worse. The researcher found that the very compliant subjects who wore the brace for 23 hours, did not like to take the brace off, as they felt uncomfortable and occasionally if it was off too long they had some pain. Using a compliometer or thermobrace, not currently used in South Africa, would have been more accurate in measuring actual brace wearing hours.

Clinical Implications.

- The more the brace is worn during the day, the better the results. Wearing the brace 21.5 hours a day resulted in an improvement in Cobb angle, apical rotation, ATR and peak flow. Wearing the brace less than 21.5 hours a day results in stabilisation or progression of the curves. Therefor the researcher recommends wearing the brace at least 21.5 hours per day. Patients need to understand this result, at the beginning of treatment and need to be constantly reminded of the consequences of brace wearing hours during the treatment procedure.

Research Implications.

- Studies need to include actual brace wearing time using a compliometer or a temperature sensor as compliance to wearing a brace leads to better results. The results from the compliometer need to be compared with what the patients' report.
- Brace manufacturers need to prescribe brace wearing hours on research evidence and include a compliometer in their structural design.

6.4 Exercise Programme and Exercise Sessions per Week

The treatment aims in the specific management programme were presented in Chapter 4.6.2. Patient and family education occurred mostly in the first visit, however education was an ongoing process. An aim of the researcher's exercises was to achieve stability, alignment around the sacrum, pelvis and hip joints. Scoliosis is a condition strongly aggravated by gravity (Zetterberg et al, 1983) and the researcher's aim was to keep the base of the spine stable and aligned, to prevent postural collapse above. Another reason for stabilising the sacral base was that many of these subjects have vestibular problems (Gauchard et al, 2001; Provencher et al, 2003; Lamantia et al, 2007) and their balance and stability would have been affected. The exercise programme given to the subjects is described in Appendix XI, page 228 and justification for these exercises is in Appendix X on page 218.

Clinical Implications.

- The exercises prescribed in this study can be done without supervision at home, as long as subjects visit the physiotherapist once a month for correction and feedback. The exercises are not difficult and are recommended as they can be included in a busy school schedule.

Research Implications.

- A study needs to be done on the effect of these exercises alone, on subjects with smaller Cobb angles not requiring bracing. The advantage of these exercises is that many can be given to subjects, as young as four years of age. This needs to be investigated in future research as not many methods address or are suitable for infantile scoliosis.

The compliant group completed the regime of exercises 3.9 times per week and the non compliant group exercised 1.7 times a week. Exercising four to five times a week, for 20-25 minutes was recommended. This recording was quite accurate as the parents were asked to check, when the exercises were done, and subjects had to record them in their diaries. The compliant group all improved their curvature measures. If the exercise regime in this study is compared with Scroth method, after SIR, they recommend less exercises, four exercises, done for 30 minutes at home daily (Weiss, 2006). Schroth exerecises are therfor done more often, but about for the same period of time as in this study. The Dbosiewicz Method of exercises (Dobosiewicz et al, 2008) and the Side Shift Method of exercises (Maruyama et al, 2002) are done daily. In the SEAS method exercises are done twice a week for 45 mins (8-10 exercises) or daily for 15 minutes. The exercises in this study, took subjects 20-25 minutes to complete. The researcher has previously found that longer than 25 minutes resulted in patients losing concentration, and compliance could have been affected. This period of time also suited their school day, as their afternoons were filled with various activities, such as homework, extra-lessons and sport.

The American College of Sports Medicine recommends that adults with chronic diseases or disabilities, should exercise to develop and maintain cardiorespiratory and muscular fitness (Garber et al, 2011) and also recommend exercise for spinal conditions, such as arthritis and low back pain. They recommend moderate cardiorespiratory exercise training ≥ 30 minutes per day on ≥ 5 days a week (walking, cycling, swimming) vigorous- intensity cardiorespiratory training ≥ 20 minutes, on ≥ 3 days per week and resistance training (strength training) 2-3 days a week (Garber et al, 2011). Strength training in adolescence of resistance exercise using own body weight, balls, bands is recommended 2-3 times a week, performing 1-3 sets of 10-15 repetitions, 6-8 exercises initially by the American Academy of Pediatrics (Benjamin and Glow, 2003). These studies support the volume and type of exercises that were given to the subjects in this study. A comprehensive literature review on 850 papers showed that adolescence should participate daily in 60 minutes or more of moderate to vigorous physical activity that is enjoyable and involves a variety of activities, including aerobic and resistance activities (Strong et al, 2005) to maintain cardiovascular and muscular fitness.

Clinical Implications.

- As exercising 3.9 times a week improved the curvatures, the researcher recommends prescribing the exercise regime four to five times a week. During the weaning phase of the brace, in eight subjects the curvatures did not progress and therefor the same amount of exercise or more if possible should be prescribed during weaning.

Research Implications

- Completing the regime of exercises four to five times a week with additional cardiovascular exercise, such as swimming and cycling, three times a week for 30 minutes needs to be investigated.

6.5 Cobb Angle Changes

The Cobb angles were significantly reduced in the compliant group, thus the natural history of AIS was altered. In the non compliant group there was significant progression of the curvatures, following the natural history of scoliosis and three progressed to surgery. In the compliant group the worst/major Cobb angle significantly improved, a mean of 10.19 degrees and the non compliant group progressed 5.5 degrees.

Supporting this study is the study by Landauer et al (2003) already described above and the results of a small study by Wood (2003) on 23 subjects, with Cobb angles greater than 30 degrees, using the Cheneau brace during a four year period (Wood, 2003). Progression risk was 68 percent in these subjects. Compliance was not measured in the Wood study however, and the subjects' physiotherapy was not explored or described. Wood (2003) showed that the major Cobb angle improved a mean of 13.2 degrees and the minor Cobb angle improved eight degrees at the end of brace wearing. Physiotherapy has been shown to have favourable outcomes in scoliosis patients and Rigo claims that physiotherapy can improve the actions of the Cheneau brace, by making the curve more flexible and preventing muscle atrophy (Rigo, 1996; Rigo, 1999).

Cinnella et al (2009) using the Cheneau brace showed a 23 percent correction in Cobb angle at the end of a mean treatment period of 4.5 years, and after five years the correction was 15 percent. Compliance was not monitored in their study however. All other studies on the Cheneau and RSC braces show stabilisation of curvatures and reduction in children requiring surgery (Rigo et al, 2002; Weiss et al, 2003; Weiss et al, 2003B; Maruyama et al, 2007; Pham et al, 2007; Durmala et al, 2010; Zaborowska-Sapeta et al, 2011).

When comparing the RSC brace studies to other brace studies, such as the Boston brace, compliance is not measured or described. A prospective study by Nachemson and Peterson (1995) shows that the Boston brace alters the natural history of AIS in the short term, stabilising the curves. A long term study by Lange et al (2009) on 109 subjects in the Boston brace showed an improvement of five degrees in Cobb angle at the start of weaning and then at a 19 year follow up 86 subjects had the same size Cobb angle as at the start of bracing, thus altering the natural history of scoliosis. Six subjects had large progressions at follow-up, but no reasons are given for this. Milwaukee brace studies show that the brace alters the natural history of scoliosis, preventing progression in most cases (Lonstein and

Winter, 1994), however some curves still progress with 22 percent progressing to surgery in the Lonstein and Winter (1994) study. Compliance was measured in this study by a questionnaire sent to all subjects. Out of 1020 subjects only 283 replied, and 89 percent of these wore the brace 20 hours or more per day. Therefor many questionnaires were not returned possibly because of non compliance, which was not stated by the authors. The study did however show that single thoracic curves had a better outcome than double curves, which is similar to this study, in which Thoracic Type curves had a better Cobb angle improvement than the Cobb angle improvement in the Double Major type curves. Double curves nearly always progress more than single curves (McMaster, 1985; Weinstein, 1999).

The reason for the improvement in the Cobb angles in the compliant group in this study is possibly because of the structure of the brace and the nature of the exercises. The RSC brace achieves maximum deflection by optimum location and shape-direction of the pressure areas. Deflection is corrected in the frontal plane by translation of different sections of the trunk and the three- point pressure system. Pressure at the apex of the curve plays an important role. As described previously Cheneau (1996) reported that curve pressure is placed two vertebra above and two vertebras below the apex of the thoracic curve and one vertebra above and one below the apex of the lumbar curve to achieve maximum coronal plane correction (Cheneau, 1996; Wood, 2003). The expansion areas of the brace allow small voluntary and involuntary movements and allow for the patients' own growth, which provides an active mechanism of correction. In the thoracic region, the expansion room allows space for respiratory movement and active correction in the direction of derotation and reduction of flatback, improving the kyphosis. In the lumbar area of the brace, pressure comes from the ventral aspect of the brace and extends between 25 percent from the posterior midline to crossing over the midline, depending on the lumbar lordosis of the patient. The Cheneau brace takes into account the sagittal plane deformity and the pelvis rotation (Cheneau, 1996; Wood, 2003). The RSC brace allows sagittal normalisation because of its physiological profile in the sagittal plane and every trunk section is aligned to allow a normal sagittal profile (Rigo, 1999; Rigo and Weiss, 2008).

Clinical Implications.

- Compliance to a conservative treatment programme resulted in a significant improvement in the Cobb angles and the natural history of scoliosis was altered, decreasing the risk of surgery. Surgery alone has been shown to improve Cobb angles in the past. The subjects in this study had non-invasive therapies to stabilise or reverse scoliosis before it progressed to a deformity with lifelong difficulties with signs and symptoms. The compliant subjects in this study will perhaps have a better QoL later in life than they would have, if they had not had the treatment. Non compliance to a conservative treatment programme results in progression of Cobb angle, following the normal history of scoliosis. Early treatment is required to prevent functional curvatures becoming structural curvatures. The effects of compliance and non compliance on the Cobb angle must be explained to subjects at the beginning of their treatment programme and when discussing different treatment options, as the results are different.

Research Implications.

- This study shows that 21.5 hours of brace wearing and exercising three or more times a week in compliant subjects can improve the Cobb angle. Wearing the brace 12 hours and exercising less than three times a week, results in progression of the curve. Research is needed on the minimum number of hours in the brace that would be needed to stabilise the Cobb angle. The reason for this is that some subjects cannot wear the brace full time, without psychological support as it affects their quality of life. The QoL will be discussed later.
- Further studies are required to determine the long term effects of this exercise programme with 21.5 hours of brace wearing.

In this study, end of the study data, showed kyphosis Cobb angles were significantly higher ($p<0.05$) and within normal limits (34.3°±6.4) in the compliant group compared to the non compliant group, which were lower and below normal limits (21.5°±6.9). Kyphosis angles improved in the compliant group and deteriorated in the non compliant group, and therefor the sagittal profile improved in the compliant group. The compliant group is similar to several studies that show normalisation of kyphosis and lordosis with the Cheneau brace (Rigo, 1999; Kotwicki et al, 2002; Rigo, 2003). In many Cheneau brace studies however, the sagittal profile is not mentioned, presented or researched (Landauer et al, 2003; Wood, 2003; Rigo, 2007; Cinnella et al, 2009; Gallo et al, 2011; Zaborowska-Sapeta et al, 2011). Hypokyphosis and hypolordosis are factors of progression of scoliosis and are not initiating factors for scoliosis (Rigo et al, 2006B). The Boston and Milwaukee braces are associated with thoracic and lumbar flat back syndrome (Winter et al, 1975; Willers et al, 1993; Labelle et al, 1996; Aubin et al, 1997; Wong and Evans, 1998), which affects cosmesis and pulmonary function. Therefor there is not a full three dimensional correction associated with these braces, because of the decrease in sagittal profile. Loss of lumbar lordosis, and lumbar kyphosis is related to low back pain in adulthood (Glassman et al, 2005). Most studies on the Boston and Milwaukee brace have not assessed the sagittal profile (see studies in Table 2.8 on page 54).

Clinical Implications.

- Although the sample size was small, improved kyphosis in the compliant group at the end of the study, resulted in improved cosmesis and improvement in pulmonary function, which is evident in the significant improvement in the peak flow in the compliant group.
- Medical practioners in this country need to be informed on the importance of sagittal view assessment in the monitoring of scoliosis.

Research Implications.

- The sagittal profile must be assessed in all future studies, in order that correction assessment is done in all three planes and not just the frontal plane.

6.6 Apical Vertebral Rotation

Measurements of the vertebral rotation are important in the prognosis and treatment of scoliosis curves (Perdriolle and Vidal, 1985). Vertebral rotation increases with increasing Cobb angle and is a reflection of the severity of the deformity (Burwell et al, 1983; Leathermann and Dickson, 1988). The angle of axial rotation predicts the incidence of progression of a curve better than the size of the Cobb angle (Perdriolle and Vidal, 1987). In this study all apical vertebra were significantly reduced in rotation in the compliant group compared to the non compliant group, p<0.0001 in the worst/major curves. Most Cheneau brace studies do not present apical vertebral rotation changes, however the studies that do present the rotation changes and compare with this study, will be presented below.

This study's compliant group results are better than, but similar to the study by Wood (2003) already mentioned. Wood (2003) showed that after four years in a Cheneau brace the mean apical rotation in the major curves improved from a mean of 14.61 degrees to 10.74 degrees and the minor curves improved a little. A retrospective study on the Cheneau brace by Rigo et al (2002) on 105 IS subjects, showed stabilisation of the apical rotation with a mean follow-up of 16.8 months. Another Cheneau brace study on thoracolumbar curves only, found the best apical rotation correction of 52 percent was at 3-8 months after starting treatment (Kotwicki et al, 2002). Rigo (2003) presented a single case study of a 12.8 year old girl, with a 53 degree Cobb angle and 30 degree apical rotation treated with an RSC brace and Schroth exercises (Rigo, 2003). Five years after weaning, the major Cobb angle was 36 degrees, and the apical rotation was 20 degrees. There was a 10 degree improvement in worst apical rotation. Although this is only a single case study, it indicates what the RSC brace can do with exercise and supports the study presented here. The Rigo case study is noticable as the Cobb angle and apical rotation were very large, large enough for surgery. The RSC and the Cheneau brace has also been shown to improve the wedge deformity of the apical vertebra, by over 50 percent in some cases (Cheneau et al, 2009; Rigo et al, 2009).

The possible reason for the significant improvement in the apical vertebral rotation in the compliant group in this study is because of the structure of the brace and the nature of the exercises. The local derotation effect achieved at the apex of the curve in the brace is achieved by a pair of forces acting at the same level, by the pressure or pad areas of the brace (Rigo and Weiss, 2008). In a classic thoracic curve, derotation is achieved by two pads acting on the dorsal rib hump and on the ventral aspect of the concave ribs in the same transverse plane. The pads are orientated to produce simultaneous derotation and translation. The strategically placed pads with large expansion rooms allow for correction of the deformity. If the Cheneau brace is compared to the Boston brace, the pressure in the Cheneau is two vertebras above the apex and two vertebras below the apex of the curve, whereas in the Boston brace the pads are located only below the apex of the curve. When comparing this study to Boston brace studies, it is shown that the brace does not improve apical rotation, however the brace prevents progression of the apical rotation (Willers et al, 1993). Therefor the Boston brace does not correct in three dimensions (Rigo and Weiss, 2008) and the RSC brace does correct the deformity in three dimensions.

Clinical Implications.

- The subjects in the compliant group had a significant three dimensional correction of their deformity, whereas the non compliant group deteriorated.
- End of study data showed the worst apical rotation in the compliant group at 11.54 degrees (baseline was 18.96) and in the non compliant group significantly more at 17.95 degrees (baseline was 14.29). In the compliant group the apical vertebral rotation significantly decreased, decreasing the risk of progression later in life. The decreased rotation will lead to less progression, deformity, signs and symptoms of scoliosis later in life than the non compliant group. Quality of life later on in life may be affected by larger curves in the non compliant group (Bowen, 1995; Asher and Burton, 2006).

Research Implications.

- Studies need to include measurements of vertebral rotation, to present the three dimensional nature of curves, as very few studies include the measure. No extra X-rays are required for the measure.

