RADIOGRAPHIC AND CLINICAL ANALYSES OF SCOLIOSIS OF ADULT SUBJECTS IN THE GREATER DURBAN AREA

By

Shethal Gajeerajee

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Durban University of Technology

I, Shethal Gajeerajee, do hereby declare that this dissertation is representative of my own work in both conception and execution (except where acknowledgements indicate to the contrary)

…………………………………….......... Date: ……………………………
Shethal Gajeerajee

Approved for Final Submission

…………………………………………….. Date: ……………………………
Dr. J. Shaik
M. Tech. Chiro., M. Med. Sci. (SM), MCASA

DEDICATION

I dedicate this dissertation to:

My parents, Allan and Usha Gajeerajee. Thank you for the gift of my education, for the support and unconditional love. Words are not enough for everything that the both of you have provided for me. You both have sacrificed your lives to give me the one I lead now. Everything that I am and ever will be is because of the two of you. I hope this dissertation fills you with as much pride as it does to call myself your daughter.

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ABSTRACT

Aim: To determine a radiographic and clinical profile of adult subjects with scoliosis and to determine an association between selected radiographic and clinical parameters.

Subjects: Sixty subjects between 18 and 45 years, with or without neck/back pain, previously diagnosed with scoliosis.

Methodology: A case history and a physical examination of the subject which included an orthopedic assessment of the cervical, thoracic and lumbar spinal areas were conducted for all subjects. Selected clinical data viz. a case history, family history, level and location of pain if present, presence of leg length inequality, pelvic obliquity, shoulder height inequality and/or rib hump was recorded. A full spine A-P radiograph was taken for each subject in the weight-bearing position. Selected radiographic parameters viz. location of curve/s, side of convexity, degree of pedicle rotation, level of the apex vertebra and the Cobb angle of inclination were assessed and recorded. SPSS version 15.0 (SPSS Inc., Chicago, Illinois, USA) was used for data analysis.

Results: The mean (± SD) age of the subjects was 26.8 (± 7.9) years. The majority of the subjects were females (63.3 %). A family history of scoliosis was reported by 14 subjects. Most of the subjects (73.3%) complained of pain of moderate severity at the time of presentation. The thoracic and lumbar regions were common areas of complaint in symptomatic subjects and they were most likely to experience pain at the level of the apex vertebra. Shoulder height inequality was observed in 96.7% of subjects, LLI in 91.7% of subjects, rib hump in 73.3% of subjects and pelvic obliquity in 86.7% of subjects. The majority of scoliotic curves were of idiopathic origin (96.7%). Thirty subjects presented with more than one curve. The mean (± SD) Cobb angle for the major curve was 21.3º (± 13.1º) while the mean (± SD) Cobb measurement for the minor curve was 16.7º (± 5.4º). The range for the major and minor curve was 11.5º - 97.0º and 10º-37º respectively. Both the major and minor curve had the majority of curves located in the thoracic region. However, the apex vertebra was most likely to be found in the T7/T8 region for the major curve and L1/2 region for the minor curve. Pedicle rotation was Grade 1, Grade 0 or Grade 2 (in that order) for the major curves and Grade 0, Grade1 and Grade 2 for the minor

curves. There was no significant association between the gender of the patient and the severity of pain ($p = 0.725$), severity of the major curve ($p = 0.545$) or grade of pedicle rotation ($p = 0.639$). There was also no significant association between the ethnicity of the subjects and severity of the major curve ($p = 0.088$) or degree of pedicle rotation ($p = 0.882$). No significant association was found between location of the major curve and presence of pain ($p = 0.565$) or between the side of the curve and pain ($p = 0.812$). There was no correlation between the degree of pain and the degree of curve ($r = 0.102$). No significant association was found between LLI and degree of curvature ($p = 0.470$). A significant association between LLI and reported pain was found ($p = 0.034$). A significant association was observed between the presence of a rib hump and the degree of curvature ($p = 0.049$). A positive correlation was found between rib hump elevation and degree of curvature ($r = 0.814$). A positive correlation between rib hump elevation and degree of pedicle rotation was found (*rho* = 0.308).

Conclusion: Idiopathic scoliosis is the most common form of scoliosis in young adults. Pain is a common clinical feature in adult scoliosis. The size of the curve does not influence the magnitude of the LLI, pelvic obliquity or shoulder height inequality, however since these clinical features are common findings in the scoliotic individual, it is suggested that these parameters be routinely evaluated for their diagnostic significance. The presence of shoulder height inequality, LLI, rib hump and pelvic obliquity are deemed to be good clinical signs of scoliosis. Even though LLI was not associated with the magnitude of the curve, it may be a significant contributor to the back pain as LLI was found to be the only clinical parameter to have a significant association with pain. Therefore clinicians should explore the treatment of LLI to alleviate pain associated with scoliosis. The presence of a rib hump is a good clinical indication of the presence of a scoliosis.

LIST OF SYMBOLS AND ABBREVIATIONS

1º:	Primary
2º	Secondary
>:	Greater than
↑:	Increase /increased/results are more than the findings of this study
↓:	Decrease/decreased/results are less than the findings of this study
+ve:	Positive
-ve:	Negative
AIS:	Adolescent idiopathic scoliosis
ANOVA	Analysis of variance
A-P:	Anterior to posterior
ASA	Adult scoliosis of adolescent onset
AS:	Adolescent scoliosis
assoc.:	Association
BP:	Back pain
CDC:	Chiropractic Day Clinic
C:	Cervical
cm:	Centimeters
CT:	Cervicothoracic
DDS	*de novo* Degenerative scoliosis
DUT:	Durban University of Technology
EpOb:	End plate obliquity
F:	Female
IS:	Idiopathic scoliosis
L:	Lumbar
LBP:	Low back pain
LL:	Leg length
LLI:	Leg length inequality
LS:	Lumbosacral
M:	Male
mm:	Millimeters

***n*:**	Sample size/count
N/A:	Not applicable/Not available
N/C:	No curve
NRS:	Numerical Pain Rating Scale
Pelvic Ob:	Pelvic obliquity
pts:	Patients
Rib Hmp:	Rib hump
Sh Ht I:	Shoulder height inequality
SPSS:	Statistical Package for the Social Sciences
SRS:	Scoliosis Research Society
T:	Thoracic
TL:	Thoracolumbar
T+L:	Thoracic and lumbar
USA	United States of America
***vs*:**	Versus
VR:	Vertebral rotation
yrs:	Years

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CHAPTER ONE

INTRODUCTION

1.1 INTRODUCTION TO THE STUDY

Scoliosis is a spinal disorder that involves both a lateral and rotary deformity of the vertebrae (Dangerfield, 2003). The rotational transformation that occurs forces the ribs towards the convex side leading to a rib cage deformity, commonly known as a rib hump. This is related to a significant amount of body asymmetry. Scoliosis may be observed at any age, from birth to adulthood, and can either be acquired or idiopathic (Armour, Seimon, Marguiles, 1998; Dangerfield, 2003).

The lateral deformity may be classified in several ways e.g. according to the cause, the anatomical features and the magnitude, rotation and the level of the apex vertebra (Schulthess, 1905; Goldstein and Waugh, 1973; Scoliosis Research Society, 2002; Dangerfield 2003; Yochum and Rowe, 2005). When classified according to the etiology, the deformity may either be structural or non-structural (also termed functional) (Goldstein and Waugh, 1973). The nature of the curve depends on the flexibility of the spine; a non-structural scoliosis is one that the patient can correct by bending to the convex side, a transient structural scoliosis corrects with the patient lying down and a structural scoliosis is a rigid curve that does not correct itself on lateral bending (Musa, 1999).

When scoliosis presents itself in a skeletally mature individual, it is defined as an adult scoliosis. This may either be a curve that has progressed from adolescence into adult life or one that is due to degenerative changes in the spine (Schwab, Smith, Biserni, Gamez, Farcy and Pagala, 2002; Aebi, 2005). Adult scoliosis is a more frequent problem encountered in spine-based practice than scoliosis in children and adolescents and has been shown to have a significant and measurable impact on an individual's health-related quality of life (Aebi, 2005; Lowe, Berven, Schwab and Bridwell, 2006).

Scoliosis was reported to be a common spinal anomaly in the setting of a Chiropractic Teaching Clinic in North America (McCoy and Pryor, 2006). However, the prevalence and incidence of scoliosis appears to differ between different populations and depends largely on the age group studied and the definition of scoliosis that is utilized. In Johannesburg, South Africa, and Austin, Texas (United States of America) it was found that the incidence of the spinal deformity is higher in the Caucasian/White population than in the Black/African-American population (Segil, 1974; Voros, Neubauer, Khoshnevisan, Skolasky and Kebaish, 2007).

Scoliosis is diagnosed both radiographically and clinically (Yochum and Rowe, 2005). The magnitude of scoliosis may be measured by using either the Risser-Ferguson or the Cobb-Lippman method (Musa, 1999). Radiographic assessment allows for the determination of the location of the curve, the angle of inclination of the curve/s, location of the apex vertebra/e, the degree of pedicle rotation of the vertebrae that is most affected by the curve and sometimes, even the cause of the curve/s (Lonstein, Bradford, Winter and Ogilvie, 1995; Yochum and Rowe, 2005; Kuklo, Potter, Shroeder and O'Brien, 2006).

Clinical manifestations of scoliosis may include unequal shoulder heights, leg length inequality (LLI), pelvic obliquity and a rib hump (Lonstein *et al*., 1995; Armour *et al*., 1998). As a result of these structural changes, patients may present with back pain (Morscher, 1977; Aebi, 2005) although the association between the development of back pain and the presence of scoliosis has not yet been well determined (Jackson, Simmons and Stripinis, 1983; Ramirez, Johnston and Browne 1997; Schwab *et al*., 2002; Schwab, el-Fegoun, Gamez, Goodman and Farcy, 2005; Glassman, Berven and Bridwell, Horton and Dimar, 2005; Pouramat, Scattin, Marpeau, de Loubresse and Aegerter; 2007).

The correlation between certain clinical presentations and radiographic measurements has also not yet been well determined despite attempts by several researchers (Grosso, Negrini, Boniolo and Negrini, 2002; Krawczyński, Kotwicki, Szulc and Samborski, 2006; Djurasovic and Glassman, 2007; Grameaux, Casillas, Fabbro-Peray, Pelissier, Herisson and Perennou, 2008). Grameaux *et al*. (2008) concluded that further studies are required to clarify the clinical significance of the radiological features of spinal deformities including especially adult scoliosis as it has received little attention.

1.2 AIMS AND OBJECTIVES OF THE STUDY

The aim of this study was:

- To determine a clinical and radiographic profile of adult subjects with scoliosis and to determine an association between selected radiographic and clinical parameters.

Specific objectives were identified and these included:

1.2.1 To determine the clinical profile of adult subjects with scoliosis with respect to the following:

a) LLI
b) Shoulder height inequality
c) Pelvic obliquity
d) Rib Hump

1.2.2 To determine the radiographic profile of adult subjects with scoliosis with respect to the following:

a) Presence of more than one curve
b) Side of convexity
c) Location of the curve/s
d) Location of apex vertebra/e
e) Cobb angle of inclination of the major and minor curve
f) Grade of pedicle rotation of the major and minor curve

1.2.3 To determine the number of subjects (in the asymptomatic group, in the mild, moderate and severe Numerical Pain Rating Scale (NRS) group and in the mild, moderate and severe spinal curvature group) presenting with:

a) LLI
b) shoulder height inequality
c) pelvic obliquity
d) clinically detectable rib hump,

and to determine if there were any significant differences between these groups.

1.2.4 To determine the association* between:

a) The presence or absence of any neck/back pain and
   - Location of the curve
   - Direction of curve and

b) Severity of the neck/back pain and degree of the curvature.

1.2.5 To determine an association between the LLI and spinal curve magnitude.

1.2.6 To determine an association between the degree of pedicle rotation and the height of a clinically detectable rib hump.