6.7 Scoliometer Measurements

Scoliometer readings improved significantly in the compliant group compared to the non compliant group during the study. These results compare well with studies by Kinel et al (2007). In one of their studies of AIS girls with Cobb angles 25-40 degrees, wearing a Cheneau brace, revealed less clinical deformity than a group of non treated girls with similar radiological deformities (Kinel et al, 2007A). The Bunnell scoliometer was used to measure the deformity and the brace was worn 16 hours per day for more than six months, therefor less than this study. The ATR in the main curve was 8.4 (± 2.7) degrees in the braced group, significantly different to the non-braced group, which was 11.4 (± 2.7) degrees. These results compare with the difference between the compliant group and the non compliant group of this study. In another study by Kinel et al (2007), AIS girls with larger Cobb angles above 45 degrees, who were treated with the Cheneau brace for more than a year revealed significantly less clinical rotation deformity than non-treated girls having similar Cobb angles (Kinel et al, 2007).

A study by Rigo (2003) on a 12 year old girl, with a 53 degree Cobb angle, showed the scoliometer reading as 17 degrees at the thoracolumbar region and after full time RSC brace, the ATR was 6.5 degrees after weaning (Rigo, 2003). This is only a case study however, but it supports this study's results. Another study with similar results is that by Kotwicki et al (2002) for idiopathic thoracolumbar scoliosis using the Cheneau brace that resulted in a mean 42 percent correction of the rib hump after 3-8 months of Cheneau brace treatment (Kotwicki et al, 2002).

Many studies use the Formetric system to evaluate the three dimensional correction effect of conservative treatment and surface topography changes (Rigo, 1999; Rigo et al, 2007). This system provides quantitative values to assess the spine in frontal, sagittal and transversal planes and unfortunately is not in South Africa and therefor could not be used in this study. The Formetric system with the scoliometer readings could have given a better overall picture of the three dimensional results and surface topography results of this study, however only scoliometer readings were used to assess trunk deformity. The effect of the

Cheneau brace on the back shape, trunk deformity, in AIS patients was done by Rigo (1999) using the Formetric system. Average major Cobb angle was 36.4 (± 9.6) degrees and 49 subjects were 12.2 (+ 2.1) years of age. The Cheneau brace and Schroth exercises resulted in a significant reduction in trunk imbalance, lateral deviation, rotation and maintained a three dimensional correction effect on back shape. The Formetric system was also used in the study by Wood (2003) previously mentioned. Surface topography results showed a reduction in lateral deviation and rotation of the trunk.

The reasons for the improvement in scoliometer readings in the compliant group of subjects in this study, is possibly because of the design of the brace and the nature of the exercises, including the breathing exercises. The three dimensional design of the brace, the direction and location of the strategically placed pressure points with their corresponding expansion chamber provides space for the correction of rotation. The three point pressure system and pressure at the apical vertebra all contribute in reducing the torso deformity. The large expansion room in the thoracic area allows for respiratory movement and for active correction in the direction of derotation and reduction of flat back. The scoliometer was used in this study during the exercises to determine the effect of each of the exercises on the ATR. Bialek et al (2007) recommend using the scoliometer to monitor changes in trunk rotation during scoliosis physiotherapy (Bialek et al, 2007). They found that an intensive 14 day in patient physiotherapy programme significantly reduced primary curve rotation from 9.5 (± 4.7) to 8.5 (±8.5) degrees.

Scoliometer measurements were initially taken (by the researcher) at each visit to the researcher, on arrival of the subject and after each exercise to establish the effect of each exercise. The researcher found for example that immediately after the side shift of the pelvis exercise and the figure of four exercise (see Appendix XI, page 229 later), the lumbar rotation was decreased. The lumbar rotation was also decreased immediately after the Jacknife exercise (page 234). Lying on the side (rotated 45 degrees) of the thoracic curve with a rolled towel (page 236) decreased the thoracic rotation immediately after the exercise and the upper trunk rotation in supine, blocking the ear (page 232) decreased the thoracic rotation immediately after doing the exercise. The height was measured before and after all the exercises and there was a 0.5 to 1.00 centimeter increase in height after the exercises were completed. This indicated that the exercises were effective in elongating the spine and improving the Cobb angles.

Clinical Implications.

- The compliant group had a significant improvement in ATR and therefor improvement in their rib hump and back shape, compared to the non compliant group. There was a cosmetic improvement in the compliant group who wore the brace over 21.5 hours a day and exercised over three times a week. The non compliant group basically maintained their trunk deformity. The complaint group will possibly have less of a deformity later in life than the non compliant group. This will also depend on the exercises they do to prevent progression of the curve.

Research Implications.

- Each individual exercise in this study needs to be done intensively without the other exercises over a period of weeks to see the specific effect of each exercise on the ATR. This would be important to investigate if the exercises alone can change the clinical deformity.
- Scoliometer readings could be taken after doing different sports or gym exercises to determine the effect of the individual sports on the trunk rotation. Exercises and sport types that accelerate progression of curvatures need to be identified.

6.8 Peak Flow

At baseline the peak flow readings in both groups were below normal values, bearing in mind that the heights measured are not true heights as a result of the deformity. Significant reduction in peakflow in AIS patients has been shown in a few studies (Shneerson, 1980; Zatloukal et al, 1997; Zaba, 2003; Durmala et al, 2008). The peak flow changes in the compliant group improved significantly more than the non compliant group during the study. The compliant group improved their peak flow, by a mean of 20 percent and the non compliant group by a mean of nine percent. End of study peak flow was however still below normal limits for their mean height. The compliant group improved significantly more (63.31 l/min) than the non compliant group (31.15 l/min).

There are not many studies found using spirometry in scoliosis subjects, except in studies using other methods of physiotherapy, such as the Dobomed and Schroth method for scoliosis. Studies supporting the results of this study include those on the Dobomed method, in which there was an improvement in FVC and FEV1, respiratory capacity, as a result of rehabilitation using asymmetric respiratory exercises (Dyner-Jama et al, 2000), mentioned in Table 2.3, page 40. The Dobomed method has also been shown to improve exercise efficiency significantly using ergospirometry (Durmala et al, 2002; Dobosiewicz et al, 2008). A study using the Schroth method, at the Katharina-Schroth Hospital, Germany, lead to an increase in vital capacity, and chest expansion increased 20 percent (Weiss, 1991). The average improvement in vital capacity, in subjects 14-17 years, was 16 percent, and in subjects 10-13 years, vital capacity improved 18.9 percent, which is similar to the results of this study. Other studies using outpatient or in-patient Schroth method have shown significant improvements in VC (Otman et al, 2005; Freidel et al, 2009). Weiss and Bickert (1996) showed that scoliosis patients, having SIR at the Schroth Clinic, improved in chest expansion and cardiopulmonary function, measures of right heart stress.

Dos Santos Alves et al (2006) in a study that had 34 AIS subjects having outpatient physiotherapy, including aerobic exercises three times a week for an hour, over a period of four months, resulted in a significant improvement in FVC, FEV1, inspiratory capacity and expiratory reserve volume. Exercise included walking, cycling, stretching and relaxation techniques (Dos Santos Alves et al, 2006), very different to the exercises used in this study as their exercises were more cardiovascular in nature. In addition a later study, a RCT, by Dos Santos Alves (2009) used the same programme of exercises as above and showed a significant increase in the maximum inspiratory and expiratory pressure, indicating an improvement in respiratory muscle strength (Dos Santos Alves, 2009).

The effect of other braces on the lung function in AIS is shown in a 8.5 year follow-up, by Willers et al (1993), on the Boston brace. The authors showed a reduction in sagittal diameter and they concluded that this would affect pulmonary function, which does not compare with this study, in which there was an improvement in sagittal profile and peak flow.

The reasons for the better improvement in peak flow readings in the compliant group of subjects in this study, is possibly because of the design of the brace and the nature of the exercises done, including the breathing exercises. The three dimensional design of the brace, the direction and location of the strategically placed pressure points with their corresponding expansion chamber provides space for the correction of rotation. The dorsal thorax is not in contact with the brace and the large expansion room in the thoracic area allows for respiratory movement and for active correction in the direction of derotation and reduction of flat back. (See Appendix XI, page 228 for exercise description).

Spirometry is the first method of choice to identify any changes in the course of a respiratory disease (Durmala et al, 2008). Spirometry should include the measurement of VC and its subdivisions and the measurements of the flow-volume curves. Diagnostic spirometry should be performed in a laboratory and was not possible to do in the private practice of the researcher, due to the costs envolved. The flow of air through the lungs can be measured using FEV1 however, which is normally 70-80 percent of forced vital capacity (FVC) (Gaskell and Webber, 1988). The researcher therfore used the Mini Wright peak flow meter, to measure FEV1, as it is simple, portable, reproducible and practical to use clinically (Wright and McKerrow, 1959; Wright, 1978). More detail of the subjects lung function could have been reported in a laboratory situation, however challenging in a physiotherapy private practice.

Clinical Implications.

- AIS is a restrictive lung disease occurring with decreased chest wall compliance, reduced thoracic volume, inefficient respiratory muscles and consequently a decrease in VC and total lung volume. The flow of air through the lungs can be measured using FEV1, normally 70-80 percent of FVC. The RSC brace and a specific regime of exercises can improve the FEV1, lung function, significantly, if the brace is worn 21.5 hours per day and exercises are done four times a week. Exercises will help improve mobility of the frozen rib cage and spinal mobility. Possibly these compliant subjects will not have reduced lung function later in life and will not avoid activities requiring cardiovascular endurance associated with larger curves (Bowen, 1995; Asher and Burton, 2006; Weiss, 2010), whereas the non compliant subjects, with larger curves, may be avoiding endurance activities later in life and may have to adapt to reduced function.

Research Implications.

- Use of all spirometry tests in studies will allow a reliable assessment of the influence of a conservative management programme on respiratory impairment during the natural course of progressive scoliosis. Spirometry will also indicate the impact of the deformity on subjects' quality of life.

6.9 Height

Trunk height loss in AIS is related to curvature progression (Gremeaux et al, 2009). Loss of height is a method of monitoring the natural history of scoliosis. There were no significant differences in the change in height between the two groups, with both groups increasing in height. The researcher found that at the end of an exercise session with the subjects, their heights were between 0.5 - 1cm taller than at the start of the exercise session, indicating that the exercises were elongating the spine. The researcher also found that during school holidays, when there was less sitting at a desk for subjects, they were generally one centimetre taller. This had to be considered when monitoring the subjects. Subjects were weaned out the brace when they were as close to or at Risser 5 and when height had been static for six months. This occurred 3.46±0.5 (compliant) to 4.03±0.6 (non compliant) years after menarchy, however these data was not obtained in all subjects. These results indicate when peak height was reached.

Clinical implications.

- Any drop in height is an indication of curve progression, bearing in mind that the height can vary 1.4cm in a day. Orthotists adjusting the brace should monitor height changes and consider them when making changes to the brace, rather than waiting for X-rays to change the brace.
- Peak height was reached between 3 to 4.5 years after menarchy. These static height measurements should be considered along with other skeletal maturity factors, such as Risser sign, Geurlich and Pyle Index, Tanner scale, fusion of other growth plates when making a decision on weaning out of the brace, to prevent deterioration during the weaning process that has been reported.

Research Implications.

- The effect of individual exercises and different sports on the height in AIS individuals needs to be studied. This is a non invasive, inexpensive method of measuring scoliosis.
- A larger study needs to be done on when peak height is reached after menarchy.
- Monitoring sitting heights, for spine length, would have been valuable to compare in the two groups. This would indicate actual spine length changes.
- Comparing the actual heights, using arm span, to the height of the subjects at the end of the study in each group would also be valuable to determine if the compliant subjects are closer to their actual height than the non compliant subjects and to determine how much height is actually lost by the curves.

6.10 End of Study, Brace Weaning Process and Risser Sign

The end of the study occurred when weaning out the brace was started. Preliminary results, for a future study, of the weaning process of eight subjects is presented in Appendix XVI, page 241, as these results are not part of the study presented. Weaning the subjects out the brace once height had been static for six months and as close to Risser 5 as possible, did not result in any progression of curvatures during the weaning process in eight subjects of the compliant group. The optimal weaning process is not known (Lou et al, 2008; Zaina et al, 2009). The Risser sign, ossification of the iliac apophysis across the iliac crest, occurs simultaneously with the vertebral end plates (Risser, 2010). Hoppenfeld et al (2004) found no growth after Risser 5 in girls and recommended growth centres in conjunction with serial height measurements to determine skeletal maturity. End of vertebral growth can therefor be determined by Risser Sign and when the height is static (Hoppenfeld et al, 2004; Sanders, 2007) and this was used in this study. The weaning process in this study was started later than other studies reported in the Literature Review, Chapter 2.11.6 on page 61. Weaning in those studies was Risser 4+ or Risser 3 (Rigo, 2007B; Negrini et al, 2008C). Weaning out the brace in the compliant group of this study was at the mean age of 17.14 (±0.6) years, which is later than the studies presented in Chapter 2.11.6. In some of those studies exercises were recommended to prevent progression or loss of correction occurring during weaning (Zaina et al, 2009), indicating that they do have loss of correction during their weaning regime. The researcher therefor decided to keep the subjects in the brace for a longer period, wearing it full time until Risser 5, in order to prevent progression and postural collapse, as the postural collapse can be dramatic (Eisinger et al, 1996; Zaina et al, 2009). The fact that peak bone mineralization and peak muscle strength occurs at 25 years of age, and peak ligamentous stability occurs in the early 20’s (Shephard, 1998), was considered in the decision of weaning out the brace at a later stage. Preventing progression during the weaning phase is very important, as this is possibly the reason bracing is sometimes considered not to be effective, when actually the subjects have just been weaned out too early or too quickly (Rivett et al, 2009A).

6.11 Brace Questionnaire

Evaluation of QoL is an important part of AIS treatment (Aulisa et al, 2010) and monitoring of stress levels allows for the possibility of modification of treatment in order to maintain good compliance (Kotwicki et al, 2007C). Good compliance in this study has resulted in a good outcome, which is supported by studies mentioned previously in 6.2 on page 133. The compliant group in this study had a better quality of life than the non compliant group. The non compliant group had less vitality, less physical functioning, lower self esteem, were less satisfied with their bodies and had more pain. The non compliant group had seen themselves as more sickly, their school activity was less, emotional function was worse than the compliant group and social function was less than the compliant group.

Scoliosis was found to be a risk factor for impairment of QoL in adolescence by Reichel and Schanz (2003), Freidel et al (2002A) and Payne et al (1997). Vasiliadis and Grivas (2008) have shown that AIS patients score lower in all the domains of the BrQ at the end of treatment with a brace. Bracing has been shown to be a stressful and traumatic experience that is superimposed on the psychological stresses of the physical condition and can leave emotional scars (Payne et al, 1997; Saccomani et al, 1998; Reichel and Schanz, 2003; Tones et al, 2006). The combination of the disease and the brace has been shown to affect self-esteem, body image, interaction with others, overall QoL and to be stressful (Eliason and Richman, 1984; Reichesi and Schanz, 2003; Vasiliadis et al, 2006B). Psychological issues have previously been shown to influence compliance of brace wear (Hawes, 2002) and nine percent of girls will discontinue wearing a brace because of psychological distress (Korovessis et al, 1996A). In this study 4% stopped wearing the brace in the non compliant group. Psychosocial and body image disturbance were less marked in patients with good social and family functioning, as well as patients who exercised regularly (Tones et al, 2006) and this is similar to the compliant group in this study. These authors recommend a support group and individual discussions, aimed at managing psychosocial or body image disturbances to help the negative impact on these facets of life. Parent-child relationships must also be considered as the parents' attitude to the child's condition is related to the child's attitude to their own condition and these attitudes are related to psychological distress (Kahanowitz and Weiser, 1989).

The compliant group of subjects in this study had larger Cobb angles than the non compliant group at baseline, therefor the severity of the scoliosis as measured by Cobb angle was not related to a poorer quality of life. The Bad Sobernheim Stress Questionnaire (BSSQ) revealed little stress from the deformity itself, however the brace increased the stress and wearing the brace was a difficult task for the patient (Kotwicki et al, 2007C). Another study by Kolebacz et al (2009) compared the QoL in Cheneau brace AIS subjects, having Dobomed physiotherapy to a group, just having Dobomed physiotherapy. The Cheneau brace negatively affected the QoL. Subjects using the brace felt ashamed and had physical discomfort compared to the group just having physiotherapy (Kolebacz et al, 2009) and this compares well with the compliant and non compliant groups of this study. Therfore it would appear that QoL issues may be related to more psychosocial coping mechanisms than the physical deformity and its consequences. Support for AIS patients in the form of psychological group or individual sessions has been shown to prevent psychosocial impairment and should be included in the holistic management plans (Reichel and Schanz, 2003). Programmes to address personal, group and family issues will improve QoL, promoting compliance (Rivett et al, 2009B). Compliance to a conservative treatment programme has better outcomes.

A Cheneau brace study, found all children had problems adapting to the brace. They had negative emotional conditions, such as dream disturbances, increased irritability, negation, anxiety, fears and change of mood. The psychological condition of 16.2 percent of subjects depended on the relatives' attitude to the process and the result of treatment (Levitskiy et al, 2009). The authors recommend monitoring the emotional response to the Cheneau brace, to improve quality of the treatment and a psychologist' s assistance in the management of these emotional responses. Psychological determinants of compliance to wearing a brace for scoliosis were analyzed by Lindeman and Behm (1999). They found non compliant girls did not expect to succeed in dealing with scoliosis and they were anxious about possibly failing. They had low self- esteem and did not seek social support from other people. Similar in this study, emotional function was lower in the non compliant group, here subjects did not believe that the brace was beneficial and had low self esteem and low social function. Lindeman and Behm (1999) found that low compliance was best predicted by a high amount of reflective thinking, poor body-image, low social success expectation and low master orientation in social behaviour (Lindeman and Behm, 1999). They also found the more the subjects experienced sleeping problems, the less they used the brace. In another study using the Cheneau brace, Pham et al (2008) found a significant reduction in QoL in those subjects wearing the brace full time compared to those wearing the brace part- time and those without a brace (Pham et al, 2008).

Clinical implications.

- Non compliance to a conservative treatment programme resulted in progression in curvatures. These subjects had a poorer quality of life. These subjects need psychosocial support in both a group and on an individual basis involving a psychologist to improve compliance and therefor treatment outcomes. This should be included as part of the management programme, as subjects do not generally seek help. Family counselling is also required, often anxiety is experienced by the parents, more so the mother and the child is affected. Compliance is also required from the parents, in bringing the child monthly for follow-up of treatment and psychosocial group therapy. Parents who are non compliant, resulted in the subjects being non compliant. Dealing with the non compliance of parents was challenging and added to the practical problems of following up the non compliant subjects.
- Research has shown that psychosocial problems are less in patients who exercised regularly (Tones et al, 2006). Regular cardiovascular, non weight bearing exercise such as swimming and cycling should be encouraged with the exercises in this programme. This will also improve lung function.
- Continuous monitoring of stress and QoL needs to be done, which will allow modification of the treatment and maintain good compliance. Regular consultations with the psycholiogist are required. The BrQ should be done at the beginning of treatment and then at regular intervals.

Research Implications.

- Studies need to be done involving comparing patients with psychological support and those without. Family dynamics should be compared between compliant and non compliant patients and mother/patient relationships should be compared in the two groups. The researcher found on observation that the compliant group, subjects had a close, good relationship with the mother, who was very supportive. It has been observed in families where the parents were separated, subjects were generally in the non compliant group.

6.12 High School Personality Questionnaire

The personality trait questionnaire revealed, after categorizing the trait scores, that the compliant group were more emotionally mature, stable and realistic than the non compliant group, who were more emotionally immature and assertive (Factor C). Higher scores in Factor C (compliant group) reveal emotional stability and controlled, high ego strength, according to the HSPQ manual (Cattell and Cattell, 1975). These patients appear calm, unruffled and behave in an adult and rational way. They are realistic, constant in interests, responsible, distinguish between emotional needs and reality, and adjust to facts. High Factor C scores also correlate with positive family relationships and leadership (Visser et al, 2003). Lower Factor C scores, in the non compliant group, indicated emotional instability and low ego strength (Visser et al, 2003). They reveal an inability to control their emotions, impulses and to find satisfying and realistic ways of expressing them. They are easily angered, are more frequently dissatisfied with their family and school, find it difficult to restrain themselves and are discouraged by their inability to meet good standards of behaviour. They are easily perturbed, confused, changeable in attitudes and interests. They evade responsibility, give up easily, tend to worry a lot, have irrational fears and get into fights and problem situations. They can experience severe adjustment problems if subjected to a regimentation and stress (Visser et al, 2003). The bracing for AIS has been shown to be a stressful experience (Weiss et al, 2007A). The non compliant group of subjects, with low scores of Factor C personality traits, had difficulty in adjusting to the regimentation of the exercises, brace hours, visits to practioners required in the conservative treatment programme. These personality traits may help to explain the reason these subjects were non compliant. The personality trait, Factor C may also explain the reason some of the non compliant subjects stopped wearing the brace, as they give up easily in a stressful situation, do not take responsibility and are emotionally immature. Psychological support during this adjustment to bracing and exercise phase as well as during the treatment is therefor essential in these patients to improve compliance.

The results of the personality questionnaire compare well with the results of the BQ, which showed that the non compliant subjects had a poorer QoL. The BQ showed that the non compliant group's emotional functioning was worse than the compliant group, their self esteem was lower than the compliant group and social functioning was also lower than the compliant group (See Table 5.22, page 126). School activity was less in the non compliant group, and the group did not pay attention in the classroom. The non compliant group experienced more pain with the brace and possibly because of their personality traits did not cope with the stress and discomfort of brace wearing. Their psychosocial coping mechanisms were possibly caused by their personality traits.

Other traits from the questionnaire, revealed marginally significant differences in that the compliant group were more obedient, mild and dependant (Factor E), tender minded, sensitive, protected (Factor I) relaxed, and composed (Factor Q_4). The non compliant group were more aggressive, rebellious, dominant (Factor E), practical tough minded and tense (Factor I) driven, irritable, and frustrated (Factor Q_4). In Factor E, lower scores, in the compliant group, traits are more accommodating, more compliant and easily influenced (Visser et al, 2003). High scores in Factor E seen in the non compliant group, show traits of stubbornness, are headstrong, arrogant and disobedient. They act independently. All these personality traits mentioned resulted in the compliant group being more compliant, mature and responsible about carrying out the programme or instruction, whereas the non compliant group were more immature, rebellious, independent, had minds of their own and were thus non compliant. The compliant and non compliant groups have different personality traits. Different personality traits have resulted in different levels of compliance. The results of this study may help to explain the controversy, over whether bracing is stressful or not and whether it does or does not affect QoL. Different personality traits have different coping mechanisms and when put in a stressful situation, result in different levels of compliance which affects treatment outcomes.

The HSPQ can be used to identify individuals with emotional and behavioural problems, to understand individuals and their problems better, to predict future school achievement, to promote pupils' self-knowledge and to monitor personality growth (Cattell and Cattell, 1975). These personality traits can predict daily behaviour, coping patterns, self-esteem, conscientiousness, frustration tolerance, job performance, academic success and interpersonal skills (Russel and Karol, 2002). This study has determined the personality traits of compliant and non compliant subjects and these traits can be used to predict compliance of a subject. Should a patient be predicted to be non compliant using the HSPQ, at the beginning of treatment, then interventions, such as regular individual and family counselling could be implemented at the beginning of the programme to improve compliance. The HSPQ and 16 PF have been widely used internationally and have been translated into over 35 languages and therefor would be practical to use in AIS management programmes. As this study was started six years ago, the current, up to date questionnaire is the "16PF Adolescent Personality Questionnaire", by Scheurger (2001), which can be used on 11-22 year olds and is recommended by the editors of the HSPQ.

One of the earliest personality trait theories was introduced by Carl Jung (born-1875) (Boeree, 2003). Carl Jung believed that traits were inborn, inherited genetically determined (Grant, 2010). There are many personality development theories described in the literature and personality developement is very complex, however Jung believed that personality type is a developemental process, which is affected by an individual's environment. He believes one is born introverted or extraverted. The early phases of life determine the dominance ordering of four functions (sensing, intuition, thinking, and feeling) and development of dominant and auxillary functions. 'Thinking' and 'feeling' allows an individual to 'judge' and 'decide' according to Jung and 'sensation' and 'intuition' enables one to 'gather information' and 'perceive'. From age 0-6 years all four functions are used in an indiscriminatory fashion, then from 6-12 years a dominant function begins to develop and assert itself. Then from 12-20 years the auxillary function asserts itself as a powerful support to the dominant function (Grant, 2010). The 16 personality types described in the literature are based on research by Carl Jung, Katharine Briggs and Isabel Briggs Myers.

Possibly ‘parenting skills’ for parents in these AIS patients would assist in achieving compliance in these individuals as personality traits are a developemental process, which could be affected by ‘parenting skills’ and the environment they are brought up in. Family counselling, with the psychologist, could be recommended.

Clinical implications.

- Personality traits, which are hereditary and a devolopment process can predict whether a subject will be compliant or not. The HSPQ and 16PF used in this study and the more up to date 16 PF Adolescent Personality Questionnaire can be used in a conservative AIS treatment programme to determine initially whether a patient will be compliant or not. This intervention can improve outcomes, as if the patient is predicted to be non compliant, psychological support may be administered to improve compliance.

6.13 Other Factors Affecting Compliance

The multiprofessional team must all give thorough advice and counselling to patients and their family (Weiss et al, 2006). Commitment, time and counselling are required to increase compliance. This advice is included in the guidelines for the conservative management of scoliosis, established by the SOSORT committee (Weiss et al, 2006). Compliance is not only to treatment, but also to the treating team (Tessadri et al, 2011). Patients and their family must be given time to communicate with each of the multiprofessional team. Subjects in this study visited the researcher once a month, however the researcher, research assistant and psychologist were available at all times for advice and counselling to improve compliance. The researcher consulted with the psychologist often, as dealing with their anxieties was challenging. As the team approach was very important in this study the orthopaedic surgeons, the researcher and the research assistant communicated regularly, to improve compliance and quality of treatment. Research has shown that with the same orthopaedic surgeon, the same orthotist and physiotherapist, team building and setting play a major role in the compliance and final outcomes for patients (Tessadri et al, 2011).

Patient compliance is also affected by the type of brace used (Aulisa et al, 2009). The RSC brace used in this study was not visible compared to other braces used in South Africa, such as the Milwaukee brace. The Milwaukee brace is clearly visible around the neck region and has a five times greater risk of failure than the less visible Boston brace (Montgomery and Willner, 1989).

6.14 Conclusion

Subjects that were compliant to a conservative treatment programme of an RSC brace and a specific regime of exercises significantly improved compared to subjects who were non compliant and who significantly deteriorated. The non compliant group followed the natural history of progression of IS curvatures. Compliant subjects had a significantly better quality of life than the non compliant subjects. The compliant group were significantly more emotionally mature, stable and realistic than the non compliant group.

Conclusions drawn from this study are presented in Chapter seven.

Chapter 7

CONCLUSIONS

The main conclusions of this study are presented.

- Compliance of AIS subjects, with high progression risks (70-78 percent), to a treatment programme of wearing the brace 21.5 hours a day and exercising four times a week resulted in significant improvement of curvatures. Non compliance, wearing the brace 12 hours a day and exercising 1.7 times a week resulted in significant progression of curvatures. The number of larger curves was reduced in the compliant group, decreasing the risk of surgery and increased in the non compliant group increasing the risk of surgery.
- An in-brace correction of 44.5 percent in the compliant group resulted in significant improvement in curves at the end of the study. An in-brace correction of 35.8 percent in the non-compliant group however resulted in a significant progression of curvatures.
- At the end of the study all Cobb angles were significantly lower in the compliant group compared to the non compliant group. The worst Cobb angle, in the compliant group (25.38°±8.3) was significantly lower than the non compliant group (36.71°±9.3). Three subjects in the non compliant group progressed to requiring surgery. The kyphosis Cobb angle was significantly higher in the compliant group (34.33°±6.4) and well within normal limits compared to the non compliant group (21.5°±6.9), which was below normal limits. Kyphosis angles improved in the compliant group and deteriorated in the non compliant group, and therefor the sagittal profile improved in the compliant group. Skeletal maturity, was reached 3.46 (±0.5) to 4.03 (±0.6) years after menarche in the two groups.
- In the compliant group the mean thoracic Cobb angle, lumbar Cobb angle, worst Cobb angle, all apical rotations and scoliometer readings, significantly improved during the study. In the non compliant group these

measures all progressed. The **worst/major Cobb angles** in the compliant group improved 10.19° (±5.5) and deteriorated 5.52° (±4.3) in the non compliant group. The worst apical rotation significantly improved by 7.42° (±7.2) in the compliant group compared to the significant deterioration of 3.67° (±6.5) in the non compliant group. Scoliometer readings show that the compliant group significantly improved cosmetically, compared to the non compliant group. The compliant group improved their peak flow significantly, by a mean of 20 percent, compared to the non compliant group, which improved by nine percent. The peak flows were below normal limits at baseline and at the end of the study.

- In the **Double Major Type curves** the Cobb angles and their apical rotations improved significantly in the compliant group during the treatment compared to the non compliant group, which deteriorated. In **Thoracic Type curves** there was a significant improvement in the mean Cobb angle of 12.6° (±7) compared to the non compliant group, which deteriorated by 6° (±6.7). Apical rotations in these Thoracic Type curves significantly improved by 8.7° (±9.1) in the compliant group compared to the non compliant group, which deteriorated by 6.3°(±7.5).
- There was no progression of the curvatures during the **weaning process** used on eight subjects in the compliant group of this study. Weaning was started as close to Risser 5 as possible and when height had remained static for six months. The curvatures stabilised during this weaning process.
- The **Brace Questionnaire**, revealed that the compliant group had a significantly better Quality of Life than the non compliant group. Vitality, Physical Functioning, Self Esteem, Bodily Pain, School Activity and General Health Perception, Emotional Function were significantly better in the compliant group compared to the non compliant group. Social Function was marginally significantly better in the compliant group.
- The **HSPQ and 16 PF**, personality trait questionnaires showed that the **compliant group** was marginally more: emotionally mature, stable and realistic; obedient, mild and dependant; tender minded, sensitive, protected and relaxed as well as composed. The **non compliant group** was marginally more: emotionally immature and assertive; aggressive, rebellious, dominant;

practical, tough minded and tense, driven as well as irritable. The groups were then compared after categorizing the trait scores. Factor C in the compliant group showed the group to be significantly more emotionally mature, stable and realistic than the non compliant group. The non compliant group was significantly more emotionally immature and unstable. Possibly different personality traits have different psychosocial coping mechanisms and when put in a stressful situation, result in different levels of compliance.

In summary good compliance to a conservative treatment programme of the RSC brace and specific exercises resulted in a significant improvement in curvatures, whereas poor compliance resulted in progression of curvatures. The compliant group had a better quality of life than the non compliant group and was more emotionally mature and stable than the non compliant group. Further studies are required to determine the long term effects of this conservative treatment programme.

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UNIVERSITY OF THE WITWATERSRAND, JOHANNESBURG

Division of the Deputy Registrar (Research)

HUMAN RESEARCH ETHICS COMMITTEE (MEDICAL)
R14/49 Rivet

CLEARANCE CERTIFICATE	**PROTOCOL NUMBER M060702**
PROJECT	The Effect of Adherence on Idiopathic Scoliosis Managed with a Rigo System Cheneau Brace......
INVESTIGATORS	Ms LA Rivet
DEPARTMENT	Department of Physiotherapy
DATE CONSIDERED	06.07.28
DECISION OF THE COMMITTEE*	APPROVED UNCONDITIONALLY

Unless otherwise specified this ethical clearance is valid for 5 years and may be renewed upon application.

DATE 06.08.21 **CHAIRPERSON** ....
(Professor A Dhai)

*Guidelines for written 'informed consent' attached where applicable

cc: Supervisor : Prof A Stewart

DECLARATION OF INVESTIGATOR(S)

To be completed in duplicate and **ONE COPY** returned to the Secretary at Room 10005, 10th Floor, Senate House, University.
I/We fully understand the conditions under which I am/we are authorized to carry out the abovementioned research and I/we guarantee to ensure compliance with these conditions. Should any departure to be contemplated from the research procedure as approved I/we undertake to resubmit the protocol to the Committee. **I agree to a completion of a yearly progress report.**

PLEASE QUOTE THE PROTOCOL NUMBER IN ALL ENQUIRIES

INFORMATION LEAFLET AND INFORMED CONSENT

DEAR PARENT

I AM LOUANN RIVETT A PHYSIOTHERAPIST WORKING IN PRIVATE PRACTICE AND STUDYING AT UNIVERSITY OF THE WITWATERSRAND MEDICAL SCHOOL. I AM INVESTIGATING THE EFFECTS OF EXERCISE AND THE RSC BRACE ON SCOLIOSIS. I WOULD BE MOST GRATEFUL IF YOU AND YOUR CHILD WOULD CONSIDER PARTICIPATING IN THIS WORK.