1.2.7 To determine an association between a rib hump elevation and spinal curve magnitude.

*All associations were done with the major curve and not the minor curve

1.3 HYPOTHESES OF THE STUDY

For objective **1.2.4** with respect to the presence of pain:
The Null Hypothesis (H_o) stated that there would be no significant association between pain and the location of the curve. This was based on the conflicting results of Jackson *et al*. (1983), Ramirez *et al*. (1997), Pouramat *et al*. (2007) and Grameaux *et al*. (2008).

The Null Hypothesis (H_o) stated that there would be no significant association between pain and the direction of the curve. This was based on the results of studies by Pouramat *et al*. (2007) and Grameaux *et al.* (2008).

The Null Hypothesis (H_o) stated that there would be no significant association between pain and the magnitude of the curve. This was based on the conflicting results of Kostuik and Bentivoglio (1981), Jackson *et al*. (1983), Ramirez *et al.* (1997), Schwab, Dubey, Pagala, Gamez and Farcy (2003), Glassman *et al.* (2005) and Grameaux *et al.* (2008).

For objective **1.2.5** the Null Hypothesis (H_0) stated that there would be no significant association between LLI and the degree of curvature. This was based on the conflicting results by Hoikka, Ylikoski and Tallroth (1989) and Ramirez *et al.* (1997).

For objective **1.2.6** the Null Hypothesis (H_0) stated that there would be no significant association between the degree of pedicle rotation and the height of the clinically detectable rib hump. This was based on the conflicting results of Thulborne and Gillespie (1976) and Krawczyński *et al.* (2006).

For objective **1.2.7** the Null Hypothesis (H_0) stated that there would be no significant association between the height of the clinically detectable rib hump and the degree of curvature. This was based on the conflicting results of Villemure, Aubin, Dansereau, Petit and Labelle (1999), Grosso *et al.* (2002) and Krawczyński *et al.* (2006).

1.4 SCOPE OF THE STUDY

The results of 60 adult subjects with scoliosis who met all of the inclusion criteria of this study are reported in this dissertation. These subjects were recruited using convenience sampling from the general population of Durban, KwaZulu Natal. The subjects were informed of the nature of this study and each one signed an informed consent form. All subjects underwent a case history, physical examination and orthopedic assessments of the cervical, thoracic and lumbar spinal regions. The selected clinical parameters were then analyzed by the researcher. An erect anterior to posterior (A-P) radiographs of the entire spine was taken for each subject. The selected radiographic parameters of the spine were then evaluated by the researcher.

1.5. LIMITATIONS OF THE STUDY

The sample size was limited to 60 individuals between the ages of 18 – 45 years. This excluded a fair number of adults with a scoliosis above 45 years of age. Only one radiographic view was assessed as all the data needed could be derived from the single A-P view. This reduced the amount of radiation dosage to the subjects, but excluded radiographic data that could be analyzed using the lateral view e.g. sagital balance, lumbar lordosis and end plate obliquities. These were found to correlate with clinical symptoms by some researchers (Glassman *et al*., 2005, Schwab *et al*., 2005). In terms of subjective clinical data, only the intensity or severity of the pain was recorded. The study did not include aspects relating to the subjects' health-related quality of life which was the focus of several previous studies (Schwab *et al.*, 2003; Asher, Lai, Burton and Manna, 2004; Glassman *et al*., 2005, Schwab *et al*., 2005). This study therefore focused on selected clinical and radiographic data as it was beyond the scope of this research dissertation to investigate all clinical and radiographic parameters.

CHAPTER TWO

LITERATURE REVIEW

2.1 DEFINITION AND DESCRIPTION OF SCOLIOSIS

The term scoliosis was first introduced into medical terminology by the Greek physician Galen in the second century A.D. (Huebert, 1967; Lonstein *et al.,* 1995). It is derived from the Greek word "*skolios"* meaning twisted or crooked (Yochum and Rowe, 2005). The disorder manifests as a bending of the spine in the coronal plane (Armour *et al*., 1998). The Scoliosis Research Society (2009) defines it as "a lateral deviation of the normal vertical line of the spine which, when measured by x-ray, is greater than ten degrees." This lateral deviation is often accompanied by rotation of the vertebrae within the curve leading to rib cage and flank muscle asymmetry (Scoliosis Research Society, 2009).

2.2 CLASSIFICATION OF SCOLIOSIS

Classification systems are essential to all physicians to describe an ailment in order to guide treatment and decision-making and to provide a standardized base for reporting results (Garbuz, Masri, Esdaile and Duncan, 2002).

Attempts to classify scoliosis can be dated back to Hippocrates. He wrote extensively on the spinal deformity and noted that the severity of the deformity was related to the age at which it appeared. He was, however, unable to provide a detailed classification of the possible causes. He is furthermore reported to have stated: "There are many varieties of curvatures of the spine even in persons who are in good health, for it takes place from natural conformation and from habit, and the spine is liable to be bent from old age and from pains" (Hippocrates [translated by Adams], 1849). Today, scoliosis is classified in several ways. A summary of the methods of classification of scoliosis is presented in **Table 2.1**.

Table 2.1 A summary of the methods of classification of scoliosis

Classification	Description	Reference	Categories
Spinal location	Location of apex vertebra	Schulthess (1905); SRS (2002) Yochum and Rowe (2005)	• C: apex between C1 and C6 • CT: apex between C7 and T1 • T: apex between T2 and T11 • TL: apex at T12 and L1 • L: apex between L2 and L4 • LS: apex at L5 or S1
Etiology	Causative factor	Goldstein and Waugh (1973); McAlister and Shackelford (1975)	• Structural or non-structural
Idiopathic	Curve pattern	Ponseti and Friedman (1950)	• Single, double or triple curves
Idiopathic	Age of presentation	James (1954); Stokes (1994)	• Infantile: birth to 3 yrs • Juvenile: between 3 and 10 yrs • Adolescent: older than 10 yrs till skeletal maturity
King and Moe	Cobb angle and flexibility index on bending radiographs	King *et al*. (1983)	• I: S-shape curve crossing midline of T+L curves. L curve is longer. Flexibility index is –ve. • II: S-shape. T major and L minor. Crosses midline. T is longer. • III: T curve. L curve does not cross midline. • IV: Long T curve. T5 centered over sacrum and T4 angled toward direction of the curve. • V: T double curve. T1 angles into convexity of upper curve.
Lenke	Level and number of curves	Lenke *et al*. (2001)	• I: Main T which is structural. • II: Double T curve where the minor curve is structural. • III: T double major curves • IV: Triple major • V : 1º TL/L. Major curve is TL or L • VI: 1º TL/L with main T curve.
SRS Adult Spinal Deformity	Building on King and Moe and Lenke systems	Lowe *et al*. (2006)	• 1º Curve Type • Deformity modifier • Degenerative modifier • Global balance modifier • Regional • Specific major curves
Adult	Cause	Aebi (2005)	• 1º degenerative/ *de novo* - disc or facet joint arthritis • Progressive AIS :- • 2º to abnormality/ anomaly in bone • 2º to bone disease
Adult	Cause	Grubb *et al*. (1988); Schwab *et al.* (2002)	• ASA • DDS
Adult	Radiographic parameters (L3 EpOb and total LL)	Schwab *et al.* (2002)	• Type I: LL>55º; EpOb<15º • Type II: LL=35º-55º; EpOb=15º-25º • Type III:LL<35º; EpOb=>25º

SRS = Scoliosis Research Society; C = Cervical; CT = Cervicothoracic; T = Thoracic; TL = Thoracolumbar; L = Lumbar; LS = Lumbosacral; yrs = years; T+L =Thoracic and lumbar; -ve = Negative; 1º = Primary; 2º = Secondary; AIS = Adolescent idiopathic scoliosis; ASA = Adult scoliosis of adolescent onset; DDS = *de novo* Degenerative scoliosis; EpOb = End plate obliquity; LL = Lumbar lordosis

The classification according to spinal location, originally described by Schulthess (1905) (**Table 2.1**), is based on the level of the apex vertebra. This is defined as the most rotated vertebra in the curve or the most deviated vertebra from the vertical axis of the patient on x-ray (Scoliosis Research Society, 2009). According to the classification proposed by Goldstein and Waugh (1973) (**Table 2.1**), scoliosis may either be structural or non-structural. A structural scoliosis is rigid and does not correct itself on recumbent or lateral bending (Yochum and Rowe, 2005). It may be due to various etiologies like myopathic and neuromuscular disorders, congenital anomalies, rheumatoid disease, trauma, tumors, metabolic diseases of the bone, *etc*. Causes of a non-structural scoliosis include nerve root irritation, a LLI or hip contractures (Goldstein and Waugh, 1973; Lonstein *et al*., 1995; Yochum and Rowe, 2005). When no recognizable disorder like paralysis, metabolic disease, trauma or congenital anomaly has been established as the cause, the cause is termed idiopathic which may be further categorized according to the age of presentation (James, 1954; Stokes, 1994) (**Table 2.1**). James (1954) is credited with classifying idiopathic scoliosis according to the age of the patient at the time of diagnosis (**Table 2.1**).

The terms infantile, juvenile and adolescent are important in their prognostic significance despite seeming insignificant. Robinson and McMaster (1996) reported that out of 109 children with juvenile idiopathic scoliosis, 90% of the curves progressed and 70% of these individuals went on to require corrective surgery. Adolescent idiopathic scoliosis is the most common type of idiopathic scoliosis. Females are more likely to be affected than males and 90% of these curves occur convex to the right (Armour *et al*., 1998; Al-Arjani, Al-Sebai, Al-Khawashki and Saadeddin, 2000).

Any medical or biological classification system should be based on an etiological and pathological understanding of the problem and it is etiology that is one of the most important factors when describing a spinal deformity (Dangerfield, 2003). The etiological classification, though useful for comprehending the diagnosis and any associated co-morbidities, is however limited with its guidance for care of specific types and locations of curves (Lowe *et al*., 2006). The King and Moe classification (**Table 2.1**) has been shown to be useful in treatment planning as it is based on the extent of the spinal fusion which is required (King, Moe, Bradford and Winter, 1983). But, recent reports have highlighted the poor reliability of the classification due to inter- and intra-observer variability (Cummings, Loveless, Campbell, Samelson and Mazur, 1998; Dangerfield, 2003).

An adult scoliosis is defined as a spinal deformity in a skeletally mature patient with a Cobb angle of more than ten degrees (Aebi, 1987; Aebi 2005) and is divided into two main categories as shown in **Table 2.1** (Schwab *et al.*, 2002). It can either be due to degeneration or it may be an adolescent scoliosis that has progressed into adulthood (Schwab *et al*., 2002; Aebi, 2005). Adult scoliosis has received minimal attention in comparison to the other categories of classification of the spinal deformity, viz. congenital, neuromuscular and idiopathic scoliosis. (Schwab *et al*., 2002; Aebi, 2005). It, therefore, lacks a useful classification system and recognized treatment guidelines. This has been attributed largely to the inadequate understanding of the relevant radiographic parameters of that category of the deformity (Schwab *et al*., 2002). The Scoliosis Research Society's classification of Adult Deformity (**Table 2.1**) is useful in its prediction for surgical strategies but it is limited in that it does not include essential clinical considerations such as presenting symptoms and age (Lowe *et al*., 2006). The classification of adult scoliosis that separates the deformity into Adolescent Scoliosis of the Adult and *de novo* Degenerative Scoliosis (**Table 2.1**) covers patients that have a progressive scoliosis from childhood or adolescence in the first category and the patients in whom the deformity develops after skeletal maturity and comprises of some form of degeneration in the second category (Grubb, Lipscomb and Suh 1994; Schwab *et al*., 2002). However, this classification excludes other causes of scoliosis such as trauma and osteoporosis (Thevenon, Pollez, Cantegrit, Tison-Muchery, Marchandise and Duquesnoy, 1987). The system outlined by Schwab *et al.* (2002) (**Table 2.1**) was useful for showing a correlation between clinical and radiological parameters, but is limited in that it is restricted to the lumbar spine. Furthermore, this system developed by Schwab *et al.* (2002) as well as newly developed Lenke system (**Table 2.1**) has not been utilized frequently (Lenke, Betz, Harms, Bridwell, Clements, Lowe and Blanke 2001). Therefore, due to the differing views on classification, the clinician treating the deformity may utilize a classification based on his/her treatment protocol (Dangerfield, 2003).

2.3 EPIDEMIOLOGY AND FAMILY HISTORY

Idiopathic scoliosis is the most common type of spinal deformity confronting orthopedic surgeons (Lonstein *et al.*, 1995). The prevalence and incidence of scoliosis appears to vary depending on the population studied and the definition of scoliosis that is utilized (**Table 2.2**).

A summary of studies reporting either the incidence or prevalence and/or family history of scoliosis is presented in **Table 2.2**.

Table 2.2 A summary of the incidence, prevalence and family history of scoliosis

Reference	Population	Incidence	Prevalence	Family History
Segil (1974)	South African students	> in Caucasian (2.5%) than in the Black population (0.03%)	N/A	N/A
Brooks *et al.* (1975)	474 seventh and eighth Grade students (California) with IS	N/A	13.6% of 3492 individuals	21.3%
Stirling *et al.* (1996)	15,799 individuals (range 6-14 yrs)	N/A	0.5%	N/A
Ramirez *et al* (1997)	2 442 individuals with IS	N/A	N/A	21%
Kim *et al.* (2003)	13,397 middle and high school students	N/A	12.6%	N/A
Schwab *et al.* (2005)	75 adult subjects (mean age 70.5 yrs, range : 60-90 yrs)	N/A	68%	N/A
Voros *et al.* (2007)	2 973 individuals (mean age 60.8 yrs, Range 40-97 yrs)	N/A	8.85%	N/A

N/A = Not available; > = Greater; IS = Idiopathic scoliosis; yrs = years; USA = United States of America

The prevalence of the spinal deformity was reported to be 0.5% in England (Stirling, Howel, Millner, Sadiq, Sharples and Dickson, 1996) whereas in Korea 12.6% of the population studied had a scoliosis (Kim, Alamin, Lee, Choi, Park, Oh and Woo, 2003) (**Table 2.2**). In the adult population, the prevalence of scoliosis was reported to be as high as 68% (Schwab, Dubey, Gamez, el Fegoun, Hwang, Pagala and Farcy, 2005). Interestingly, studies involving both the South African and American population, reported the incidence of scoliosis to be higher in Caucasian than in Black individuals (Segil, 1974; Voros *et al*., 2007) (**Table 2.2**;). Stirling *et al*. (1996) and Al-Arjani *et al*. (2000) observed that the point prevalence of scoliosis is greater in females than in males. It was also observed that the incidence of scoliosis increased with increasing age (Voros *et al*., 2007). Studies in India and at a spinal clinic in Saudi Arabia reported that the most common type of scoliosis observed was idiopathic scoliosis (Reddy, Dave and Kotwal, 1987; Al-Arjani *et al*., 2000).

The spinal deformity may be present in most members of the same family, possibly due to a multigene dominant condition (Reamy and Slakey, 2001). Although this etiology has been hypothesized for many years, the incidence of family history in patients presenting with scoliosis has not yet been fully determined. Armour *et al.* (1998) stated that the majority of people affected with the deformity will have an idiopathic scoliosis and a high number of these individuals will present with a family history. An incidence of 21% of patients with a family history of scoliosis has been reported with idiopathic scoliosis (Brooks, Azen, Gerberg, Brooks and Chan, 1975; Ramirez *et al.,* 1997; **Table 2.2**).

2.4 ASSESSMENT OF SCOLIOSIS

When compared to the general population, patients with scoliosis had a higher self-reported rate of arthritis and a poorer perception of overall health and inability to participate in vigorous activities (Goldberg, Mayo, Poitras, Scott and Hanley, 1994). Another study by Schwab *et al.* (2003) in the United States analyzed adult patient perception of health using the Short Form 36 (SF-36). The results showed that patients had lower scores when compared to conditions like hypertension and chronic low back pain. These authors concluded that adult scoliosis is becoming a medical condition of significant impact affecting the fastest growing section of society.

2.4.1 CLINICAL ASSESSMENT

The diagnosis of scoliosis is based both on a clinical and radiological assessment of the individual. Due to the lateral bending of the spine, obvious asymmetry may be seen when the back is observed. This can manifest as unequal shoulder heights, pelvic asymmetry, rib hump and/or a LLI (Lonstein *et al*., 1995). Shoulder height inequality was reported to be a common clinical feature among 474 individuals presenting with idiopathic scoliosis. It also showed a tendency to be present on the left side (Brooks *et al*., 1975). One of the major skeletal adaptations to unequal leg length is a scoliosis; therefore it would seem likely that clinically significant biomechanical alterations may exist between scoliosis and LLI (Specht and De Boer, 1991).

Together with the lateral bending of the spine, the rotational transformation of the vertebrae in the thoracic region forces the ribs on the convex side of the curve dorsally, creating a rib hump (Armour *et al*., 1998). This clinical feature was observed to be present in 47.7% of individuals in the study by Brooks *et al.* (1975). They also observed a right-sided tendency for the presence of the rib hump.

The prominence of the rib hump can be observed by performing the Adams Forward Bend Test (Lonstein, Bjorklund, Wanniger, Winter and Moe, 1976). The patient stands with his/her feet together and knees straight and bends forward at the waist. The arms are loosely hanging forward with the hands together and palms and fingers in opposition. The patient is then viewed from a head-on position where the examiner compares the sides of the back for asymmetry which presents itself as a prominence on one side caused by the ribs that attach to the laterally deviated and rotated vertebrae (Lonstein *et al*., 1995).

This simple test was found to be the best non-invasive clinical test to evaluate scoliosis. The diagnostic reliability of the Adams Forward Bend Test and the Scoliometer was compared in 87 girls and 18 boys (mean age (±SD) - 15.5 (±4.8) years) with scoliotic curves measuring ten degrees or greater. The Scoliometer had 23% sensitivity and 48% specificity whereas the Adams Forward Bend Test had 51% sensitivity and 96% specificity (Côte, Kreitz, Cassidy, Dzus and Martel, 1998).

MacEwen, Winter and Hardy (1972) reported that 18% of 231 individuals presented with urological anomalies which was a common finding in those patients with congenital scoliosis. But, studies indicated that a long-term follow-up or the incidence of the anomaly in the adult population has not been fully investigated (Vitko, Cass and Winter, 1972; Beals, Robbins and Rolfe, 1993; Rai, Taylor, Smith, Cummings and Plunkett-Cole, 2002)

Pain is also an important feature reported to be associated with scoliosis. Patients with a spinal deformity may present with pain at the curvature, leg pain (radicular distribution) or neurogenic claudication (Aebi, 2005; Djurasovic and Glassman, 2007). Pain and dysfunction in the deformity may be the result of the regional failure of the stabilizing structures or it can be due to the disproportionate loads in the muscle groups that are caused by the lateral deviation of the spine (Avikainen, Rezasoltani and Kauhanen, 1999; Schwab *et al.*, 2005; Morningstar and Joy, 2006). Myofascial trigger points may develop from asymmetrical loading. The inflammation and decreased circulation associated with these myofascial trigger points may also be a source of pain in scoliosis (Travell and Simons, 1999)

Pain is not as common in young scoliotic patients compared to older individuals, particularly those with lumbar curves (Armour *et al*., 1998). Patients with adolescent idiopathic scoliosis are largely asymptomatic and are referred mainly on the basis of signs of the deformity (Djurasovic and Glassman, 2007). Adult scoliosis, on the other hand, differs from the adolescent classification in that the complaints are significant. Back pain can be localized at the apex, in the concavity of the curve, the facet joint or in the counter-curvature above and below the major curve and is reported as a frequent complaint (Aebi, 2005).

2.4.2 RADIOGRAPHIC ASSESSMENT

In addition to a clinical assessment, imaging is the most definitive and objective diagnostic tool in the assessment of scoliosis (Young, Oestreich and Goldstein, 1970; Kuklo *et al*., 2006; Musa, 1999). The radiograph is essential for determining the cause, the site, magnitude of the curvature, the location of the apex vertebra and for monitoring curve progression or regression, and aid in selecting appropriate treatment (Yochum and Rowe, 2005). X-ray has been shown to be a relatively safe diagnostic tool (Levy, Goldberg, Hauley, Mayo, Poitras, 1994) and the radiation doses to scoliotic patients are relatively low (Chamberlain, Huda, Hojnowski, Perkins, Scaramuzzino, 2000). There are two commonly utilized methods for the radiographic evaluation of scoliosis. These are the Cobb-Lippman (Cobb, 1948) (commonly referred to as the Cobb method) and Risser-Ferguson method (Risser and Ferguson, 1936). Both methods require the identification of the apical vertebra (as defined earlier) as well as the end vertebrae. The description of these two methods is presented in **Table 2.3**

Table 2.3 Description of the Cobb-Lippman and Risser Ferguson methods

Method	Reference	Description
Cobb-Lippman	Cobb (1948)	The superior and inferior end vertebra is selected and lines are drawn from the upper end of the superior end plate and the lower end of the inferior end plate. When the endplates cannot be seen on the radiograph the bottoms or the tops of the pedicles may be used. Perpendicular lines are then drawn from each endplate line and the vertical angle formed by their intersection is measured
Risser-Ferguson	Risser and Ferguson (1936)	Lines are drawn from the center of the superior and inferior end plate of the vertebral bodies to the center of the apex vertebra. The degree of the curve is measured by the intersection of the two lines.

Although the magnitude of the curve can be adequately assessed using these methods, the Cobb method has been observed to be the most consistent and reliable (Behrend *et al.,* 1989; Cóte *et al*., 1997). It is a more popular and frequently utilized method of measurement in research relating to scoliosis than the Risser-Ferguson method (Watanabe *et al*., 2005; Kuklo *et al*., 2006; Krawczynski *et al*., 2006). It still remains the most accepted method of angle measurement despite the speculation regarding its intra- and inter-observer reliability (Stirling *et al*., 1996). The Cobb method has been shown to have good reproducibility and better reliability when compared to the Risser-Ferguson method (Pruijs, Hageman, Keessen, van der Meer and van Wieringen, 1994; Gupta, Wijesekera, Sossan, Martin, Vogel, Boakes, Lerman, McDonald and Betz, 2007). The findings of Kuklo, *et al.,* (2006) also support the use of the Cobb method for it showed good reliability particularly in patients prior to or without surgical correction.

The degree of pedicle rotation of the vertebrae that is most affected by the curve is also determined radiographically. This is the dimension of the deformity that is closely associated with the external cosmetic deformity. For determining the degree of pedicle rotation, the Pedicle Method described by Nash and Moe (1969) is the most accepted technique. The movement of the pedicle on the convex of the curve is graded between 0 and +4 and is a measure of the anterior deformity (Nash and Moe, 1969; Lonstein *et al*. 1995; Yochum and Rowe 2005; Kuklo *et al*., 2006).

2.5 THE ASSOCIATION BETWEEN CLINICAL FEATURES AND RADIOGRAPHIC PARAMETERS

To treat a patient optimally, it is imperative to decide if the treatment is to target the deformity or the subjective clinical symptoms or both. It is, therefore, important to determine the correlation of clinical symptoms to specific radiological findings. A review of studies that have attempted this correlation has reported that the prediction of the patients overall health based on the degree of the deformity, has been difficult (Djurasovic and Glassman, 2007).

A summary of the various studies that attempted to correlate clinical features and radiographic parameters are tabulated in **Tables 2.4 - 2.7**.