Each ***participant's parent*** must receive, read and understand this document

before any study-related procedure takes place

STUDY TITLE: THE EFFECT OF COMPLIANCE ON IDIOPATHIC SCOLIOSIS MANAGED WITH THE RIGO SYSTEM CHENEAU BRACE AND A SPECIFIC EXERCISE PROGRAM.

INVESTIGATOR: Miss Lou Ann Rivett

INSTITUTION: LouAnn Rivett Physiotherapy Practice
130 Hendrik Verwoerd Drive, Randburg, Johannesburg

DAYTIME AND AFTER HOURS
TELEPHONE NUMBER(S): 011 787-0495
011 706-6677 (ah)

To the Parent of the Participant: *This consent form may contain words that you do not understand. Please ask the Louann or the study staff to explain any words or information that you do not clearly understand. You may take home* ***an unsigned copy of this consent*** *form to think about or discuss with family or friends* ***before making your decision.***

1. INTRODUCTION:

1. Before agreeing to your child participating, it is important that you read and understand the following explanation of the purpose of the study, the study procedures, benefits, risks, discomforts, and precautions as well as the alternative procedures that are available to you, and your right to withdraw from the study at any time. This information leaflet is to help you to decide if you would like your child to participate. You should fully understand what is involved before you agree to your child taking part in this study.
2. If you have any questions, do not hesitate to ask me.
3. You should not agree to your child taking part unless you are satisfied about all the procedures involved.
4. Your child may not participate in another investigational medicine research study, nor take any other investigational medicine during their participation in this study.
5.
6. If you decide that your child can take part in this study, you will be asked to sign this document to confirm that you understand the study. You will be given a copy to keep.
7. If you have a personal doctor, please discuss with or inform him/her of your possible child's participation in this study. If you wish, I can also notify your personal doctor in this regard.

2. PURPOSE OF THE STUDY

- Your child has been diagnosed as having Idiopathic Scoliosis and I would like you and your child to consider taking part in the research of scoliosis managed using the Rigo System Cheneau (RSC) Brace and exercises.
- The purpose of this study is to determine the effect of compliance on idiopathic scoliosis managed using the RSC brace and a specific exercise programme. The purpose is also to determine what factors affect compliance to the treatment protocol and changes in the curves during management up to point of weaning out the brace.
- This study will compare the effect of the RSC brace and specific exercises on scoliosis between girls who wear the brace for 20-23 hours per day and do specific exercises at least three or more times a week and those who wear the brace for less than 20 hours per week and who exercise a maximum of twice per week.
- Participants will be drawn from LA Rivett physiotherapy practice in Randburg. Participants will be divided into two groups when brace weaning starts, which is when the study will end.

3. LENGTH OF THE STUDY AND NUMBER OF PARTICIPANTS:

- The participants will be between the ages of …12.. and …18years…..
- The total amount of time required for your child's participation in this study will be from when going into the brace

to the day they start weaning out the brace.

- Your child will be asked to visit me once a month during the study. You and your child will visit the orthotist fitting the brace on a regular basis, usually after X-rays, which will be every four months. This regime is routine for scoliosis treatment.

4. PROCEDURES:

- If you and your child agree to take part in this study, you will first be asked questions and your child examined to see if she qualifies for this study. Normal routine treatment regime for scoliosis will be followed.
- At your first visit before going into the brace a history will be taken. Her X-rays will be examined. The reseacher will then do a physical examination (routinely done for scoliosis) which will involve assessing the following: posture, range of movement of hamstrings, gluteal strength, pelvic alignment, leg length, degree of rotation of curve using a scoliometer (a spirit level used for scoliosis). Exercises will then be given and demonstrated to her for her to do at home. Principles of scoliosis treatment, including the brace and exercises will be explained. For best results the brace needs to be worn 23 hours a day, and the exercises done four to five times a week. A diary will be given to your child to record hours of brace worn and when exercises are done. Your child will then fill out a psychological personality questionnaire. This will be kept confidential and handed to the psychologist for assessment. This questionare is to determine what factors affect compliance to the treatment regime. The researcher will then see the participant a week later, two weeks later and then once a month. At these visits, reassessment done, exercises will be checked, new exercises given, brace hours and amount of exercise done will be checked. Brace comfort and difficulties will be addressed.
- Your child will visit the orthotist, the research assistant, after she has had her first X-ray. He will take some measurements and at a later stage fit the brace. X-rays will be done at six weeks of wearing the brace and then every six months, routine for scoliosis treatment. Your child's X-ray visit will coincide with a visit to the orthotist, who will check the X-rays, check the brace and make any adjustments reguired. The measurements he will take at her first and following visits will include: angles of the curves on the X-rays; her height; her weight; the amount of air she breathes out in one breath, using a peak flow meter; the amount of rotation of the vertebrae in her back using the scoliometer.

5. WILL ANY OF THESE STUDY PROCEDURES RESULT IN DISCOMFORT / INCONVENIENCE?

- X-ray is a commonly used diagnostic procedure that exposes you to a small amount of radiation. Although all radiation is cumulative over your child's lifetime, small doses from X-rays should not create a significant risk to her health. X-rays are important to monitor the curve, The normal routine for monitoring scoliosis is being used ,which is used by local orthopaedic surgeons.

- The brace can be uncomfortable in the beginning and takes getting used to. Your child will be weaned into the brace slowly to get used to it. The orthotist is there to help her with any adjustments to ensure comfort. Redness of the skin might develop in pressure areas of the brace this is normal, however the redness must must not become significant. These areas will be checked by the researcher and the research assistant. The brace can make her feel hot in very hot weather. In these conditions its best to wear a pure cotton vest under the brace and to keep the brace clean. Her clothing that she wears over the brace might not fit or cover the brace, This might have to be changed or adjusted ,especially if it is tight fitting.
- The exercises done are exercises done all over the world for scoliosis. The exercises are not strenuous, are safe and are good for healthy children. Children should be exercising at least three to four times a week.

6. BENEFITS:

- The potential benefit from your child participation in this study may be to control her curve.and prevent progression of the curve and in some cases prevent surgery. You and your child will be educated in scoliosis.She will learn what exercises she can do that will help her cosmetic looks and posture for the rest of her life. These exercises will also prevent pain and deformity associated with scoliosis.
- However, she may not benefit from this study.
- Her participation in this study will contribute to medical knowledge that may help other patients that, like your child, have scoliosis.

7. ALTERNATIVE TREATMENT:

- Alternative treatment in the form of other types of braces and different exercises are often used to treat scoliosis.
- If you and your child decide not to take part in this study your child will still receive the best current care, from the researcher, orthotist and your usual doctor.

ARE THERE ANY WARNINGS OR RESTRICTIONS CONCERNING MY PARTICIPATION IN THIS STUDY?

- If your child has a heart condition or her scoliosis is not idiopathic(of unknown cause), she may not take part in the study
- While taking part in this study any form of exercise, cardiovascular, must be checked with the researcher. No other strengthening exercises other than those given by the researcher can be done. The reason for this is that other exercises could make the curves worse.

INTERACTIONS:

- It is important that you let me know of any medicines (both prescriptions and over-the-counter medicines), alcohol or other substances that your child is currently taking.
- During this study, your child should not take anti inflammatory medication or painkillers; if she has to, please inform me **<u>immediately</u>**.

RIGHTS AS A PARTICIPANT IN THIS STUDY:

8. Voluntary:

Your child's participation in this study is entirely voluntary and your child can decline to participate, or stop at any time, without stating any reason. Her withdrawal will not affect her access to other medical care.

- **Discontinuation of study treatment.**
- Your child must inform me if she wishes to stop doing the exercises and wearing the brace.

  I will supervise any discontinuation with her, her health as the first priority.

9. New findings:

- I will provide you and your child with any additional information that becomes available during the study, which may affect your willingness to continue on the study

10. Withdrawal:

- Your child's withdrawal will not affect your access to other medical care.
- I retain the right to withdraw your child from the study if it is considered to be in your best interest. If your participation is ended early, you may be asked to return for study-ending tests and procedures for your safety .

11. FINANCIAL ARRANGEMENTS

- Assessment and treatment costs with the researcher and research assistant is your responsibility, as these interventions are normal procedure for scoliosis.

12. REIMBURSEMENT FOR STUDY PARTICIPATION:

- You and your child will not be paid to participate in this study.

13. ETHICAL APPROVAL:

- This clinical study protocol has been submitted to the University of the Witwatersrand, **Human Research Ethics Committee (HREC)** and written approval has been granted by that committee.
- The study has been structured in accordance with the **Declaration of Helsinki** (last updated: October 2000), which deals with the recommendations guiding doctors in biomedical research involving human participants. A copy may be obtained from me should you wish to review it.

14. SOURCE OF ADDITIONAL INFORMATION:

For the duration of the study, your child will be under the care of LouAnn Rivett. If at any time between your visits, you feel that any of your child's symptoms are causing her any problems, or you have

any questions during the study, please do not hesitate to contact me.
Other doctors from this department who are working on this study are:

- ***ROWAN BERKOWITZ, RESEARCH ASSISTANT***
  (w) 011 803 0583

The **24-hour telephone number** through which you can reach me or another authorised person, is 0834565839.

- If you want any information regarding your child's **rights as a research participant, or complaints regarding this research study**, you may contact Prof. Cleaton-Jones, Chairperson of the University of the Witwatersrand, Human Research Ethics Committee (HREC), which is an independent committee established to help protect the rights of research participants at (011) 717 2229.

For **research information** you can contact LouAnn Rivett, researcher at 011 787-0495 (w).

15. **CONFIDENTIALITY:**

- All information obtained during the course of this study, including hospital records, personal data and research data will be kept strictly confidential. Data that may be reported in scientific journals will not include any information that identifies your child as a participant in this study.
- The information might also be inspected by the University of the Witwatersrand, Human Research Ethics Committee (HREC), as well as your personal doctor. Therefor, you hereby authorise me to release your child's medical records to local and foreign regulatory health authorities and the University of the Witwatersrand, Human Research Ethics Committee (HREC).
- These records will be utilised by them only in connection with carrying out their obligations relating to this clinical study.
- Any information uncovered regarding your child's test results or state of health as a result of her participation in this study will be held in strict confidence. You will be informed of any finding of importance to her health or continued participation in this study but this information will not be disclosed to any third party in addition to the ones mentioned above without your written permission. The only exception to this rule will be cases of communicable diseases where a legal duty of notification of the Department of Health exists. In this case, you will be informed of my intent to disclose such information to the authorised state agency.

16. PERSONAL DOCTOR / SPECIALIST NOTIFICATION OPTION:

Please indicate below, whether you want me to notify your personal doctor or your specialist of your child's participation in this study:

- **YES**, I want you to inform my personal doctor / specialist of my child's participation in this study.

- **NO**, I do not want you to inform my personal doctor / specialist of my child's participation in this study.
- **My child does not have** a personal doctor / specialist.

IF YOU ARE HAPPY TO ALLOW YOUR CHILD TO TAKE PART IN THE STUDY, PLEASE READ AND SIGN THE ATTACHED CONSENT FORM.

THANKYOU,

LOUANN RIVETT.

INFORMED CONSENT:

INFORMED CONSENT FOR PARENTS/LEGAL GUARDIANS:
(On behalf of minors under 18 years old)

- LouAnn Rivett **has provided me with a copy of the Participant Information Leaflet and Consent regarding clinical study:** The effect of compliance on idiopathic scoliosis managed with a Rigo System Cheneau brace and a specific exercise program. She has fully explained to me the nature, risks, benefits and purpose of the study.
- LouAnn has given me the opportunity to ask any questions concerning both the treatment regime and the study.
- It has been explained to me that I will be free to withdraw my child from the study at any time, without any disadvantage to future care.
- I have understood everything that has been explained to me and I consent for my child to participate in this clinical study.

PARENT/LEGAL GUARDIAN:

Printed Name **Signature / Mark or Thumbprint** **Date and Time**

PARTICIPANT ASSENT: * (Seven (7) years old and above)

Printed Name **Signature / Mark or Thumbprint** **Date and Time**

(* Minors competent to understand must participate as fully as possible in the entire procedure)

STUDY DOCTOR:

Printed Name **Signature**
Date and Time

INFORMATION SHEET
CHILD

Hello

I am LouAnn Rivett a physiotherapist studying at the University of Witwatersrand Medical School. I am investigating the effects of compliance of exercise and the RSC Brace on scoliosis. I would be most grateful if you would consider participating in this work.

Why are we doing this? If children are compliant in doing their exercises and wearing their brace over 20 hours a day, what effect would this have on their scoliosis? I also want to determine what factors affect compliance. We know that curves progress and would lie to develop a treatment regime to prevent progression of the curves. I would be grateful if you would participate in this study to examine this.

What do we expect from participants in the study? You will be required to participate in the study from when you go into the brace until you start weaning out the brace. The treatment is normal routine treatment for scoliosis. I will examine you and give you and give you some exercises to do. You will be required to do the exercises four to five times a week, which you will record in a diary, which I will give you. The number of hours the brace is worn per day will also be recorded in this diary. I will give you a psychological questionnaire to fill out. You will see me regularly once a month to monitor your curves and give you exercises. You will also have to see Rowan, the research assistant. He will check your x-rays, take some measurements and check the brace for you. He will help you with any problems with the brace and also see you regularly.
X-rays will be done every four months to monitor your curves. The X-rays are small doses and should not create a risk to your health. The brace takes getting used to and may be a little uncomfortable at first, but you will wean into it slowly. Any red areas from pressure from the brace Rowan and I will check. The exercises are not difficult to do and will improve your posture and cosmetic looks.

Are there benefits to participants? Yes. You will learn about your back condition and learn exercises that will prevent the curves progressing. Exercises will help your posture and what your back looks like and they will prevent pain and deformity associated with scoliosis. Your participation will contribute to knowledge of scoliosis and help other patients with scoliosis.

Withdrawing from the study. You may at anytime withdraw fro the study, without a reason. The study is voluntary and there is no penalty for withdrawing.

Confidentiality. All information obtained ie. personal data and research data, will be kept confidential. Only LouAnn, Rowan and the Human Ethics Committee will have access to the data.

If you have any queries, more information you can contact LouAnn at telephone number (011) 787-0495.

If you are happy to take part in the study, please read and sign the attached consent form.

Thankyou

LouAnn Rivett

(Vasiliadis et al, 2006B) in Developement and preliminary validation of the brace questionnaire: a new instrument for measuring quality of life of brace treated scoliotics. Scoliosis 1: 7

BRACE QUESTIONNAIRE

This questionnaire asks how you feel about your health, while you are wearing a brace. This is not a test and there are no right or wrong answers

- *Please read carefully every question*
- *Choose the best answer and mark with an x*

Example	Never	Almost never	Sometimes	Most of the time	Always
During the last week you were in a good mood for studying	☐	☐	☐	x	☐

Please tell us a few things about yourself:

You are: ☐ a girl ☐ a boy Age: ……… years old

You are wearing the brace since ………

You are wearing the brace for ….. hours /day

Date..