PAIN AND HEALTH-RELATED QUALITY OF LIFE

Table 2.4 A summary of studies that have examined pain and other health-related quality of life measures in scoliotic patients

Reference	Sample	Results
Kostuik and Bentivoglio (1981)	189 patients with scoliosis	BP present in 59% of individuals, 43% - mild pain, 50% - moderate pain and 7% had severe pain. Severity of pain↑ with curves > 45º. Patients without pain had smaller curves and age had no relation severity of pain.
Jackson *et al.* (1983)	197 adults	Severity of pain is greater in scoliosis pts. 51% had significant pain. Pain ↑ with age and with the degree of curve ($p < 0.0005$). Pts with major L curves experienced more pain.
Ramirez *et al*. (1997)	2 442 Individuals with IS (mean age 14 yrs)	23% had BP. Significant assoc. between maturity and prevalence of BP ($p < 0.001$). No assoc. was found between pain and the type of curve ($p = 0.882$) or magnitude of the curve ($p > 0.05$)
Schwab *et al.* (2002)	98 pts (mean age 20 yrs). Mean (±SD) Cobb = 30º (±19)	78 pts (74%) had some degree of back pain
Schwab *et al.* (2003)	49 pts with AS, 22 with ASA and 27 with DDS (mean age 63)	Cobb angle not significantly associated with social function ($p = 0.018$), emotion ($p = 0.038$) or general health($p = 0.05$)
Asher *et al.* (2004)	Mean age 15 (range 10mth-20 yrs). MeanCobb = 63º	Cobb *vs.* function ($p = 0.0027$, $r = -0.53$), Cobb *vs.* self image ($p = 0.0099$, $r = -0.46$),
Glassman *et al.* (2005)	298 pts 172 prior to surgery and 126 with surgical correction	Correlation of pain, self image, social function and health related quality of life with a ↓ sagital balance (when C7 plumb line falls anterior to the L5/S1 disc, on lateral radiographs, it is a +ve sagital balance) but not with magnitude of curve or apical rotation on A-P radiograph.
Schwab *et al.* (2005)	95 pts (mean age 59 yrs, range18-88 yrs)	No correlation of pain with the Cobb angle or general health but correlation with L3 obliquity of end plate, coronal olisthesis and L1/S1 lordosis
Pouramat *et al.* (2007)	51 adults with IS (48 F and 3 M) (mean age 37 yrs)	42 individuals had LBP, 4 were asymptomatic and 22 had nerve root pain
Grameaux *et al.* (2008)	100 pts (50 with scoliosis and 50 without) (mean (±SD) age 62.3 (± 13.7) yrs, range 27-83 yrs in those with scoliosis)	No difference with regards to severity of pain in group with scoliosis than the group without. Intensity of pain in adults increased with large curves in the L spine ($p < 0.05$). Severity of pain also correlated well with VR ($p < 0.05$) and rotary olisthesis ($p < 0.05$)

BP = Back Pain; IS = Idiopathic scoliosis; assoc. = Association pts = Patients; yrs = years; F = Female; M = Male; LBP = Low back pain; ↑ = Increase; L = Lumbar; VR = Vertebral rotation; ↓ = Decrease; +ve = Positive; AS = Adult scoliosis; ASA = Adult scoliosis of adolescent onset; DDS = *de novo* degenerative scoliosis; *vs.* = Versus

CURVE PATTERNS

Table 2.5 A summary of studies that have described curve patterns in scoliotic individuals

Reference	Sample	Results
Stokes *et al.* (1988)	141 pts	80 pts with single curve, 59 with double curve and 2 pts with triple curves
Stirling *et al*. (1996)	0.5% of population of 15,799 individuals had a scoliosis (aged between 6 – 14yrs)	58% had a T primary curve. T and TL curves tended to be right sided ($p = 0.02$) L curves to be left ($p = 0.02$). Tendency of large curves to be T. Association between site and size of the curve ($p = 0.07$)
Schwab *et al.* (2005)	98 pts older than 20yrs (mean age 68 yrs, Mean Cobb (±SD) = 30º (± 19º)	44 pts with L curves, 30 pts with T curves, 1 pt with TL curve and 21 individuals with a double curve (T + L)
Wong *et al.* (2005)	72,699 schoolchildren in Singapore	TL curves more common (40.1%) followed by T curves (33.3%), double curves (18.7%) and L curves (7.9%)
Glassman *et al.* (2005)	172 pts without surgery out of 298 pts	44 pts with T curves, 47 pts with TL curves and 41 pts with a L curve
Pouramat *et al.* (2007)	51 adults with idiopathic scoliosis (48 F and 3 M) (mean age 37 yrs)	30 single major curves, 18 double curves and 3 triple curves. 19 L curves, 11 TL curves.
Grameaux *et al*. (2008)	50 patients with scoliosis. Mean Cobb (±SD) = 23.1º (±13.1º)	26 curves to the left 24 curves to the right

yrs = years; T = Thoracic; TL = Thoracolumbar; L= Lumbar; pts = Patients; F = Female; M = Male

LEG LENGTH INEQUALITY

Table 2.6 A summary of studies that have examined LLI in scoliotic individuals

Reference	Population	Results
Hoikka *et al.* (1989)	100 pts with chronic LBP (53 M and 47 F). Mean (±SD) age = 40 yrs (± 7 yrs)	LLI had a poor correlation with L scoliosis ($r = 0.338$, $p < 0.001$). 56 pts – right leg was shorter. 36 pts- left leg was shorter
Specht and de Boer (1991)	106 pts (53% F) (mean age 41.1 yrs)	53% of pts with a LLI > 6 mm had a scoliosis or abnormal lordosis
Ramirez *et al.* (1997)	2442 pts with IS (mean age 14 yrs)	13 % had a LLI > 1.5 cm. 6% were asymptomatic and 7% experienced BP. LLI had no significant assoc. with pain ($p = 0.704$)

pts = Patients; LBP = Low back pain; M = Males; F = Females; yrs = years; LLI = Leg length inequality; L = Lumbar; mm = Millimeter; IS = Idiopathic scoliosis; cm = Centimeter; BP = Back pain; assoc = Association

ROTARY DEFORMITY

Table 2.7 A summary of reports of rotary deformity of the spine in scoliotic individuals

Reference	Population	Results
Thulborne and Gillespie (1976)	52 pts	No correlation between the degree of the scoliosis and vertebral rotation
Villemure *et al.* (1999)	40 adolescents (mean Cobb angle = 44º)	Correlation between axial rotation (mean = 15º) and Cobb angle
Grosso *et al.* (2002)	116 pts with scoliosis	No correlation between the degree of curvature and the rib hump height
Asher *et al.* (2004)	67 pts with IS (preoperative) (range = 10 months – 20yrs)	Hump index *vs.* Function (p = 0.0005, r = -0.60)
Kracwzynski *et al.* (2006)	50 pts	Strong linear correlation between angle of trunk rotation (measured with a scoliometer), the pedriolle angle and the Cobb angle.
Pouramat *et al.* (2007)	51 adults with IS	50 pts had a rotary subluxation
Ploumis *et al.* (2009)	56 pts with degenerative lumbar scoliosis	Patients with a rotary olisthesis > Grade 1 had poorer functional results

IS = Idiopathic scoliosis; *vs.* = Versus; pts = Patients; yrs = years

Despite the observation that back pain is a frequent complaint in the scoliotic patient (Aebi 2005), the association between the development of back pain and the presence of scoliosis has not yet been well established. This is supported by the conflicting results reported by several studies (**Table 2.4**). Ramirez *et al.* (1997) reported that 23 % of patients had some degree of back pain at the time of diagnosis whereas Schwab *et al.* (2002) reported that up to 74% of patients are symptomatic at the time of presentation. Later in 2007, Pouramat *et al.* in a study of 51 scoliotic patients observed that all but eight subjects had low back pain, 22 had nerve root pain and only four were asymptomatic (**Table 2.4**). When comparing the general population to those with the spinal deformity, Jackson *et al*. (1983) observed that the severity of the pain tended to be greater in patients with scoliosis. However, a recent study reported no significant difference in the severity of the pain in the individuals with scoliosis compared to those without (Grameaux *et al*., 2008) (**Table 2.4**).

Kostuik and Bentivoglio (1981) reported that the degree of pain was not associated with the age of the patient (**Table 2.4**). On the other hand, a significant association was observed between the prevalence and the severity of back pain and the maturity of the patients with scoliosis in both the adolescent and adult population (Jackson *et al*., 1983; Ramirez *et al*., 1997) (**Table 2.4**).

Kostuik and Bentivoglio (1981) also observed that the severity of pain increased with curves greater than 45º (severe curves) and that asymptomatic patients tended to present with smaller curves. They also reported that more individuals tended to report the intensity of pain as mild or moderate rather than severe (**Table 2.4**). It seems quite reasonable to assume that the severity of pain increases as the degree of curvature increases. Although two studies have reported that the intensity of back pain increases with large curves in the lumbar region (Jackson *et al*., 1983; Grameaux *et al*., 2008) (**Table 2.4**), no significant association was observed between the type or the magnitude of the curve and pain (Ramirez *et al*., 1997; Schwab *et al*., 2005, Glassman *et al*., 2005).

In terms of objective clinical data, many studies have focused on the correlation between the patients' perception of their health-related quality of life and radiographic parameters. Interestingly, it was observed that the magnitude of the curve had no significant correlation with the patients' perception of self image, social function and general health (Schwab *et al*., 2003; Asher, Lai, Burton and Manna, 2004; Schwab *et al*., 2005; Glassman *et al*., 2005) (**Table 2.4**).

Various curve patterns are noticed in patients with scoliosis and attempts have been made to find a predictive pattern in these curves (**Table 2.5**). Stirling *et al*. (1996) reported that even though there was no association between the location and the magnitude of the curve (p = 0.07), there was a tendency for the majority of the larger curves to be located in the thoracic spine. Kim *et al*. (2003) also observed that the thoracic location for the curve was more common than the thoracolumbar or lumbar locations and reported that no gender differences were observed in the patterns of the curves (**Table 2.5**). Schwab *et al*. (2005) also reported that there was no correlation between the gender of the patient and the location of the curve, but their study indicated that the lumbar region was the most common location for the lateral deviation of the spine. On the other hand, Wong, Hui, Rajan and Chia (2005) and Glassman *et al*. (2005), observed that curves were most commonly located in the thoracolumbar region. Patients with a double curve and with curves located higher up in the spine have been reported as having better postural control than those patients with a single curve or with curves located lower down in the spine (Gauchard, Lascombes, Kuhnast and Perrin, 2001). More patients were reported to present with a single major curve than a double or triple curve

(Stokes, Armstrong and Moreland, 1988; Wong *et al*., 2005; Glassman *et al*., 2005; Pouramat *et al*., 2007) (**Table 2.5**). Stirling *et al.* (1996) observed that curves in the thoracic and thoracolumbar spinal regions tended to be right-sided while curves in the lumbar spine tended to be left-sided. However, Grameaux *et al*. (2008) reported no significant differences in the overall side of convexity in 50 patients with scoliosis (**Table 2.5**).

A common clinical observation in scoliosis is the presence of a LLI. Morscher (1977) reported that a scoliosis may occur due to a LLI resulting in asymmetrical loading of the vertebral column. This would predispose to early degeneration of the intervertebral discs leading to back pain. In individuals with an anatomical short leg, it has been established that pelvic obliquity and scoliosis may be the resultant main adaptation and reaction of the skeletal system (Specht and De Boer, 1991). Complex physical relationships may then exist between these structural features and clinical significance may emerge from these adaptations (Specht and De Boer, 1991). The relationship between LLI, spinal adaptation and back pain has been extensively contemplated, but there is still no reliable data to support the relationship between these parameters. There was a poor correlation between lumbar scoliosis and LLI in patients with chronic low back pain (Hoikka *et al.*, 1989) (**Table 2.6**).

Specht and De Boer (1991) analyzed the x-rays of 106 patients at a chiropractic practice to determine the relationship between anatomical LLI, scoliosis and lumbar lordosis. They reported that 53% of patients with a LLI greater than 6 mm had a scoliosis or changes to the lumbar lordosis. Their observation suggests that LLI greater than 6 mm results in some degree of abnormal spinal adaptation (**Table 2.6**). In the adolescent population, Ramirez *et al*. (1997) reported that 13% of the 2 442 individuals studied had a LLI greater than 1.5 cm, but no significant association was found between LLI and pain as 6% of the subjects were asymptomatic and only 7% of individuals reported experiencing back pain (**Table 2.6**).