1

During the past 3 months...	Never	Almost never	Sometimes	Most of the time	Always
1. The brace made you feel ill	☐	☐	☐	☐	☐
2. You were afraid that your back will get worse	☐	☐	☐	☐	☐

During the past 3 months while you were wearing the brace...	Never	Almost never	Sometimes	Most of the time	Always
3. You felt tired when walking	☐	☐	☐	☐	☐
4. You were able to run	☐	☐	☐	☐	☐
5. You managed to wear the brace without any help	☐	☐	☐	☐	☐
6. You managed to take out the brace without any help	☐	☐	☐	☐	☐
7. You couldn't eat well	☐	☐	☐	☐	☐
8. You couldn't sleep well	☐	☐	☐	☐	☐
9. You couldn't breath well	☐	☐	☐	☐	☐

2

During the past 3 months...	Never	Almost never	Sometimes	Most of the time	Always
10. The brace made you feel nervous	☐	☐	☐	☐	☐
11. You felt worried because of the brace	☐	☐	☐	☐	☐
12. You felt happy	☐	☐	☐	☐	☐
13. You believed that your life would be better if you were not on brace	☐	☐	☐	☐	☐
14. You believed that brace treatment was beneficial	☐	☐	☐	☐	☐

During the past 1 month...	Never	Almost never	Sometimes	Most of the time	Always
15. You felt proud of yourself	☐	☐	☐	☐	☐
16. You were satisfied with your body	☐	☐	☐	☐	☐

During the past 1 month...	Never	Almost never	Sometimes	Most of the time	Always
17. You felt strong and full of energy	☐	☐	☐	☐	☐
18. You felt tired and exhausted because of the brace	☐	☐	☐	☐	☐

3

During the past 1 month, because of the brace...	Never	Almost never	Sometimes	Most of the time	Always
19. You had difficulties with your lessons	☐	☐	☐	☐	☐
20. You were absent from school	☐	☐	☐	☐	☐
21. You found it hard to pay attention in the classroom	☐	☐	☐	☐	☐

During the past 1 month, while you were wearing the brace...	Never	Almost never	Sometimes	Most of the time	Always
22. You had to take medication for pain	☐	☐	☐	☐	☐
23. You had pain during the night	☐	☐	☐	☐	☐
24. You had pain when walking	☐	☐	☐	☐	☐
25. You had pain when sitting	☐	☐	☐	☐	☐
26. You had pain when climbing stairs	☐	☐	☐	☐	☐
27. You felt pins and needles to your arms or legs	☐	☐	☐	☐	☐

During the past 1 month, because of the brace...	Never	Almost never	Sometimes	Most of the time	Always
28. You couldn't go out with your friends	☐	☐	☐	☐	☐
29. Your friends felt compassion for you	☐	☐	☐	☐	☐
30. You felt different from your peers	☐	☐	☐	☐	☐
31. You had problems with your family	☐	☐	☐	☐	☐
32. You believed that your relationship with your family or your friends would be better if you were not on brace	☐	☐	☐	☐	☐
33. You stayed at home because you were ashamed	☐	☐	☐	☐	☐
34. You worn special clothes	☐	☐	☐	☐	☐

Thank you!

5

BRACE QUESTIONNAIRE SCORING SHEET

Name :
Group :
Done: Last 3 months / First 3 months

Never 1 Almost Never 2 Sometimes 3 Most of Time 4 Always 5

Q
4
5
6
12
14
15
16
17

Never 5 Almost Never 4 Sometimes 3 Most of Time 2 Always 1

Q
1
2
3
7
8
9
10
11
13
18
19
20
21
22
23
24
25
26
27
28
29
30
31
32
33
34 TOTAL SCORE (TC) = _______

TC (   ) x 20 =
Divide by 34 =
SCORE _________

Amercan authors of the HSPQ
Prof. R.B. Cattell
Mary D.L. Cattell

Acknowledgement is made to Drs E.M. Madge and L.B.H. du Toit for the **adaptation and first standardization** of the HSPQ in South Africa and for the compilation of the South African manual on which this revised manual has been based.

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(Visser et al, 2003)

SCOLIOSIS DIARY: NO OF HOURS BRACE WORN IN A DAY (HRS)
EXERCISE
(E)

		OCTOBER		NOVEMBER		DECEMBER
SUN	1	*e.g. 16hrs, (E)*				
MON	2					
TUE	3					
WED	4		1			
THUR	5		2			
FRI	6		3		1	
SAT	7		4		2	
SUN	8		5		3	
MON	9		6		4	
TUE	10		7		5	
WED	11		8		6	
THUR	12		9		7	
FRI	13		10		8	
SAT	14		11		9	
SUN	15		12		10	
MON	16		13		11	
TUE	17		14		12	
WED	18		15		13	
THUR	19		16		14	
FRI	20		17		15	
SAT	21		18		16	*RECONCILIATION DAY*
SUN	22		19		17	
MON	23		20		18	
TUE	24		21		19	
WED	25		22		20	
THUR	26		23		21	
FRI	27		24		22	
SAT	28		25		23	
SUN	29		26		24	
MON	30		27		25	*CHRISTMAS DAY*
TUE	31		28		26	*DAY OF GOOD WILL*
WED			29		27	
THUR			30		28	
FRI					29	
SAT					30	
SUN					31	

Assessment Sheet (Research Assistant). *APPENDIX VIII*

			DATE	DATE	DATE	DATE	DATE
PATIENT NAME:							
	Cobb <s	Cobb <					
		Degrees					
Tx							
		p =					
		@					
Lx							
		p =					
		@					
Kyphosis <							
Lordosis <							
Scoliometer Reading: Thoracic		TX					
Lumbar		LX					
Risser Sign							
Tanner Scale							
Height							
Weight							
Peak Flow							

NAME: DATE:

BIRTHDATE:

DR REFER:

AGE OF ONSET

X RAY (Cobb <)

In Brace Out Brace

WHO DIAGNOSED

FAMILY HISTORY – Diag
History

AGE AT MENARCHY

SPORTS

MEDICATION

MEDICAL CONDITIONS

CLINICAL EXAM

TANNER SCALE

HEIGHT (m)

WEIGHT (kg)

LEG LENGTH DISCREP?

SCOLIOMETER READ – Lx
Tx

X RAY - RISSER SIGN

ROT APICAL VERT (Perdriolle) - Tx
Lx

KYPHOSIS <

LORDOSIS <

PROGRESSION FACTOR - $\frac{\text{Cobb}\angle - 3 \times \text{Risser Sign}}{\text{Chrono Age}}$

PEAK FLOW

DATE : FINDINGS

The researcher has previously found that in balanced double major curves (Cobb angles almost equal), convex lumbar left, thoracic convex right, subjects like to stand on their right legs. In thoracic curves, three curve scoliosis, convex right, they like to stand at ease on the left leg. In the thoracolumbar curves convex to the right (three of them) they preferred to stand at ease on their left leg. Asymmetrical distribution of weight was found in free standing of scoliosis subjects by Nowotny et al (2011). At the first visit to the researcher, the transitional point between curves was found on the X-ray. This point is between the thoracic curve and the most caudal curve (Rigo, 2005) and is in the centre of a vertebra or disc. The position of this point is considered with reference to the Central Sacral Line (CSL). The CSL is a vertical line perpendicular to the horizontal line of reference, drawn from the centre of the cranial end of S1 (Rigo, 2005). The spinal balance in the coronal plane at the transitional level was assessed. The patient was asked to side shift the pelvis towards the transitional point, that is to the left in a balanced double major, convex lumbar left, thoracic convex right (equal curve sizes)(See Figure 7.14 in Appendix XII, page 237) as the pelvis was translated to the right and movement, side shift, to the left was also found to be restricted. In a three curve, thoracic curve convex right (See Figure 7.15 in Appendix XII) the patient was asked to side shift the pelvis to the right as it was translated to the left, the transitional point was to the right of the CSL and movement of the pelvis to the right was found to be restricted. These same principles applied to the thoracolumbar curves convex to the right, in which movement was resticted to the right, patients preferred standing on the left leg. These side shifts of the pelvis were done in **exercise 1** and **2** in Appendix XI, page 228. The side shifts were done repetitively in **exercise 3** to the limit of range, Appendix XI, page 229. The side shifting of the pelvis is supported by the principles of correction according to the frontal pattern, when translation of the pelvis is described by Rigo (2005). In free standing the double major curves, convex lumbar left were encouraged therefor to stand on the left leg, to translate the pelvis towards the transitional point and in the three curve, thoracic curves convex right, were encouraged to always stand at ease on the right leg. A subject with a thoracolumbar curve only, convex right, was told to stand on the right leg only.

The action of the RSC brace compliments the side shift of the pelvis exercise as for a three curve convex right thoracic scoliosis the lumbo-pelvic area must be derotated and translated to the right by means of a left pelvis pad (supra-trochanter) combined with a left lumbar pad (Rigo, 2005). In a four curve scoliosis, convex lumbar left and thoracic right, a right lateral pelvis pad translates the pelvis from right to left, against a lumbar pad. The researcher's rationale for doing a repetitive side shift exercise of the pelvis in **exercise 3** came from Robin Mckenzie's method of a self treatment regime of a lumbar disc derangement, when there is an acute lateral shift deformity of the hips (McKenzie, 1994; Ross, 1998; McKenzie, 2005). Mckenzie does a slow, rhythmical, repetitive movement 10-15 times a couple of times a day to correct mechanical dysfunction. He also does a manual side shift on the subjects, which can be done on infantile scoliosis subjects.

Asymmetries of hip rotation were found in scoliosis subjects by Kotwicki et al (2008). They found no limitation of range of movement, but there is movement of one hip towards internal rotation and the other hip towards external rotation during gait. The implication of this is a 'torsional offset' of activation of muscle patterns around the spine in girls with structural idiopathic scoliosis during gait (Kotwicki et al, 2008). Evidence to support side shifting the pelvis and standing on one leg in this study, is in studies by Karski (2002) and Karski et al (2007). They found that a syndrome of hip contractures in newborns and children could cause idiopathic scoliosis. The contractures were due to the first foetus position during pregnancy (Karski et al, 2007). Newborns (n=629) with hip dysplasias, torticollis and foot deformities were followed up to the age of 5-7 years and found they all showed signs of idiopathic scoliosis (double curve) at 5-7 years. Curves of convex lumbar left and thoracic right are related to a 'left sided syndrome of contractures in 85-90 percent of pregnancies when the foetus is on the left side of the abdomen of the mother. They found that IS was connected to an asymmetry in the hips and pelvis region induced by a adduction contracture of the left hip and in the right hip, a real or functional, abduction contracture (sometimes with flexion and external rotation) in newborns.

The contracture leads to a permanent habit of standing on the right leg. They found in older children with the habit of permanently standing at ease on the right leg developed a scoliosis (a lumbar and sometimes a thoracic curve). The abduction contracture of the right hip has a great influence on the spine in the period when the child starts to stand and walk (Karski et al, 2007). Asymmetry in movement in both hips causes asymmetry in gait and loading and symmetry of growth and development of the spine. Pelvic bone asymmetry, caused by contracture of adductors of the left hip can be seen on X-ray. As part of their rehabilitation exercises for IS, they recommend encouraging standing 'at ease' only on the left leg (for double curve, convex lumbar left, thoracic convex right) (Karski et al, 2009). The researcher prescribed the exercise for the same curves (See **Exercise 1**, Appendix XI, page 228).

When assessing the tightness of the piriformis muscle in the subjects, the researcher found that in double major curves, convex lumbar left, thoracic convex right, the left piriformis was tighter than the right. Therefor stretching of piriformis on the left was given in exercise 4, on page 230. Whichever piriformis was found to be tight, a stretch was given for that particular side; in the thoracic curves convex right (three curve scoliosis) and thoracolumbar curves convex right (three curve), the left piriformis muscle was tighter and also stretched. Piriformis originates from the anterior surface of the sacrum between the first, second, third and fourth sacral foramina, a few fibres arise from the margin of the greater sciatic foramen, the joint capsule and the anterior sacrotuberous ligament. It exits the pelvis through the greater sciatic foramen and inserts into the upper part of the greater trochanter posteriorly (Boyajian-O'Neill et al, 2008). Piriformis mainly externally rotates the extended thigh, and is involved in abduction in the neutral hip position. When the hip is in over 60 degrees flexion piriformis changes its function and abducts and internally rotates the hip joint (Papadopoulos and Kahn, 2004; Byrd, 2005; Swafford, 2006; Boyajian-O'Neill et al, 2008). In standing piriformis aids slightly in tilting the pelvis down laterally and it aids in tilting the pelvis posteriorly by pulling the sacrum down towards the thigh (Kendall et al, 2005). As a result of piriformis attachments to the sacrum, piriformis contributes to counternutation and intrapelvic torsion, particularly if there is a shortness (Comerford et al, 2006A). The literature is sometimes contradictory when function is described with regard to internal and external rotation and because of this, the best way to stretch piriformis was done in a study by Swafford (2006). The study showed that the upper sacral fibres of piriformis were best stretched when the hip was at 90 degrees and 50 degrees of external rotation and the lower fibers of piriformis were best stretched at 90 degrees hip flexion. Adduction was not included in the study. Comerford et al (2006), move the hip to the end point of adduction and then laterally rotate it, until the pelvis gives in to a lateral tilt (Comerford et al, 2006). These methods of stretching piriformis support the stretching used in this study in **exercise 4.**

The role of piriformis in abduction of the flexed thigh is important in the action of walking, because it shifts the body weight to the opposite side of the foot being lifted, which prevents falling (Byrd, 2005). Therefor if it is tight and shortened on the left side, during gait and standing the hips will be shifted to the right, which occured in the double major, convex lumbar left thoracic right curves in this study. Following stretching of piriformis, bridging adduction was given, **exercise 5**, page 231. After the previous two exercises (exercise 3 and 4) the scoliometer readings improved, sometimes also in the thoracic area, the improvement in alignment needed to be sustained, which was the aim of **exercise 5 and 6** (bridging abduction), on page 231.

The muscles, which attach to the innominate and produce posterior innominate rotation or a sacral nutation force, can increase form closure, increasing stability across the sacroiliac joint (Comerford et al, 2006A). Muscles attaching to the sacrum that produce a nutation force on the sacrum, can also increase stability. These muscles include: Gluteals (maximus, medius and minimus), abdominals (oblique abdominals and transversus abdominis), multifidus and psoas. All these muscles were exercised in **exercise 5 and 6**. Gluteus maximus was activated in both these exercises, and by lightly touching to facilitate the gluteus maximus, contraction of deep gluteals was reinforced. The reason for the facilitation was subjects were able to bridge without contracting deep gluteals. Gluteus maximus is the only muscle in the pelvis and lower limb, that has three functions according to its different attachments, it is a local stabiliser (deep sacral fibers), global stabiliser (deep fibers) and global mobiliser (superficial fibers) (Comerford et al, 2006A). Gluteus maximus is attached to the posterior iliac blade and crest, thoracolumbar fascia, sacrotuberous ligament (longitudinal and lateral stabiliser of the sacrum), lateral crest of the sacrum and coccygeus and the gluteal tubersosity of the femur and Iliotibial band. The researchers aim was to stabilise the sacral base. All muscle slings described by Vleeming (Vleeming et al, 1990; Vleeming et al, 1990A), longitudinal and oblique are coupled to the Sacro Iliac Joint (SIJ) and are an effective energy storage system for gait (Enslin-Madden and Rosenberg, 1997). Unstable pelvic connections or diminished/ unbalanced muscle function can lead to sustained counternutation of the sacrum, flattening of the spine, shear forces in the SIJ and lumbar spine. Flattening of the kyphosis and lordosis occurs in AIS patients with larger curves, as mentioned in Chapter 2. All the muscle slings were activated in the exercises to increase stability and force closure across the SIJ and pubic symphysis. Symmetrical limb loading was used to minimise rotation. The muscle slings included in the exercises, were described by Vleeming (Vleeming et al, 1990; Vleeming et al, 1990A) who stated that compression controls shear at the SIJ and compression can be provided by the deep stabilizing muscles. He stated that the SIJ may be involved in muscles responsible for postural control. The slings are:

Posterior oblique sling: Latissimus dorsi, thoracolumbar fascia and contralateral gluteus maximus, iliotibial band. There are muscle attachments to sacrotuberous ligament. (Muscles used in **exercise 5, 6 and 8**).

Anterior oblique sling: External oblique, contralateral internal oblique and transversus abdominis via the rectus sheath, contralateral adductors. (**Exercise 5**, **9 and 10**).

Posterior longitudinal sling: Multifidus, thoracolumbar fascia, long dorsal SIJ ligament, sacrotuberous ligament, biceps femoris. (**Exercise 10**).

Lateral Sling: Gluteus medius, minimus and contralateral adductors. (**Exercise 6**).

In **exercise 5, 6, and 8** (on page 233) a posterior pelvic tilt was done using mainly abdominals, gluteals and psoas. Psoas major segmentally connects the lumbar spine, pelvis (sacroiliac joints) and the femur. Psoas major has posterior fascicles attaching inferiorly on the transverse processes T12-L5 and anterior fascicles attaching to anterior bodies of T12-L5 and all discs, except L5-S1 (Bogduk et al, 1992; Gibbons, 1999; Comerford et al, 2006). A review of the literature reveals psoas has been poorly investigated and there is controversy concerning its true functional role (Gibbons, 1999). It has a local stabiliser role and global stabiliser role (Gibbons, 1999; Gibbons, 2001). It has a primary local role, which is stability of the lumbar spine by axial compression and spinal rotatory control, and it has minimal movement function of the lumbar spine (Bogduk, 1997; Comerford et al, 2006). It generates force along a longitudinal moment, by axial compression increasing spinal stability. Psoas can shorten 1-1.5 centimeters (posterior) and 1-2.25 centimeters (anteriorly) and therefor is unable to produce sufficient range of force to be an effective hip flexor (Comerford et al, 2006). If psoas is activated or facilitated there is an improvement in lumbar segmental control of induced displacement, spinal axial compression and rotatory control (Comerford et al, 2006). It is more suited to eccentric control of spinal movements. Anderson et al (1995) states that psoas controls spinal lateral movement eccentrically. The global stabiliser role of the anterior fascicles of psoas is posterior rotation of the innominates, and posterior tilt of the pelvis (Gibbons, 2001; Comerford et al, 2006). The primary force of psoas on the hip is axial acetabular compression (Bogduk et al, 1992) and psoas contributes to hip flexion via associated posterior pelvic tilt (Anderson et al, 1995; Comerford et al, 2006). The global stability role of psoas is functionally combined with iliacus.

Psoas has fascial relations with the diaphragm (medial arcuate ligament), pelvic floor, transversus abdominis, internal oblique, pelvic rim, iliacus, anterior SIJ and iliolumbar ligaments. Fascial connections to the sacrum and innominate provide a mechanism of force closure across the SIJ (Gibbons, 2001). The segmental attachments of psoas, its axial compression and its links to the diaphragm and pelvic floor mean that psoas plays a role in spinal stability and should be considered an important stabiliser of the lumbar spine (Gibbons et al, 2002).

During expiration the diaphragm ascends, pulling on psoas and abdominal breathing in crook lying (the position used in **exercise 5, 6 and 7**) will have the best leverage for any fascial pull on psoas. Psoas exercises co-activate with transversus abdominis.

In **exercise 5, 6, 8 and 10** (on page 234) transversus abdominis was activated. Transversus abdominis can be simultaneously activated by contraction of the pelvic floor (Sapsford et al, 2001). The function of the transversus abdominis muscle is to resist anterior rotation of the innominate and tensions the thoracolumbar fascia and therfore is a local stabilser (Comerford et al, 2006A). Transversus abdominis and multifidus increase spinal stability by increasing intra-abdominal pressure, increase joint stiffness and via the thoracolumbar fascia increase rotational stability (Gray, 2011). Transversus abdominis has been shown that it is active asymmetrically during trunk rotation (Allison et al, 2008; Hodges, 2008; Gray, 2011). Allison et al (2008) was the first to show that feedforward activity of transversus abdominis is specific to the direction of arm movement and is not symmetrical bilaterally. She concluded that the muscle has an additional role and is also an axial rotator (Allison and Morris, 2008). This is confirmed by Gray's (2011) work, that transversus abdominis has a role in control of rotation. The contribution of the muscle to rotation may be control of the linea alba, while the contralateral external oblique and ipsilateral internal oblique contribute most to the torque (Hodges, 2008). Rehabilitation should include an evaluation of the whole muscular system, not just a single muscle (Hodges, 2008).

Normal gait is a low force, non-fatiguing functional movement (Comerford et al, 2006). During stance phase (weight bearing), which is 50 percent of the time, muscles work eccentrically. Swing phase of the leg is non weight bearing and occurs 40 percent of the time. There is single leg support phase (acceleration phase) and a double leg support phase (deceleration phase). During single leg support phase, substantial forward motion, there is greatest rotational stress and global stabiliser efficiency is required to control rotation especially in the single supporting limb. During double leg support (deceleration) phase eccentric control of rotation and forward movement is required. Stability is important to take the body load, especially in the sagittal plane. Asymmetry of the leg position, which was found in this study, will produce rotational stress at the pelvic and lumbar motion segments. Supporting this finding is Karski's work on hip contractures at birth developing into a side shift of the pelvis, when the child starts weightbearing (Karski, 2002; Karski et al, 2007).

In **exercise 9,** supine lying and lumbar rotation (on page 233), external and internal oblique muscles work eccentrically. Stance phase is mainly eccentric work. The thoracolumbar fascia and the oblique abdominal fascias store energy as the pelvis rotates under the trunk to decelerate lumbopelvic rotation and to assist with rotation of the pelvis in gait (Comerford et al, 2006A). In convex lumbar left, thoracic right and thoracic curves, the trunk is rotated to the right creating the rib hump. In **exercise 9**, the right external oblique was exercised eccentrically with the left internal oblique (dropping the rib flare often seen on the lower few ribs anteriorly on the left in thoracic convex right curves). These muscles provide rotation and torsion control via the trunk (Comerford et al, 2006A). In **exercise 7,** upper trunk rotation**,** the 'barrel roll' (on page 232), the right external oblique is exercised concentrically with the left internal oblique, rotating the trunk to the left, with scapular set, restricting forward movement of the right shoulder.

In **exercise 10,** 'the Jacknife' (on page 234), an aim was to increase kyphotisation, with full weight bearing through the arms, with breathing into the concavity of the thoracic curve. This is similar to the four point kneeling done with the Dobomed Method, where kyphotisaton is increased and breathing mechanics have been shown to improve (Dobosiewicz et al, 2008). **Exercise 10**, in a double major curve, lumbar convex left, thoracic convex right, as the left hemipelvis is in retroversion, the exercise was done moving the pelvic rotation to the right and dropping the left innominate into anteversion towards the subjects' right elbow. The right hemipelvis was held in anteversion and therefor was retroverted. After doing this exercise, the researcher found the lumbar rotation convex left was decreased when measured with the scoliometer. In a three curve scoliosis, convex thoracic right, if the lumbar region and pelvis (which act coupled together) were counter-rotated against the thoracic region, in other words pelvis rotated to the left, the knees moved towards the right elbow, rotating the pelvis to the right and anteverted the left innominate. All abdominals, external obliques, contralateral internal obliques, transversus abdominis are used in this exercise. This exercise mobilises the chest wall, as a result of the weight bearing through the arms and the asymmetrical breathing. Many muscles are being used and subjects breathe quite heavily after it, which means it possibly has some cardiovascular and chest expansion benefit.

In e**xercise 11** (on page 235) subjects were taught how to sit correcting their curve in all three dimensions. Elongation and autocorrection of the curves, in three dimensions, was done from the sacrum upwards. They were encouraged to sit for no longer than 30 minutes without standing up and sitting again. They were encouraged not to sit on the floor and bed when doing homework, but rather at a desk or diningroom table. **Exercise 12** involved lying on the side of the worst curve. The pressure on the apex of the curve was similar to that of the brace, however in a lying position. With this exercise, which was done for five minutes the researcher found the thoracic rotation could drop two degrees on scoliometer readings immediately after doing it. Subjects could read, play on their cellphones whilst doing this exercise, to alleviate boredom. **Exercise 13** (on page 236) was hanging from a pull up bar, a couple of times a day, placed in the doorway of their bedroom, which they pass through a couple of times a day. Infantile scoliosis subjects, with enough shoulder stability, can do this exercise, under supervision while playing on a jungle gym.

All exercises took no more than 25-30 minutes to complete. Cycling and swimming were encouraged for cardiovascular benefit. However long distance running was ruled out, especially during fast growth, as the researcher found this aggravated the scoliometer readings and height measurements. One subject, 15 years of age in the non compliant group wanted to run cross country whilst undergoing the brace treatment. She had a double major curve, with a thoracic Cobb angle of 40 degrees. To highlight the consequences of long distance running, the researcher asked her to jog for 15 minutes on a treadmill, as the cross country was 3km, at talking pace. After the jog the thoracic ATR increased from 10 to 15 degrees and her height dropped one centimetre. The ATR took a week to return to 10 degrees after doing the exercises three times that week. Another female subject, not in the study, 13 years of age, Risser 1, with a 17 degree thoracic Cobb angle, had a three curve scoliosis. Thoracic ATR was eight degrees and after a three kilometre jog it was 13 degrees. The ATR took two weeks to return to eight degrees.

Exercises were done in the order presented and prescribed 4-5 days a week. Pictures are of a subject with a double major curve, convex lumbar left and thoracic convex right (equal size curves, 46° Thoracic Cobb angle and 45° Lumbar Cobb angle). Informed consent for using the pictures was received from the subject and her parent. Headings in inverted commas are the name of the exercise used, when addressing the subject.

EXERCISES SHOWN AT FIRST TREATMENT.

Exercise 1: Autocorrection in standing

Method: Elongation of the spine and autocorrection of the curve. Side shift of the pelvis towards the transitional point of the curve. This was to the left in a balanced four curve, convex lumbar left, thoracic convex right, and to the right in a three curve, convex thoracic right. In the curves mentioned, the right shoulder was abducted and externally rotated, with the hand blocking the right ear, using the scapular to derotate the thoracic rib hump on the right. The right thoracic convexity was translated to the left and derotated anticlockwise. This position was held for one minute, with breathing into the concavity of the thoracic curve. When the subject was standing at ease they were encouraged to stand on the left leg (in a lumbar convex left, thoracic right) and on the right leg (in a thoracic convex right only curve). The exercise is presented in Figure 7.1 below.


A

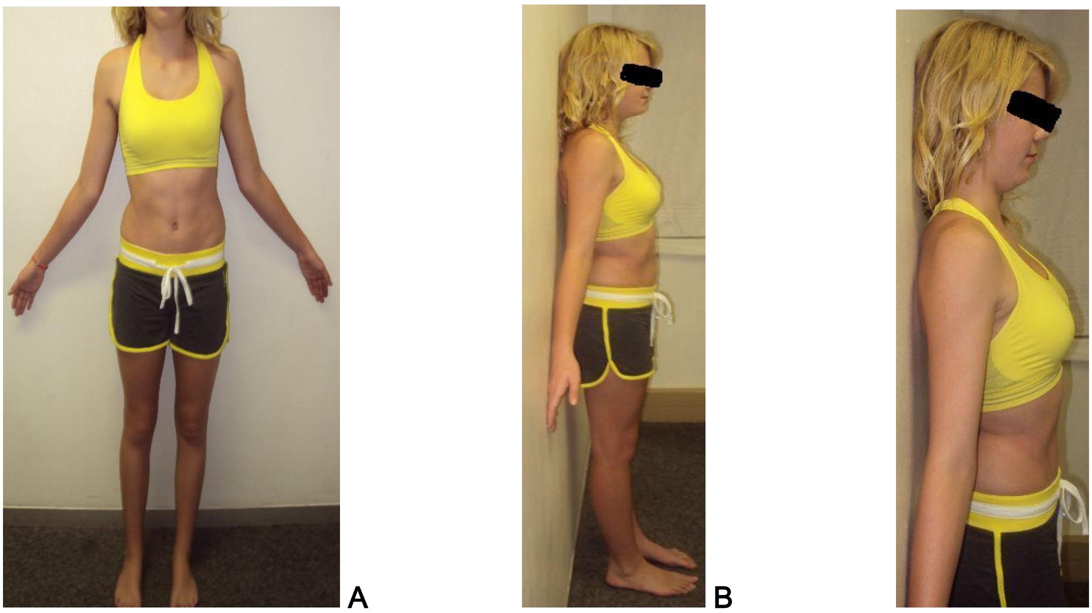
B

C

Figure 7.1. A- Free standing: B- Autocorrection in standing: C- Standing at ease on the left leg (R knee bent).

Exercise 2: Standing back against the wall (facing a mirror).

Method: Standing back against the wall, elongated. Head touching the wall and feet 10 centimeters away from the wall. Correct sagittal alignment, including lumbar lordosis in neutral, mastoid in line with the middle of the glenoid (demonstrated in a mirror at their side). Shoulders, back against the wall, arms externally rotated and abducted slightly. Shoulders must be level and not protracted on the rib hump side, shoulder blade set back and down. Pelvis side shifted to under transitional point of curve and held. Feet are shoulder width apart. The position was held for one minute, breathing into the concavity of the thoracic curve. At the second treatment head nods (20 times) were added to this exercise. The head remained on the wall, eyes horizontal, and the subject nodded the head as if there was a “pain of glass” in front of the nose, “without breaking the glass”, and without protracting the cervical spine. This was to stretch the superficial neck extensors and train the deep neck flexors associated with the forward head posture in these subjects. The exercise is presented in Figure 7.2 below.



A B C

Figure 7.2. A+ B- Standing back against the wall, in corrected position. C- Head nods

Exercise 3: “Washing the wall”. Side shifts against the wall

Method: The same posture was held as for exercise 2, however the pelvis was repetitively and rythmically side shifted towards the transitional point and to the limit of range, 20 times, without the shoulders moving, as if the shoulders were ‘‘pegged’’ to the wall. Shoulders must remain level during the exercise and spine must be elongated. Knees remain straight during the exercise. At the second treatment this was progressed to 30 times. The exercise is presented in Figure 7.3 on the next page.


A


B

Figure 7.3 Side shifts against the wall (A- Starting position, B- Endpoint).

Exercise 4: "Figure of four stretch". Piriformis stretch.

Method: For a tight left piriformis. In supine the subject flexes the left hip (in the case of double major, convex lumbar left, thoracic right curves) to 90-100 degrees, with the knee relaxed and then adducts the hip to resistance. The pelvis must remain neutral and not rotate as the hip adducts across the midline. Subjects were told to hold the left knee, medial to the line with the left shoulder. Maintaining flexed and adducted position, the left hip was laterally rotated to the end of range or until the pelvis gives to a lateral tilt and the left lower limb was resting on the right bent thigh. The subject was holding the right thigh with both hands. The position is held for 30 seconds and done four times. The exercise is presented in Figure 7.4 below.

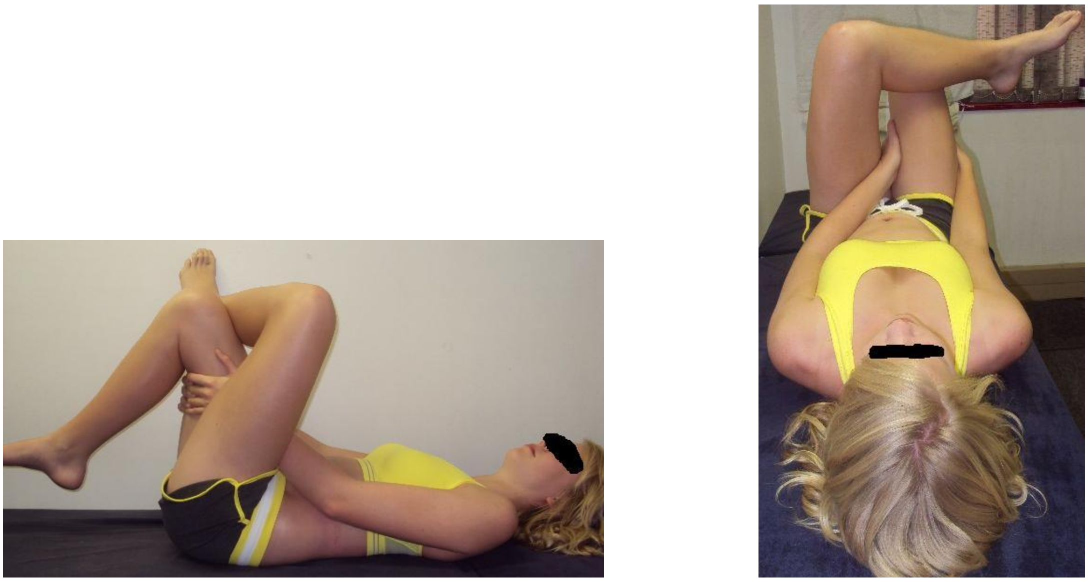


Figure 7.4 Piriformis stretch on the left leg.

Exercise 5: " Butt lifts squeezing the towel". Bridging Adduction.

Method: In crook lying with heels close to the buttocks (to isolate gluteals and not use hamstrings), with a rolled towel between the knees, the subject creates a posterior pelvic tilt using psoas major, with contracting deep gluteals and lower abdominals (transversus abdominis, external and internal obliques) and pelvic floor. The feet are shoulder width apart. The knees are adducted, squeezed, against the resistance of a towel and once the posterior pelvic tilt is achieved the pelvis is lifted one vertebra at a time, curling up into the bridge position. Deep gluteus maximus should be facilitated by palpating the area, while they do the exercise at the first treatment, to demonstrate where they should be contracting, because they can bridge without contracting the deep gluteals. The subject breathes out on lifting the pelvis. The movement is done 10 times, and the set is repeated twice(two sets of 10 repetitions). Three sets of ten are prescribed at the second treatment. The exercise is presented in Figure 7.5 below.