The rotary deformity of the spine has also been observed to be a common finding in scoliosis. Rotation of the vertebrae is one of the dimensions of the scoliotic deformity that accompanies the lateral deviation of the spine (Scoliosis Research Society, 2009). Pouramat *et al*. (2007) reported that all but one of the 51 individuals studied had a rotary deformity. Hump Index (height of the rib hump) is a clinical manifestation that occurs due to the rotation of the vertebrae (**Table 2.7**). Patients showed poorer functional results when both the height of the rib hump and the grade of vertebral rotation is taken into consideration (Asher *et al.,* 2005; Ploumis, Liu, Mehbod, Transfeldt and Winter 2009) (**Table 2.7**). Grosso *et al*. (2002) reported no correlation between the magnitude of the curvature (Cobb angle) and the rib hump height in 116 scoliotic patients. On the other hand, a strong significant correlation of the Cobb angle was observed with both the degree of vertebral rotation (on radiographs) and its manifestation as a rib hump in two other studies (Villemure *et al.*, 1999; Krawczynski *et al.,* 2006) (**Table 2.7**). Thulborne and Gillespie (1976) observed in their study of 52 patients that the extent of the deformity increased with an increase in vertebral rotation. But some patients with minimal rotation showed a marked rib hump and therefore no correlation between the degree of the scoliosis and vertebral rotation was observed. However, Jackson *et al*. (1983) observed that there was a strong correlation between vertebral rotation and the degree of scoliosis ($p < 0.0001$, $r = 0.70$) and the parameter that had the highest correlation to pain was the vertebral rotation (**Table 2.7**).

2.6 SCOLIOSIS AND CHIROPRACTIC

From a chiropractic perspective Danbert (1989) has stated that an understanding of the biomechanics of the lateral deviation is important and it is through the application of this understanding that chiropractors have validation for treating mild curves. Scoliosis was reported to be the second most frequent spinal anomaly when McCoy and Pryor (2006) randomly analyzed 500 patient files at a North American Chiropractic Teaching Clinic for the presence of pathologies, abnormalities and anomalies. The substantial number of structural changes, clinical features and symptoms may be the primary complaint of the patient when they present to a health care professional. Patients may seek treatment for pain, neurological symptoms and spinal cord abnormalities (Schwab, 2005). The outcome of chiropractic treatment for the spinal deformity has shown conflicting results. Some studies report that chiropractic treatment does not reduce the magnitude of the curve whereas others have reported that a reduction in curvature up to 17º may be achieved through spinal manipulation and neuromuscular rehabilitation (Lantz and Chen, 2001; Morningstar, Woggon and Lawrence, 2004). In light of this, chiropractors must be able to competently diagnose a scoliosis, know its implications and have the discretion to refer if required.

2.7 CONCLUSION

Although scoliosis is a relatively common spinal disorder, the association between the development of certain clinical features and the presence of scoliosis has not yet been well established, especially in adults. There is conflicting evidence as to the correlation between pain and certain radiographic parameters (Jackson *et al.,* 1983; Ramirez *et al*., 1997; Glassman *et al*., 2005; Grameaux *et al.,* 2008). Curve pattern desciption in scoliosis has been examined more than other radiographic findings such as vertebral rotation. Common clinical features like pelvic obliquity and shoulder height inequality have been previously excluded from correlation studies in comparison with LLI (Hoikka *et al*., 1989; Ramirez *et al*., 1997). The rib hump has been explored using various outcome measures and still showed conflicting results between the radiographic parameters and its clinical manifestation. Grameaux *et al*. (2008) concluded that further studies are required to clarify the clinical significance of the radiological features of spinal deformities including scoliosis, especially adult scoliosis, as it has received little attention in the literature.

CHAPTER THREE

MATERIALS AND METHODS

3.1 STUDY DESIGN

This research was designed as a quantitative, non-interventional, cross-sectional study. Ethical approval to conduct this study was obtained from the Durban University of Technology's Faculty of Health Sciences Research Committee **(Ethics Clearance Certificate No.: FHSEC 026/09 [Appendix J])**.

3.2 ADVERTISING AND SUBJECT RECRUITMENT

Advertisements in the form of pamphlets **(Appendix A)** were posted at the following venues:

The Durban campuses of the Durban University of Technology (DUT), the Chiropractic Day Clinic (CDC), the Homeopathic Clinic, a local university, local libraries and surrounding stores. The researcher also approached local orthopedic, physiotherapy and chiropractic practices as well as surrounding radiology facilities and verbally informed the practitioners of the nature of the study and requested referrals.

3.3 SAMPLE METHOD AND SIZE

Convenience sampling method was utilised in this study. The sample size consisted of 60 subjects previously diagnosed with scoliosis. The sample size was arrived at after discussions with an experienced biostatistician (Esterhuizen, 2009).

3.4 INCLUSION CRITERIA

1. Subjects diagnosed with scoliosis by a healthcare professional (e.g. qualified chiropractors, orthopedic surgeons, radiologists, physiotherapists, general practitioners) (as reported by the subject and confirmed radiographically).
2. Subjects were aged between 18 and 45 years. Those younger than 18 years would have needed parental consent, while the possibility of degenerative changes to the spine would have been higher in those older than 45 years (Kirkaldy-Willis and William, 1999; Kalichman, Geurmazi and Hunter, 2009)

3.5 EXCLUSION CRITERIA

1. Females who were pregnant or suspected that they were pregnant.
2. Subjects who had x-rays (of any region of the body) taken within a month prior to the commencement of the study. This was to minimize the radiation dose to the subject and to protect the subject from over-exposure (Naidoo, 2008).
3. Any subject who had corrective surgery for scoliosis or any other spinal surgery
4. Subjects with kyphoscoliosis.
5. Subjects with scoliotic curves less than 10º.

Prospective subjects were then invited to attend the initial consultation at the CDC.

3.6 RESEARCH PROCEDURES

3.6.1 Telephonic Respondents

Prospective subjects who responded telephonically to the advertisements (**in 3.2**), were asked the following questions:

1. “Do you have a scoliosis or a curvature in your spine?”
2. “Are you between the ages of 18 and 45 years?”

3. If female – “Are you pregnant or suspect that you might be pregnant?”
4. “Have you had any x-rays taken within the last month of any region of your body?”
5. “Have you had any corrective surgery for scoliosis or any other spinal surgery?”

If the prospective subject answered “No” to either of the first two questions and “Yes” to questions 3, 4 and 5 then he/she was excluded. If the inclusion criteria were met, then an appointment was made for the subject at the CDC.

3.6.2 Phase One

When the prospective subjects arrived at the CDC for their appointment, they were given a letter of information and informed consent to read **(Appendix B)**. The researcher also verbally explained the nature of the study to them. The prospective subjects were then given an opportunity to ask any questions regarding the study and these were answered by the researcher accordingly. If the prospective subject satisfied all the inclusion criteria and expressed a willingness to participate in the study, he/she was then required to sign the informed consent form.

Thereafter, the researcher took a case history **(Appendix C)** and performed a physical examination **(Appendix D)** which included an orthopedic assessment of the cervical spine **(Appendix E)**, thoracic spine **(Appendix F)** and lumbar spine and pelvis **(Appendix G)**. All data was coded so that the subject’s identity was not revealed.

The following data was recorded on the Clinical Data Collection Sheet **(Appendix H)**.

1. Subject code
2. Age
3. Gender
4. Ethnicity
5. Family history of scoliosis
6. The presence of any known or clinically detectable uro-genital anomaly/ies (McEwen, Winter and Hardy, 1972).

7. Presenting complaint (low back pain/ mid back pain/ neck pain) or if the subject was asymptomatic.
8. Location of pain (according to the vertebral level).
9. If applicable (i.e. if the subject presented with low back pain/ mid back pain/ neck pain), then the severity of the pain was recorded using the Numerical Pain Rating Scale-11 (NRS-11) (Jensen, Karoly and Braver, 1986; Haldeman and Dagenais, 2004). The NRS has shown good sensitivity for producing data that could be statistically analyzed for audit purposes and it has been shown to be easier to administer and score (Breivik, Gudmunder and Skovlund, 2000; Williamson and Hoggart, 2005). The pain was graded as follows:
    - Mild: 1-4
    - Moderate: 5-7
    - Severe: 8-10
10. Presence of a LLI and recording of the short side. The researcher measured and recorded the distance between the anterior superior iliac spine and the medial malleolus on both sides with the subject in the supine position (Magee, 2006).
11. Clinically detectable cause or etiology (Goldstein and Waugh, 1973; McAlistar and Shackelford, 1975; Yochum and Rowe, 2005). An example of this would be a structural curve caused by an acute bone infection or a congenital spinal malformation.
12. Shoulder height inequality was assessed according to the technique described by Lonstein *et al*. (1995). A spirit level was placed horizontally at the acromio-clavicular joint of the lower shoulder and then the vertical distance from the level to the elevated shoulder was recorded in centimeters.
13. Presence of pelvic obliquity was determined by comparing the levels of the posterior superior iliac spines. This examination was carried out on the subject while they were standing.
14. Presence of a rib hump and the recording of the side that it appeared. This was done by using the forward bending test described by Lonstein *et al*. (1976).

The subject then proceeded to Phase Two of the research

3.6.3 Phase Two

If time allowed, the subjects then proceeded to the Radiography Clinic or an appointment was made for the subjects to have their x-rays taken at the Radiography Clinic within one week. Upon arrival, the researcher prepared the subject according to the Radiography Clinic protocols (viz. changing into an appropriate gown and the use of protective shields). Each subject then had an erect anterior to posterior (A-P) view of the entire spine taken by the researcher according to the method described by Yochum and Rowe (2005). Shoes were not worn by the subject and they stood with their feet together and knees straight. No hand support was used in order to show the full effect of gravity on the spine (Lonstein *et al*., 1995).

Once suitable quality x-rays were achieved, the subjects' names were then coded on the x-ray by the researcher and did not appear on the x-ray itself

3.6.4 Phase Three

All the full spine x-rays were evaluated by the researcher (and confirmed by the supervisor) using the **A**lignment, **B**one, **C**artilage and **S**oft Tissue (A, B, C, S) method described by Yochum And Rowe (2005). The following radiographic parameters were determined and recorded on the Radiographic Data Collection Sheet **(Appendix I)**:

1. Presence of more than one curve
2. Side of convexity (i.e. right or left) of the curve/s
3. Location of the curve/s (Yochum and Rowe, 2005):
    - Cervical: C1-C6
    - Cervicothoracic: C7-T1
    - Thoracic: T2-T11
    - Thoracolumbar: T12-L1
    - Lumbar: L2-L4
    - Lumbosacral: L5-S1
4. Etiology as evident on x-ray
5. Location of apex vertebra

6. Cobb angle of inclination according to the technique described by Yochum and Rowe (2005) (**Table 2.3**). The severity of the curve was graded as follows (Scoliosis Research Society, 2009):
   - Mild: 10°-25°
   - Moderate: 26°-40°
   - Severe: >40°
7. Degree of rotation of the pedicle of the vertebra most affected by the curve. This was determined according to the method described originally by Nash and Moe (1969).

The following instruments were utilized in this study:

1. A 30 cm ruler
2. X-ray viewing box
3. Protractor – for accurate measurement of angles
4. Soft tape measure – to measure the subject's leg length.
5. Dermatography liberty marking pen (used to mark the lines and angles on the x-ray)
6. Divider for accurate measurement between two points
7. Spirit level – for accurate determining of shoulder height inequality and extent of asymmetry of the rib hump. (Lonstein *et al*., 1995). The subjects stood on a level floor.

3.7 STATISTICAL ANALYSIS

SPSS version 15.0 (SPSS Inc., Chicago, Illinois, USA) was used for data analysis. A *p*-value of < 0.05 was considered statistically significant. One-way ANOVA testing was used to compare mean age between clinical groups. One-way frequency tables and percentages were used:

- To determine the radiographic profile of symptomatic and asymptomatic subjects with scoliosis.
- To determine the presence of selected clinical features in symptomatic and asymptomatic subjects with scoliosis.
- To determine the number of subjects presenting with clinically detectable rib hump.

Pearson's chi square tests were used to assess associations between categorical variables. Pearson's correlation analysis was used to examine the strength of relationships between quantitative normally distributed variables. Spearman's correlation analysis was used to determine the relationship between ordinal variables. Scatter plots were used to graphically depict correlations and bar charts were used to show frequencies (Esterhuizen, 2009).

CHAPTER FOUR

RESULTS

4.1 DEMOGRAPHIC PROFILE OF THE SUBJECTS

Sixty adult subjects with scoliosis participated in this study. The mean (± SD) age of the subjects was 26.8 (± 7.9) years, while the range was 18-45 years. The majority of the subjects were females (63.3 %). A family history of scoliosis was reported by 14 subjects. The ethnicity of the subjects is depicted graphically in **Figure 4.1**. More than half of the subjects were Indians (*n* = 31), followed by 14 Whites and 11 Blacks. The Coloured ethnic group was the least represented (*n* = 4).

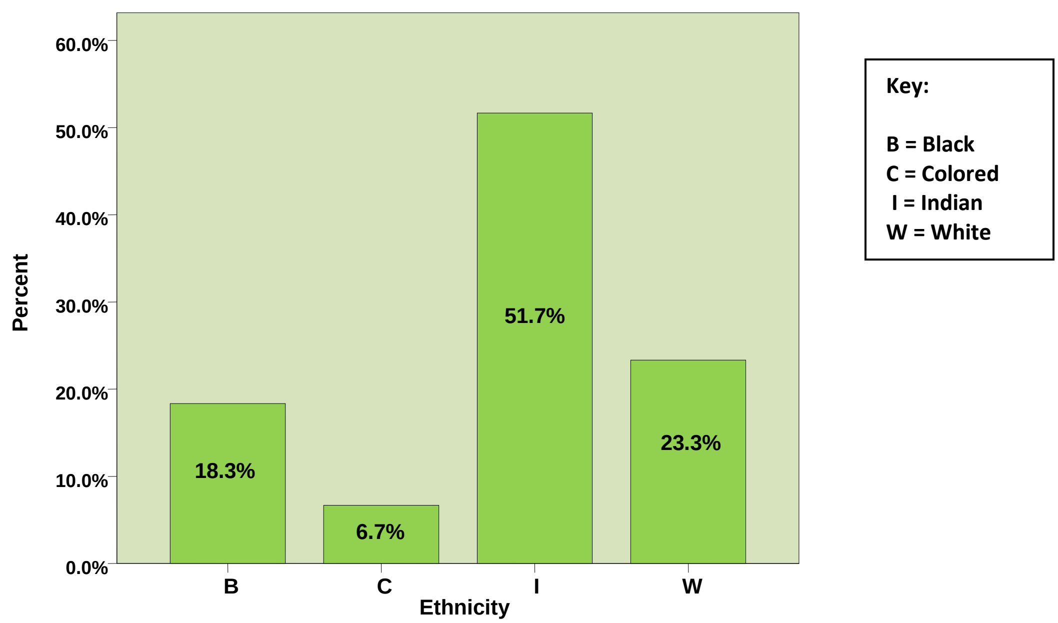

Figure 4.1 Ethnicity of the subjects

4.2 CLINICAL PROFILE OF SUBJECTS

4.2.1 SEVERITY OF PAIN

The majority of subjects reported (neck and back) pain of moderate severity followed by those who reported no pain (**Table 4.1**). More females reported pain of moderate to severe intensity than males (**Table 4.1**). The pain was located more frequently either in the thoracic or lumbar regions, or these two regions combined than pain in any other spinal region or combination of regions **(Table 4.2)**.

Table 4.1 Reported severity of pain

	Gender					
	Female		Male		Total	
NRS	***n***	**%**	***n***	**%**	***n***	**%**
Asymptomatic	10	26.4%	6	27.3%	16	26.7%
Mild pain	7	18.4%	6	27.3%	13	21.6%
Moderate pain	14	36.8%	8	36.3%	22	36.7%
Severe pain	7	18.4%	2	9.1%	9	15.0%

n **= Count; NRS = Numerical Pain Rating Scale**

Table 4.2 Location of pain in symptomatic subjects

	NRS							
	Mild		Moderate		Severe		Total	
Location of pain	***n***	**%**	***n***	**%**	***n***	**%**	***n***	**%**
C	2	3.3%	0	0.0%	0	0.0%	2	3.3%
T	3	5.0%	7	11.7%	4	0.0%	14	16.7%
L	3	5.0%	6	10.0%	3	5.0%	12	20.0%
C & T	0	0.0%	2	3.3%	0	0.0%	2	3.3%
C & L	0	0.0%	1	1.7%	0	0.0%	1	1.7%
C & T & L	0	0.0%	1	1.7%	0	0.0%	1	1.7%
T & L	5	8.3%	5	8.3%	2	3.3%	12	19.9%

NRS = Numerical Pain Rating Scale; ***n*** **= Count; C = Cervical; T = Thoracic; L = Lumbar**

4.2.2 SELECTED CLINCAL FEATURES

The frequency and mean (± SD) of the selected clinical features viz. LLI, shoulder height inequality, pelvic obliquity and the presence of a rib hump is presented in **Table 4.3**. The most observed clinical feature was shoulder height inequality, while the least observed feature was the presence of a rib hump (**Table 4.3)**. The side of occurrence of the clinical features is shown in **Table 4.4**. The elevated shoulder and the shorter leg (LLI) was most commonly located on the left side, while pelvic obliquity and rib hump were most commonly located on the right side. None of the subjects were suspected of having any urogenital anomalies after the case history, physical and radiographic examinations were concluded.

Table 4.3 Frequency of selected clinical features

Clinical Feature	*n*	Percent	Mean (± SD) in cm
LLI	55	91.7%	1.4 (± 0.7)
Sh Ht I	58	96.7%	1.7 (± 0.7)
Pelvic ob	52	86.7%	1.0 (± 0.4)
Rib hump	44	73.3%	1.0 (± 0.8)

***n* = Count; LLI = Leg length inequality; Sh Ht I = Shoulder height inequality; Pelvic ob = Pelvic obliquity**

Table 4.4 Side of occurrence of selected clinical features

Clinical Feature	Left *n* (%)	Right *n* (%)
Side of LLI	34 (61.8%)	21 (38.2%)
Side of Sh Ht I	30 (51.7%)	28 (48.3%)
Side of Pelvic ob	17 (32.7%)	35 (67.3%)
Side of Rib Hump	6 (13.6%)	38 (86.4%)

***n* = Count; LLI = Leg length inequality; Sh Ht I = Shoulder height inequality; Pelvic ob = Pelvic obliquity**

4.3 RADIOGRAPHIC PROFILE OF SUBJECTS

The overwhelming majority of scoliotic curves were of idiopathic origin (96.7%). Two (3.3%) individuals presented with a scoliosis that was caused by compression fractures due to osteoporosis. One individual presented with a single compression fracture at T11 while the other had multiple compression fractures located at T7-T12 and L4 spinal levels.

4.3.1 MAJOR CURVE

Thirty subjects presented with more than one curve. The side of convexity of the major curve was to the right in 60% of the cases. The mean (± SD) Cobb angle for the major curve was 21.3º (± 13.1º) while the range was 11.5º - 97.0º. Fourty-seven subjects had a mild curve while 11 presented with a moderate curve and a severe curve was observed in two subjects (**Figure 4.2**).

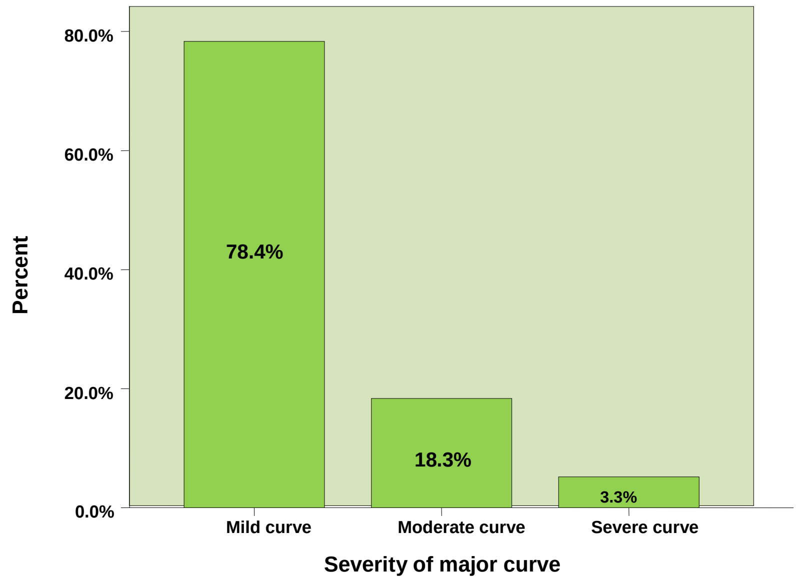

Figure 4.2 Severity of the major curve

The location of the major curve (*n* = 60) and mean (± SD) degree of curvature according to location is shown in **Table 4.5**. The majority of curves were located in the thoracic region with a predominance of right-sided curves (**Table 4.5**). There were no curves observed in the cervical region. Curves involving the transitional (cervicothoracic and thoracolumbar) regions of the spine were observed in 10 subjects. The apex vertebra was most likely to be found in the T7/T8 region (35%) followed by the L1/L2 (25.0%) (**Table 4.6**). The least likely spinal locations for an apex vertebra were T1, T2, L4 and L5 (**Table 4.6**). The degree of pedicle rotation of the most rotated vertebra in the major curve is shown in **Table 4.7**. The most frequently observed grade was Grade 1 (45%).

Table 4.5 Location, mean (± SD), range, Cobb angle and side of convexity of the major curve

Location of major curve	Frequency	Percent	Cobb Mean (± SD)	Range	Right	Left
Cervical	0	0.0	N/C	N/A	0	0
Cervicothoracic	1	1.7	16 (± 0º)	N/A	0	1
Thoracic	37	61.6	22.5º (± 15.8º)	12º-97º	27	10
Thoracolumbar	9	15.0	20.9º (± 7.7º)	12º-24º	4	5
Lumbar	13	21.7	17.7º (± 4.5º)	11.5º-36º	5	8
Lumbosacral	0	0.0	N/C	N/A	0	0

N/C = No curve; N/A = Not Applicable

Table 4.6 Location of the apex vertebra in the major curve

Location of apex vertebra	Frequency	Percent
C7	1	1.7
T1	0	0.0
T2	0	0.0
T3	2	3.3
T4	2	3.3
T5	3	5.0
T6	2	3.3
T7	12	20.0
T8	9	15.0
T9	3	5.0
T10	3	5.0
T11	1	1.7
T12	4	6.7
L1	5	8.3
L2	10	16.7
L3	3	5.0
L4	0	0.0
L5	0	0.0
Total	**60**	**100**

Table 4.7 Degree of pedicle rotation of the major curve

Grade of pedicle rotation	Frequency	Percent
Grade 0	16	26.6
Grade 1	27	45.0
Grade 2	13	21.7
Grade 3	3	5.0
Grade 4	1	1.7
Total	**60**	**100**

4.3.2 MINOR CURVE

The mean (± SD) Cobb measurement for the minor curve was 16.7º (± 5.4º) with a range of 10º- 37º. The majority of the minor curves were located in the thoracic region (**Table 4.8**) and 97% of the minor curves were classified as mild curves. There were no minor curves observed in the cervical region. Only one curve was moderate and none could be classified as severe. The minor curve was likely to be a left-sided curve (56.7%). The most common locations for the apex vertebra in the minor curve were the L1/L2 regions (46.6%) followed by T8/T9 (23.0%) (**Table 4.9**). The grade of pedicle rotation for the minor curve was zero in 46.7% of the 30 subjects with a double curve (**Table 4.10**). No vertebral rotation of Grades 3 or 4 were observed in the minor curve.