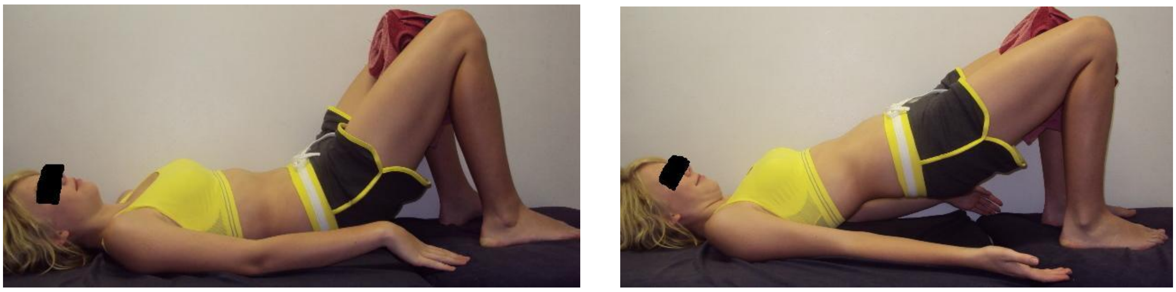


Figure 7.5 Posterior pelvic tilt and bridging adduction.

Exercise 6: " The Lift Exercise". Bridging Abduction.

Method: In crook lying with heels close to the buttocks (to isolate gluteals and not use hamstrings), with a black theraband around the knees, the subject creates a posterior pelvic tilt, contracts deep gluteals and lower abdominals (transversus abdominis, external and internal obliques) and pelvic floor. The knees remain together, feet shoulder width apart, and once the posterior pelvic tilt is achieved the pelvis is lifted one vertebra at a time, curling up into the bridge position. Breathing out on upward movement. At the top of the bridge the hips are abducted evenly against the band without dropping the pelvis, and then adducted. Breathing out on abduction. Deep gluteus maximus should be facilitated by palpating the area. The pelvis is then returned to the starting position, unwinding the spine one vertebra at a time. Two sets of 10 repetitions are prescribed. This exercise was explained to the subject as being like a "lift". They start on the ground floor, go to the first floor, open the doors (the legs), don't let the lift (pelvis) drop, close the doors and go down to the ground floor. This explanation assisted in achieving the coordination of the exercise.

This exercise can be done on subjects as young as four years of age. The exercise is presented in Figure 7.6 below.

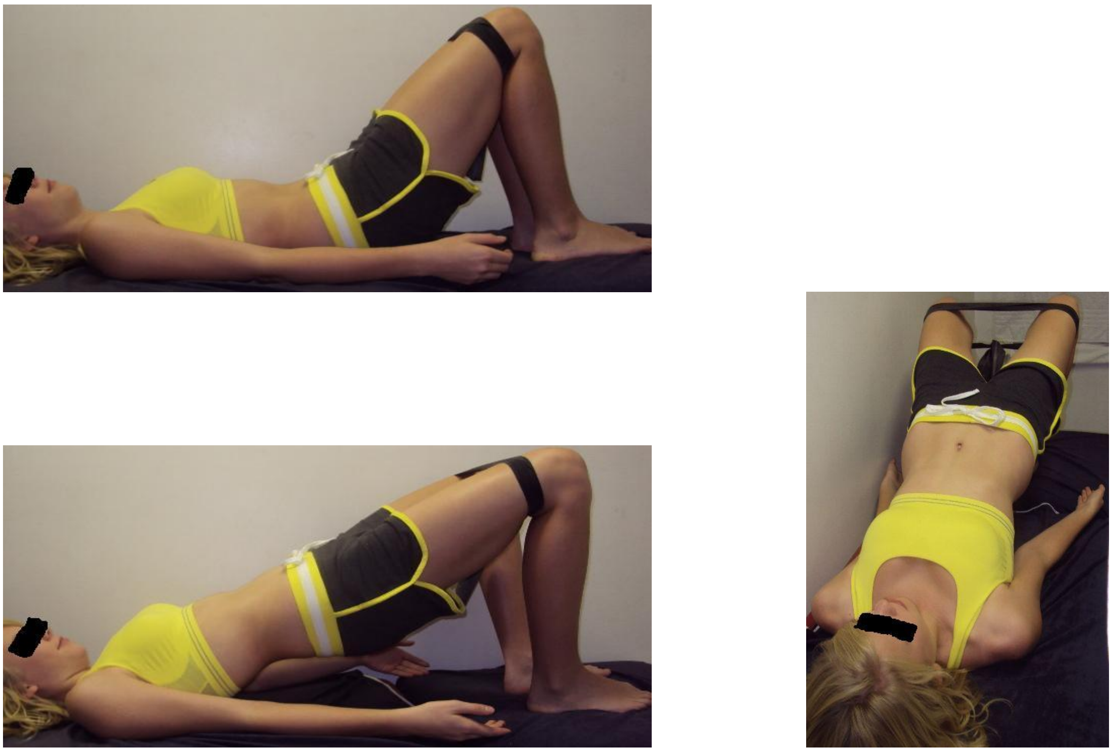


Figure 7.6 Posterior pelvic tilt and bridging abduction.

Exercise 7: " The Barrol Roll". Upper trunk rotation

Method: For convex thoracic right curve. Starting position is in crook lying, knees squeezing a towel. Right shoulder is abducted and externally rotated, blocking the right ear, shoulder is back. The spine and cervical spine remain elongated. Pelvis remains neutral and stationary and does not lift. The subject rotates the thoracic spine to the left in an anticlockwise direction, leading with the right chest, the shoulder girdle staying behind, but following. The head stays on the bed, however rotating to the left. Right external oblique is working with contralateral internal oblique. Breathing out on the active trunk rotation and on breathing in, breathing into concavity of the curve. Two sets of 10 repetitions are prescribed. The exercise is presented in Figure 7.7 below.

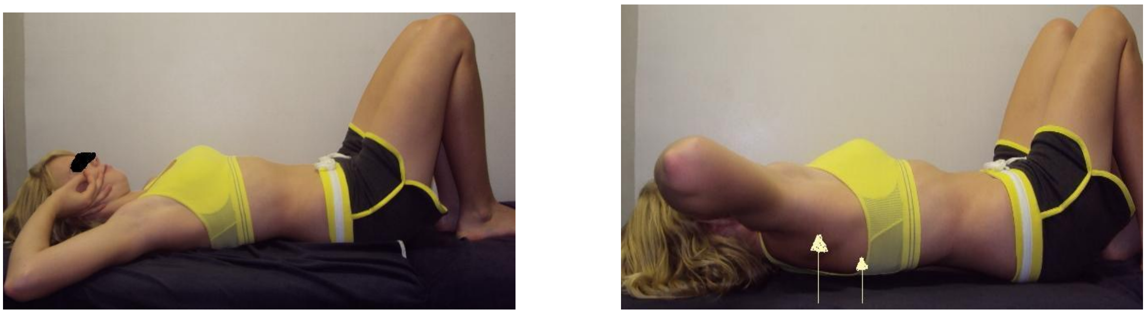


Figure 7.7 Upper trunk rotation.

EXERCISES SHOWN AT SECOND TREATMENT.

These exercises are added to the previous exercises.

Exercise 8: " Butt lift on the ball". Bridge on the ball.

Method: Starting position is supine, with the legs on the ball. Hips and knees at 90 degrees. Back of the thighs are touching the ball. A posterior pelvic tilt is done contracting all abdominals, gluteals contracting and lifting the pelvis to where the posterior pelvic tilt is lost and the lumbar spine starts extending and neutral lumbar spine is reached. If they start hyperextending the lumbar spine they have gone to far. Deep gluteals must be contracting and knees must be fully extended and hips externally rotated. The subject breathes out on lifting the pelvis. Arms remain supinated at their sides, right shoulder back (rib hump side). Then the subject moves the pelvis down to the matt, bringing the ball towards, them unwinding the spine one vertebra at a time, as done in Exercise 5 and 6, returning to the starting position. Two sets of 10 repetitions are prescribed. This exercise is progressed after two months to clasping the hands in front, at 90 degrees shoulder flexion. The exercise is presented in Figure 7.8 below.

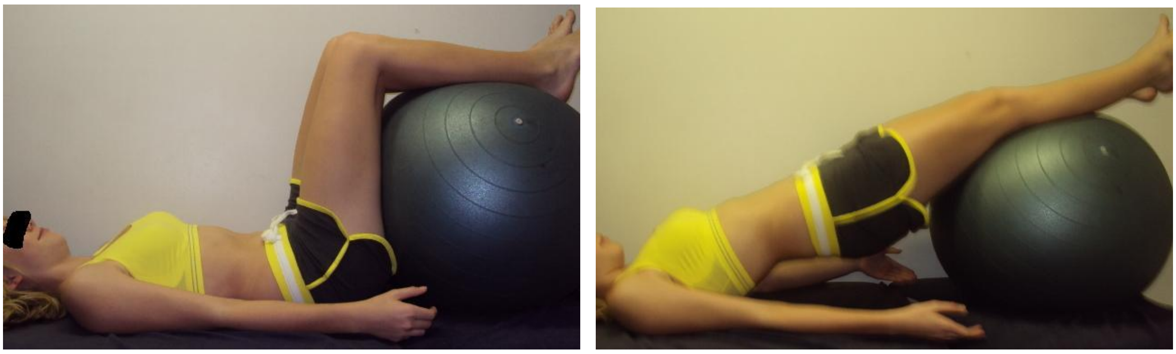


Figure 7.8 Bridge on the ball.

Exercise 9: "Roll the ball". Supine lying, lumbar rotation.

Method: For a thoracic convex right curve (in a four curve). Starting position is as for exercise 8, in supine, with the legs on the ball. Hips and knees at 90 degrees. Back of the thighs are touching the ball. The subject rolls the ball from the centre to the left, using right external oblique eccentrically and left internal oblique, breathing out on exertion. Shoulder girdle remains on the bed, when the right shoulder starts to lift, the legs are moved back to the midline of the body. Two sets of 10 repetitions are prescribed. Supine lying lumbar spine rotation is presented in Figure 7.9 is on the next page.

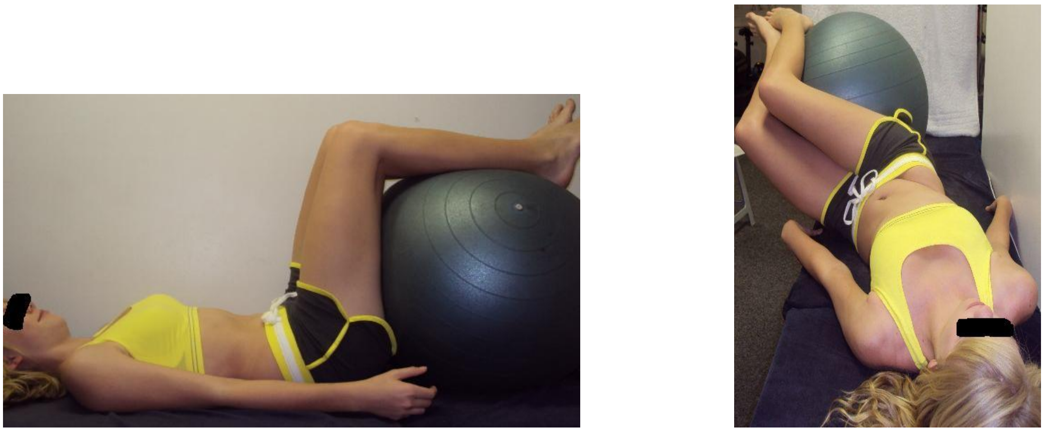


Figure 7.9 Supine lying, lumbar rotation.

<u>Exercise 10:</u> " The Jacknife". Prone lying on the ball, knee tuck to the side.

Method: Start by lying prone over the ball. The subject walks forward over the ball with their hands, until the knees just come off the ball. When shoulders are above the hands, both shoulders must be fully protracted and subject increases kyphotisation of the thorax. The body is now parallel to the ground feet on the ball. In this position, the subject is encouraged to breath into the concavity of the thoracic curve by facilitating the subject, with a strong local finger pressure (arrow in the picture) over the concavity of the curve. Then the legs are tucked under the body, aiming the left knee towards the right elbow in a convex lumbar left curve, thoracic right. A right convex lumbar curve would tuck towards the left elbow. For the left convex lumbar curve, the pelvis is rotated to the right and the left innominate dropped anteriorly into anteversion. Two tucks are done on expiration and on inspiration, breathing into the concavity of the thoracic curve is done. The subject then moves back to prone lying over the ball. The exercise is repeated four times with a 10 second rest in-between, as many muscle groups are being used. See Figure 7.10 below.

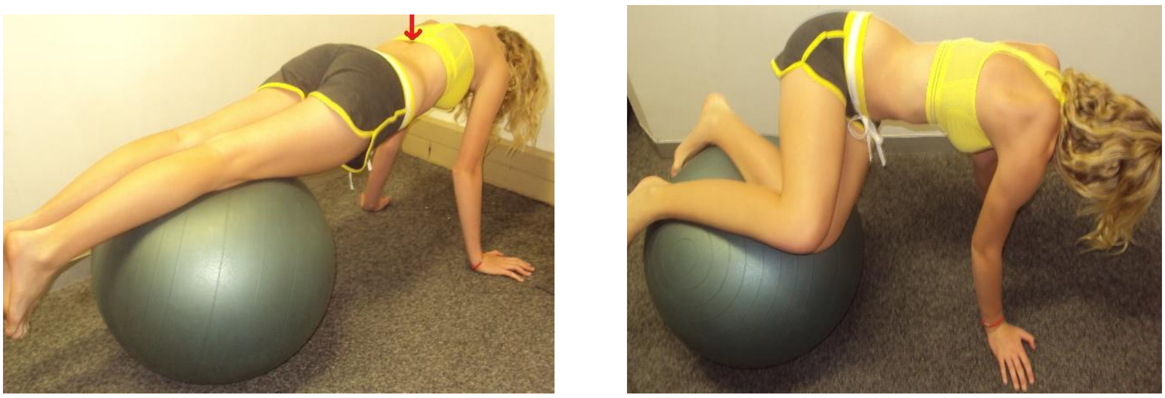


Figure 7.10 Prone lying on the ball, knee tuck to the side.

Exercise 11: How to sit.

Method: Subjects were taught to sit at their desk, or normal sitting, with correcting their curve in all three dimensions. Sagittal profile of the spine was corrected first, then the lateral deviation, then the rotation. In order to get a neutral lumbar spine into a little extension, they were encouraged to always sit with their knees below their hips and to elongate, like a puppet on a string. A cushion could be used to raise the pelvis above the knees. Autocorrection, in three dimensions, was done from the sacrum upwards, getting them to laterally shift into the concavity of the thoracic curve and then to derotate the trunk. Shoulder girdle was corrected to remain level and straight. Then the head position was corrected, making sure the chin was not protracted. These corrections of posture had to be done everytime they sat in or out of the brace. Sitting is presented in Figure 7.11 below.

Figure 7.11 Sitting in autocorrection.

EXERCISES SHOWN AT THIRD TREATMENT.

Added to previous exercises.

Exercise 12: " Cellphone exercise". Side lying on a rolled towel.

Method: Lying on the side of the worst curve. If this was the lumbar curve, they lay on a hard surface on a matt, on two bath towels rolled together, which were right under the apex of the curve, pushing it straight with a lateral pressure. This is a similar lateral pressure of the brace on the apex of the lumbar curve. The knee closest to the bed is bent to 90 degrees, and the top leg is straight and on a pillow, and a pillow under their head. If the worst curve was convex lumbar left and they are lying on the left side, with the right side up, right mastoid, right greater trochanter and right lateral malleolus must be in the same straight line. If the worst curve was in the thoracic area, say convex right, they lay on their right side, but importantly the thorax is turned 45 degrees to the left, so the pressure on the right thorax was more posterior anterior and lateral to the left, but on a diagonal, similar to that of the brace. The uppermost limb (left arm) is in shoulder extension (not shown in the picture), with flexion of the elbow and the hand resting on a pillow. The legs are in the same position as for the lumbar curve. This exercise was done for a minimum of five minutes, however could be done for a longer period. They could read or play on their cellphones whilst doing this exercise. The exercises are presented in Figure 7.12 and Figure 7.13 below.