Table 4.8 Location and the mean (± SD) Cobb angle of the minor curve

Location of the minor curve	Frequency	Percent	Cobb Mean (± SD)
Thoracic	14	46.7	16.6º (± 3.8º)
Thoracolumbar	7	23.3	15.8º (± 4.5º)
Lumbar	9	30.0	17.8º (± 8.8º)

Table 4.9 Location of the apex vertebra in the minor curve

Location of Apex Vertebra	Frequency	Percent
C7	0	0.0
T1	0	0.0
T2	0	0.0
T3	0	0.0
T4	0	0.0
T5	2	6.7
T6	2	6.7
T7	2	6.7
T8	4	13.3
T9	3	10.0
T10	0	0.0
T11	1	3.3
T12	0	0.0
L1	7	23.3
L2	7	23.3
L3	2	6.7
L4	0	0.0
L5	0	0.0
Total	**30**	**100.0**

Table 4.10 Grade of pedicle rotation of the minor curve

Grade of pedicle rotation	Frequency	Percent
Grade 0	14	46.7
Grade 1	10	33.3
Grade 2	6	20.0
Grade 3	0	0.0
Grade 4	0	0.0
Total	**30**	**100.0**

4.4 ASSOCIATIONS WITH SELECTED DEMOGRAPHIC FACTORS

There was no significant difference between the mean age groups for pain severity (p = 0.112), curve magnitude (p = 0.487) or pedicle rotation (p = 0.170) (**Table 4.11**). There was no significant association between the gender of the patient and the severity of pain (p = 0.725; Pearson's chi square test), severity of the major curve (p = 0.545) or grade of pedicle rotation (p = 0.639) as shown in **Table 4.12**. The p-value for pain *vs*. ethnicity was significant (p = 0.010; Pearson's chi square test) (**Table 4.13**), but the test was rendered invalid due to the small sample size in each group. However, the trend did show that Blacks were most likely to be asymptomatic while Indians were more likely to describe their pain as moderate or severe (**Table 4.13**). There was also no significant association between the ethnicity of the subjects and severity of the major curve (*p* = 0.088; Pearson's chi square test) or grade of pedicle rotation (*p* = 0.882; Pearson's chi square test).

Table 4.11 Difference in mean age groups to selected clinical and radiographic parameters

Clinical feature or radiographic parameter		**Age**		***p*-value**
		Mean	**SD**	
Pain severity	Asymptomatic	23.0	3.3	**0.112**
	Mild	29.6	9.1	
	Moderate	27.4	7.7	
	Severe	28.6	10.5	
Curve magnitude	Mild	27.4	8.4	**0.487**
	Moderate	24.3	5.6	
	Severe	28.0	1.4	
Grade of pedicle rotation of the apex vertebrae in the major curve	Grade 0	27.5	7.1	**0.170**
	Grade 1	28.3	9.4	
	Grade 2	22.2	3.3	
	Grade 3	30.7	6.7	
	Grade 4	27.0	0.0	

Table 4.12 Association between gender and pain severity and selected radiographic parameters

Clinical feature or radiographic parameter		**Gender**				***p*-value**
		Female		**Male**		
		n	%	*n*	%	
Pain severity	Asymptomatic	10	26.4%	6	27.3%	**0.725**
	Mild	7	18.4%	6	27.3%	
	Moderate	14	36.8%	8	36.3%	
	Severe	7	18.4%	2	9.1%	
Curve magnitude	Mild	29	76.3%	18	81.8%	**0.545**
	Moderate	7	18.4%	4	18.2%	
	Severe	2	5.3%	0	0.0%	
Grade of pedicle rotation of the apex vertebrae in the major curve	Grade 0	10	26.3%	6	27.3%	**0.639**
	Grade 1	16	42.1%	11	50.0%	
	Grade 2	8	21.1%	5	22.7%	
	Grade 3	3	7.9%	0	0.0%	
	Grade 4	1	2.6%	0	0.0%	

***n* = Count**

Table 4.13 Association between ethnicity and pain severity and selected radiographic parameters

		Ethnicity								*p*-value
		B		C		I		W		
		n	%	*n*	%	*n*	%	*n*	%	
Pain severity	Asymptomatic	8	72.7%	0	0.0%	4	12.9%	4	28.6%	**0.010***
	Mild	2	18.2%	2	50.0%	5	16.1%	4	28.6%	
	Moderate	1	9.1%	2	50.0%	15	48.4%	4	28.6%	
	Severe	0	0.0%	0	0.0%	7	22.6%	2	14.2%	
Curve magnitude	Mild	7	63.6%	3	75.0%	27	87.1%	10	71.4%	**0.088**
	Moderate	2	18.2%	1	25.0%	4	12.9%	4	28.6%	
	Severe	2	18.2%	0	0.0%	0	0.0%	0	0.0%	
Grade of pedicle rotation of the apex vertebrae in the major curve in grades	None	3	27.3%	1	25.0%	8	25.8%	4	28.6%	**0.882**
	Grade 1	4	36.3%	2	50.0%	16	51.6%	5	35.7%	
	Grade 2	2	18.2%	1	25.0%	6	19.4%	4	28.6%	
	Grade 3	1	9.1%	0	0.0%	1	3.2%	1	7.1%	
	Grade 4	1	9.1%	0	0.0%	0	0.0%	0	0.0%	

B = Black; C = Colored; I = Indian; W = White; *n* = Count
****p* = 0.010; Pearson's chi square test**

4.5 THE ASSOCIATION BETWEEN PAIN AND SELECTED CLINICAL FEATURES

A significant association between LLI and pain severity was found (*p* = 0.034; Pearson's chi square test) (**Table 4.14**). Asymptomatic individuals were more likely not to have a LLI and the probability of pain increased as LLI increased. None of the other selected clinical features were associated with pain (*p* > 0.05; Pearson's chi square test).

Table 4.14 Association between pain severity and selected clinical features

Clinical Feature		Numerical Pain rating Scale								*p*- value
		Asymptomatic		Mild		Moderate		Severe		
		n	**%**	***n***	**%**	***N***	**%**	***n***	**%**	
LLI	No	4	25.0%	1	7.7%	0	0.0%	0	0.0%	**0.034***
	Yes	12	75.0%	12	92.3%	22	100.0%	9	100.0%	
Sh Ht I	No	2	12.5%	0	0.0%	0	0.0%	0	0.0%	**0.128**
	Yes	14	87.5%	13	100.0%	22	100.0%	9	100.0%	
Pelvic ob	No	3	18.8%	2	15.4%	2	9.1%	1	11.1%	**0.841**
	Yes	13	81.2%	11	84.6%	20	90.9%	8	88.9%	
Rib Hmp	No	4	25.0%	4	30.8%	5	22.7%	3	33.3%	**0.916**
	Yes	12	75.0%	9	69.2%	17	77.3%	6	66.7%	

***n* = Count; LLI = Leg length inequality; Sh Ht I = Shoulder height inequality; Pelvic ob = Pelvic obliquity; Rib Hmp = Rib hump**
****p* = 0.034; Pearson's chi square test**

4.6 THE ASSOCIATION BETWEEN PAIN AND SELECTED RADIOGRAPHIC PARAMETERS

No significant association was found between the location of the major curve and presence of pain (*p* = 0.565; Pearson's chi square test; **Table 4.15**) or between the side of the curve and pain (*p* = 0.812; Pearson's chi square test; **Table 4.16**). The percentages between the left and the right curves with pain were very similar. The correlation between pain and location of the apex vertebra could not be statistically analyzed due to the many categories and small sample size. The number of subjects that were symptomatic and asymptomatic at the level of the apex vertebra is shown in **Table 4.17**. An example would be that out of the nine individuals who had an apex vertebra at T8, six had some degree of pain at that level and three were asymptomatic (**Table 4.17**). Subjects were more likely to experience pain at the level of the apex vertebra (73.3%). There was no correlation between the degree of pain and the magnitude of curve (*r* = 0.102; Pearson's correlation analysis). This is represented graphically in **Figure 4.3** where no discernable trend is evident.

Table 4.15 Association between pain and location of curve

			Presence of pain		
			Yes	**No**	**Total**
Location of first curve	**Cervicothoracic**	*n*	1	1	2
		%	50.0%	50.0%	100.0
	Thoracic	*n*	25	11	36
		%	69.4%	30.6%	100.0%
	Thoracolumbar	*n*	8	1	9
		%	88.9%	11.1%	100.0%
	Lumbar	*n*	10	3	13
		%	76.9%	23.1%	100.0%
Total		*n*	44	16	60
		%	73.3%	26.7%	100.0%

***n* = Count**
***p* = 0.565; Pearson's chi square test**

Table 4.16 Association between side of convexity and pain

			Presence of pain		
			Yes	**No**	**Total**
Side of convexity	**Left**	*n*	18	6	24
		%	75.0%	25%	100%
	Right	*n*	26	10	36
		%	72.2%	27.8%	100%
Total		*n*	44	16	60
		%	73.3%	26.7%	100%

***n* = Count**
***p* = 0.812; Pearson's chi square test**

Table 4.17 Presence or absence of pain at location of the apex vertebra

Location of Apex	Total	%	Symptomatic	%	Asymptomatic	%
C7	1	100%	1	100%	0	0.0%
T1	0	0.0%	0	0.0%	0	0.0%
T2	0	0.0%	0	0.0%	0	0.0%
T3	2	100%	1	50%	1	50%
T4	2	100%	0	0.0%	2	100%
T5	3	100%	3	100%	0	0.0%
T6	2	100%	1	50%	1	50%
T7	12	100%	10	83.3%	2	16.7%
T8	9	100%	6	66.7%	3	33.3%
T9	3	100%	1	33.3%	2	66.7%
T10	3	100%	2	66.7%	1	33.3%
T11	1	100%	1	100%	0	0.0%
T12	4	100%	4	100%	0	0.0%
L1	5	100%	4	80%	1	20%
L2	10	100%	7	70%	3	30%
L3	3	100%	3	100%	0	0.0%
Total	**60**	**100%**	**44**	**73.3%**	**16**	**26.7%**

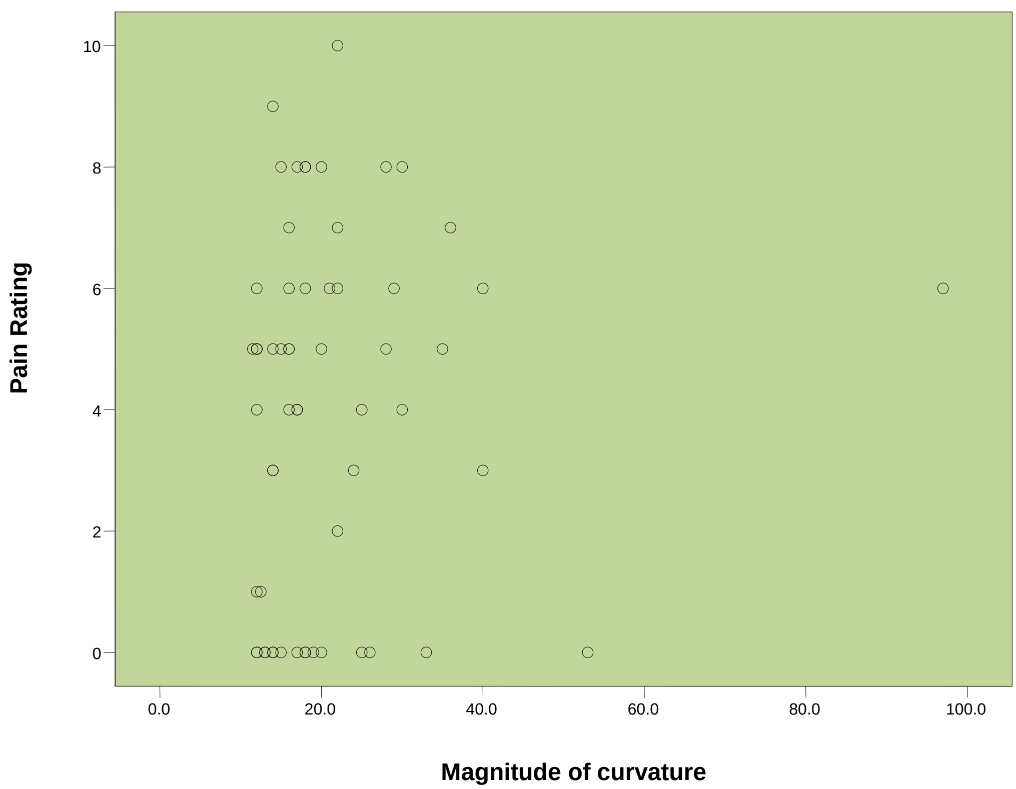

Figure 4.3 Correlation of pain severity to the magnitude of the curve

4.7 ASSOCIATION BETWEEN SELECTED RADIOGRAPHIC PARAMETERS AND CLINICAL FEATURES

No significant association was found between LLI and the magnitude of the curve (p = 0.470; Pearson's chi square test; **Table 4.18**). The prevalence of LLI was similar in all categories of curvature. No correlation was found between LLI and the quantitative Cobb measurement (r = 0.154; Pearson's correlation analysis). None of the other selected clinical features were associated with the magnitude of the curve (**Table 4.18**).