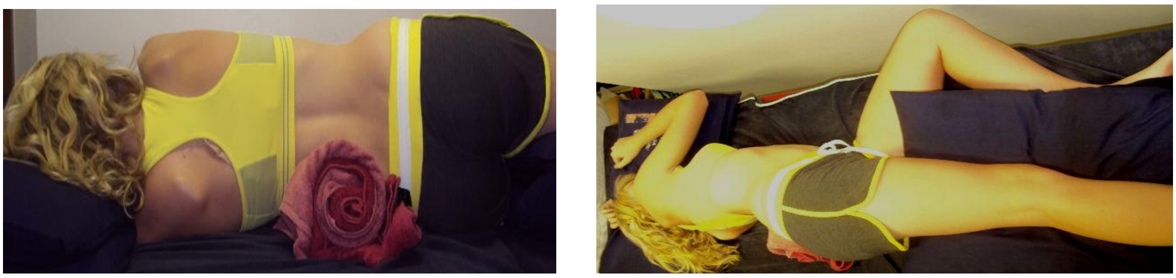


Figure 7.12 Left side lying for a convex lumbar left curve.

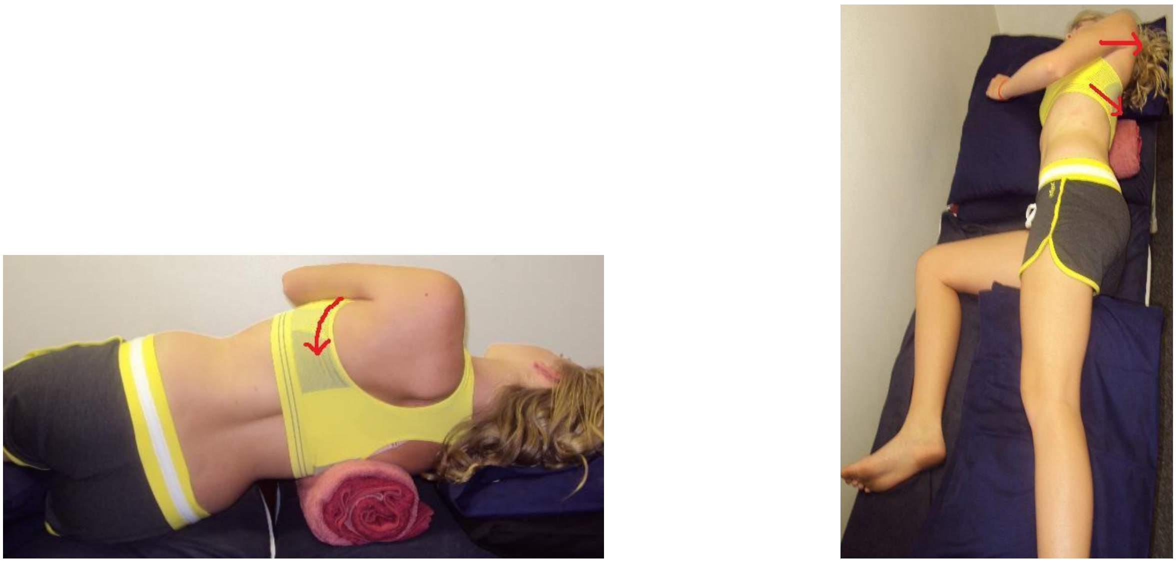


Figure 7.13 Right side lying for a convex thoracic right curve.

Exercise 13: Hanging

Method: Hanging from a pull up bar, a couple of times a day, placed in the doorway of their bedroom. Feet would gently rest on the ground or be in the air off the ground, to to get elongation of the spine, in a non weight bearing position. They would hang until they needed to rest their hands, however they must not get a lot of discomfort in their hands. Subjects normally held the position from 15-45 seconds depending on the subject's discomfort. This would be done a 3-4 times a day, everyday.

Transitional Points in Three and Four Curve Scoliosis. *APPENDIX XII*

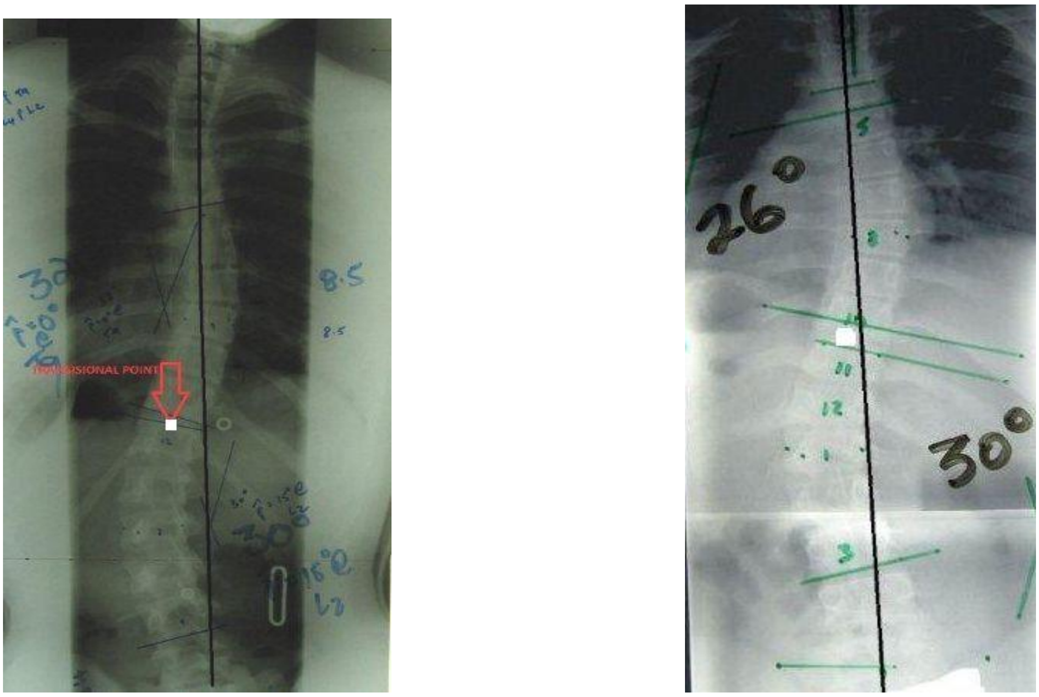


Figure 7.14 Transitional point to the left of central sacral line in convex lumbar left curves, convex right thoracic scoliosis subjects of the study.

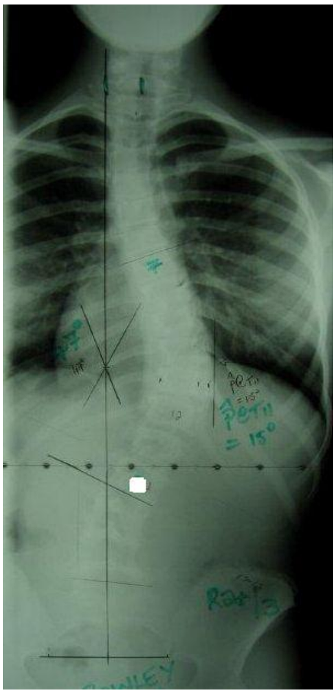


Figure 7.15 Transitional point to the right of the central sacral line in a three curve scoliosis, convex thoracic right.

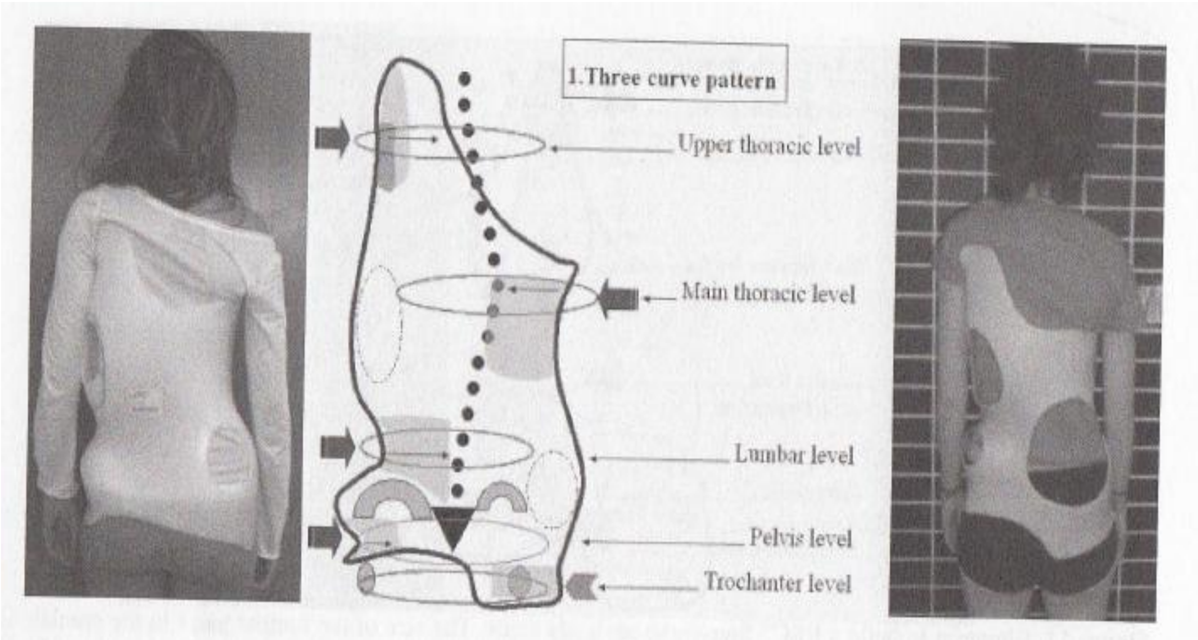


Figure 7.16 RSC brace for Three Curve, Right Thoracic Scoliosis in Rigo and Weiss (2008) The cheneau concept of bracing- Biomechanical Aspects. Studies in Health Technology and Informatics 135: 303-19.

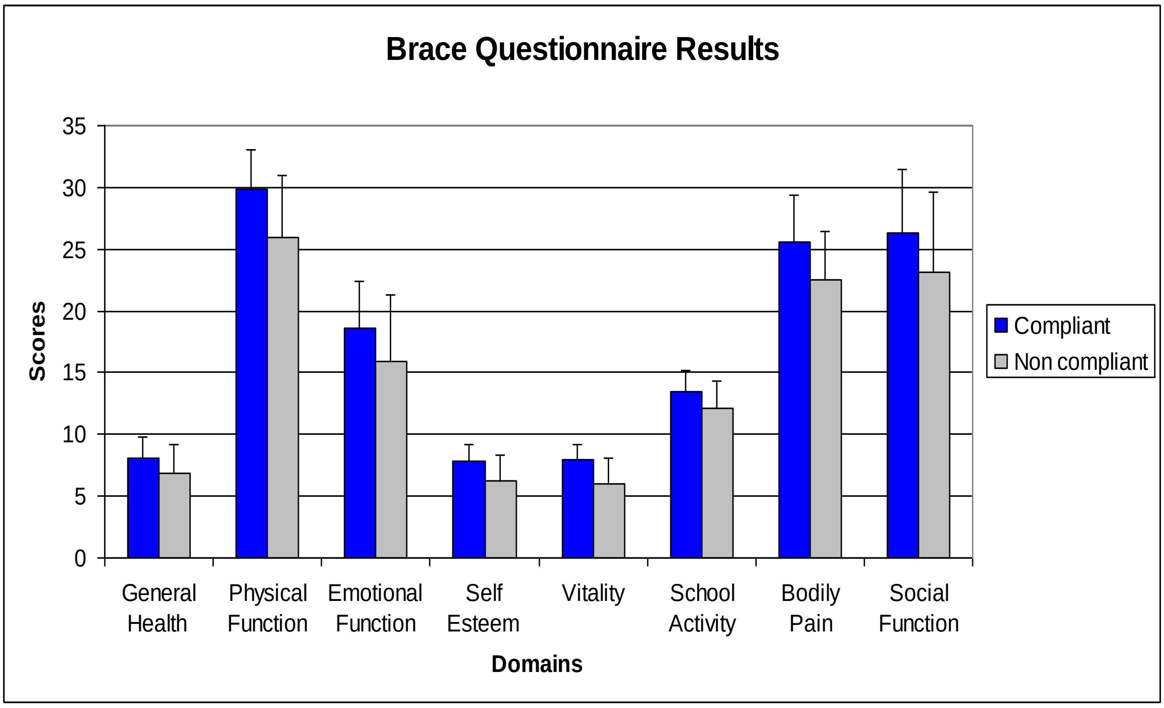


Figure 7.17 Results of the Brace Questionnaire comparing compliant and non compliant groups.

During the weaning process, the same exercises that were done during the study were used. The volume and number of exercises was not changed. The weaning process used with these subjects took 11 months and included:

- From 23 hours of brace wearing, reducing the brace hours one hour per week, for seven weeks.
- Then 16 hours brace wearing for six months
- Then re X-ray (Check Cobb angles had stabilised and if the curve remained the same, continue with weaning. This occurred in all eight subjects)
- In the next two months brace hours came down to 12 hours brace wearing. Brace hours came down one hour every two weeks for two months.
- In the next two months down to eight hours brace wearing, bringing brace hours down one hour every two weeks. That would be sleeping in the brace and they could continue this, for as long as they wished.
- If after six months of 16 hours of brace wearing the Cobb angles had not stabilised, then 16 hours would have been continued for another six months, however this did not occur in these eight subjects.

Results

The weaning process out of the brace, was started once height was static and the subjects were at Risser 5 or as close as possible to it. This was the end of this study. Not all subjects had weaned out of the brace by the end of this study. However eight subjects had completed the weaning process in the compliant group only and their data are presented in Table 7.1 below. Thoracic and lumbar Cobb angles and their apical rotations were compared at the start of the weaning process to the end of the weaning process. The weaning process took eleven months and as the group was compliant they adhered to the weaning plan, which is described in Appendix XV. In the eight subjects, six had Double Major Type curves (one T + TL, and five T +L) and two had Thoracic Type curves.

Table 7.1 Weaning Process- Start to End, Compliant Group only.(n=8)

Measure	Group	n (%)	Mean (±SD)	p Value
All Thoracic Cobb angles (degrees)	**Compliant**	8 (100) @ start 8 (100) @ end	24.5 (±12.1) 25.63 (±11.29) **= -1.13**	0.16
All Lumbar Cobb angles (degrees)	**Compliant**	8 (100) @ start 8 (100) @ end	20.13 (±8.15) 21.00 (±9.46) **= -0.87**	0.19
All (Thoracic) Rotation Apical Vertebra	**Compliant**	8 (100) @ start 8 (100) @ end	11.25 (±7.90) 10.63 (±9.43) **= +0.62**	0.68
All (Lumbar) Rotation Apical Vertebra	**Compliant**	8 (100) @ start 8 (100) @ end	6.87 (±6.51) 6.25 (±7.44) **= +0.63**	0.60

There was no significant change in the size of mean Cobb angle and apical rotations at the end of the weaning process compared to the start of the weaning process for these eight subjects. Cobb angles and apical rotations remained the same in the lumbar and thoracic areas. No significant progression of the curvatures occurred during this weaning process and the curvatures stabilised.

Discussion

The weaning process used in this study took eleven months and is described in Appendix XV above. This weaning process is supported by the work done by Negrini et al (2009A), who found in a small study that Cobb angles start worsening within four hours of removing a brace. Postural collapse occurred after one hour of brace removal and scoliometer readings changed after two hours (Negrini et al, 2009A). The researcher in this study enphasised compliance to the exercise regime during the weaning phase and subjects saw the researcher once a month during weaning, when heights and scoliometer readings were monitored. The regular visits improved compliance to the weaning programme and psychological support was important during the weaning phase to maintain compliance until Risser 5.

Clinical implications.

- The researcher recommends weaning out of a brace should be initiated as close to Risser 5 as possible and when the height has been static (measured at the same time of day) for six months as this resulted in no progression of curves during the weaning phase. These results were however on a very small group of subjects and indicate a possible trend only and were not part of this study. The weaning process used is recommended as no progression of curvatures occurred during this process.

Research Implications.

- Larger studies need to be done using the weaning method used here to prove its effectivity. Data on the compliant subjects in this study will continue to be collected until all subjects are out the brace, to determine the effect of the weaning process.
- The weaning process used here needs to be compared to other weaning processes as weaning processes have resulted in progression of curvatures.

The role of a psychologist and a support group in the weaning process needs to be investigated, to improve compliance during weaning. The researcher found that in the non compliant group, when the “weaning out the brace” was mentioned to some subjects, they stopped wearing the brace immediately. Maintaining these subjects on the correct weaning process was a difficult challenge. This was the reason the effect of the weaning process in the non compliant group was not presented and an effective weaning process could not be presented on them. At present most patients in this study are currently in the weaning process.