A significant association was observed between the presence of a rib hump and the magnitude of the curve (p = 0.049; Pearson's chi square test; **Table 4.18**). Individuals with mild curves were more likely to have no rib hump and all individuals with moderate and severe curvature had a rib hump. A linear relationship between rib hump elevation and Cobb measurement, indicating a significant strong positive correlation between the two variables (r = 0.814; Pearson's correlation analysis) is shown in **Figure 4.4**.

A weak but positive correlation between rib hump elevation and grade of pedicle rotation was found (*rho* = 0.308; Spearman's correlation analysis). In general, as the grade of pedicle rotation increased so did the rib hump elevation (**Figure 4.5**).

Table 4.18 Correlation of curve magnitude and selected clinical features

Clinical Feature		**Curve magnitude**						***p*-value**
		Mild curve		**Moderate curve**		**Severe curve**		
		n	**%**	***N***	**%**	***n***	**%**	
LLI	No	5	10.6%	0	0.0%	0	0.0%	**0.470**
	yes	42	89.4%	11	100.0%	2	100.0%	
Sh Ht I	No	2	4.3%	0	0.0%	0	0.0%	**0.751**
	yes	45	95.7%	11	100.0%	2	100.0%	
Pelvic ob	No	7	14.9%	1	9.1%	0	0.0%	**0.749**
	yes	40	85.1%	10	90.9%	2	100.0%	
Rib Hmp	No	16	34.0%	0	0.0%	0	0.0%	**0.049**
	yes	31	66.0%	11	100.0%	2	100.0%	

n **= Count; LLI = Leg length inequality; Sh Ht I = shoulder height inequality; Pelvic ob = Pelvic obliquity; Rib Hmp = Rib Hump**

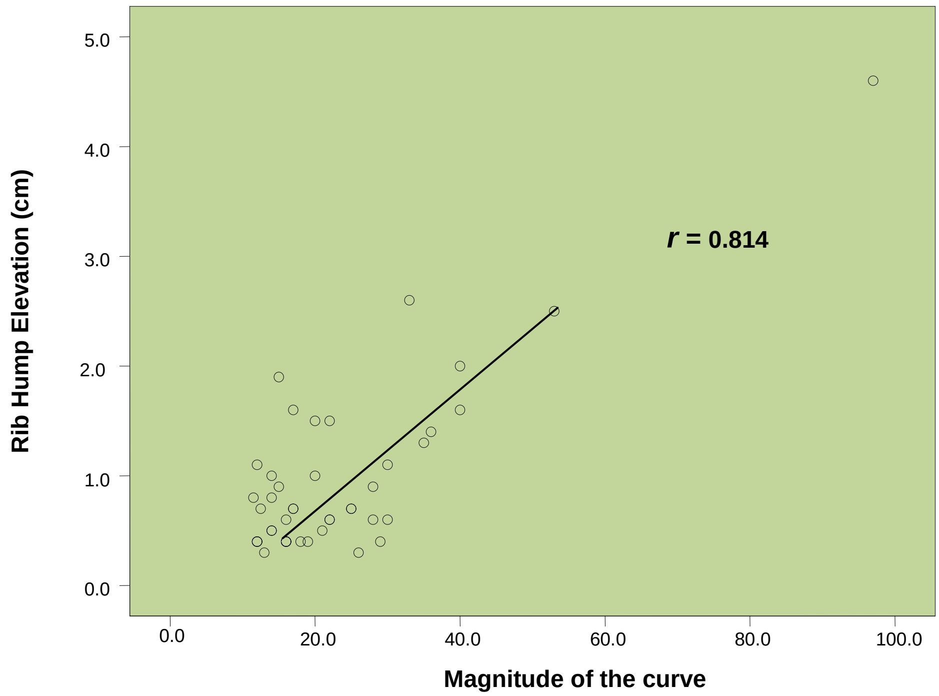

Figure 4.4 Correlation between rib hump elevation and the magnitude of the curve

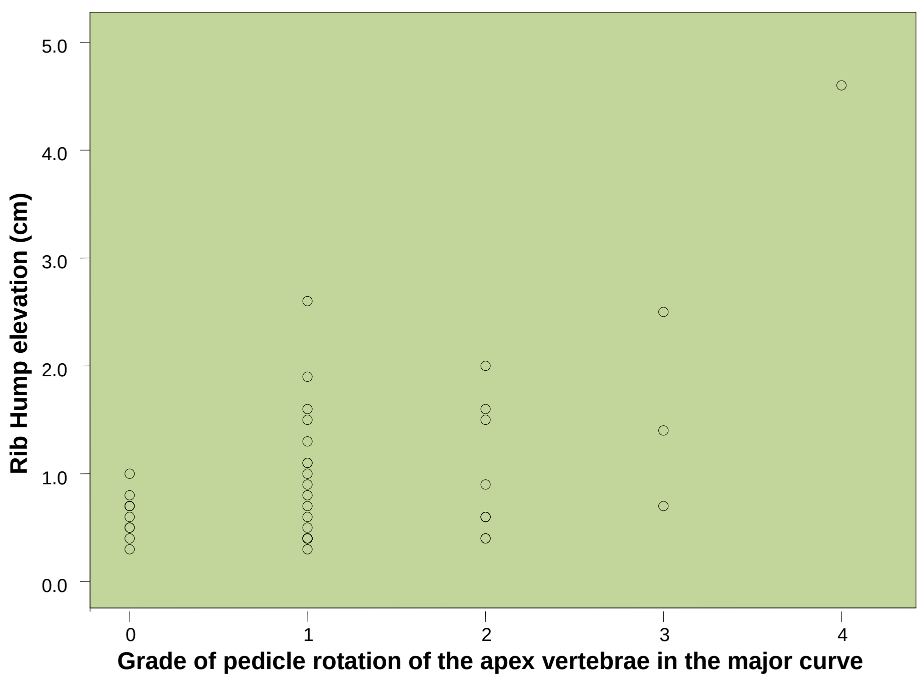

Figure 4.5 Correlation between rib hump and grade of pedicle rotation

CHAPTER FIVE

DISCUSSION

5.1 DEMOGRAPHIC AND FAMILY HISTORY DATA

All subjects who participated in this study were young to middle-aged adults (Erikson, 2001) as reflected by the mean (± SD) and range of the age of the subjects (**Table 4.1**) and based on the inclusion criteria. This age range was initially selected in order to exclude subjects with degenerative changes associated with increased aging (Kirkaldy-Willis and William, 1999; Kalichman *et al*., 2009). To the best of our knowledge, this is the first study that has investigated scoliosis in this specific age group. The subjects who participated in previous studies were generally either older (Jackson *et al*., 1983; Schwab *et al*., 2005; Glassman *et al*., 2005; Voros *et al*., 2007; Pouramat *et al*., 2007 and Grameaux *et al*., 2008) or younger (Stirling *et al*., 1996 Ramirez *et al*., 1997; Villemure *et al*., 1999; Al-Arjani *et al*., 2000 and Asher *et al*., 2004) (**Tables 2.4, 2.5 and 2.7**) than those who participated in this study. The observation in this study also supports the findings of previous studies that scoliosis is more common in females (Stirling *et al*., 1996; Armour *et al*., 1998; Arjani *et al*., 2000; Glassman *et al*., 2005 and Grameaux *et al*., 2008).

It is not entirely surprising that the majority of the subjects were of the Indian ethnic group as it is a reflection of the demographic ethnic profile of the region in which the research was conducted (city of Durban) (Seedat, Mayet, Khan, Somers and Joubert, 1990). Though the sample size is relatively small, the findings of this study also support those of previous investigators who observed that scoliosis was less common in the Black population (Segil, 1974; Voros *et al*., 2007). Interestingly, 23.3% (14) of the subjects reported a family history of scoliosis. This is similar to the observations of two other studies which reported that about 21% of scoliotic patients had a family history of scoliosis (Brooks *et al.,* 1975; Ramirez *et al.,* 1997). A possible explanation for this observation could be that idiopathic scoliosis may be due to a multigene dominant condition (Reamy and Slakey, 2001). This etiological link however, requires scientific confirmation.

5.2 RADIOGRAPHIC PROFILE OF THE SUBJECTS

The overwhelming majority of scoliotic curves observed in this study were of idiopathic origin (James, 1954; Stokes, 1994). This is in keeping with the reports of Reddy *et al*. (1987), Lonstein *et al*. (1995) and Al-Arjani *et al*. (2000). Two individuals presented with a structural scoliosis (Goldstein and Waugh, 1973) that was caused by compression fractures due to osteoporosis.

Previous researchers have reported that patients are more likely to present with a single major curve than a double or triple curve (Stokes *et al*., 1988; Stirling *et al*., 1996; Wong *et al*., 2005 and Pouramat *et al*., 2007; **Table 2.5**). The results of this study, on the other hand, have shown that 50% of the subjects presented with a double curve. A possible explanation for this finding is that the double curve develops as an adaptation to the primary curve in order to maintain normal body alignment (Scoliosis Research Society, 2009). A study of 102 patients with idiopathic scoliosis reported that patients with a double major curve had better postural control than those with single curves. Postural control was also found to be better in patients who had curves that were located higher up in the spine than those located in the lumbar spine (Gauchard *et al.*, 2001). None of the subjects observed in this study had a triple curve unlike those who participated in the studies of Stokes *et al*. (1988) and Pouramat *et al*. (2007) (**Table 2.5**).

The side of convexity and location of the curve are important radiographic parameters. Although Grameaux *et al.* (2008) reported no significant difference in the overall side of convexity of the curves in their subjects (**Table 2.5**), distinct curve patterns were observed in this study. The observation of a predominant right-sided convexity of the thoracic curves (both major and minor) was similar to the reports of Stirling *et al*. (1996; **Table 2.5**). They reported a tendency for thoracic curves to be right-sided and lumbar curves to be left-sided (**Table 2.5**), but the reported tendency for thoracolumbar curves to be right-sided was not matched in this study. More than 60% of the thoracic curves in this study were right-sided and 17% of the individuals presented with left-sided thoracic curves. Though these individuals were reported to be at greater risk of developing neurological signs associated with spina bifida and neurofibromatosis (Schwend, Henrikus, Hall and Emans, 1995, Morningstar and Joy, 2006), no clinical or radiological evidence of this was observed in this study.

The majority of the lumbar curves were left-sided (**Table 4.5**) which was in agreement with the reports of Stirling *et al*. (1996, **Table 2.5**). The observed percentage of lumbar curves in this study was less than that reported by Schwab *et al.* (2005), Glassman *et al.* (2005) and Pouramat *et al.* (2007) (**Table 2.5**). In the junctional areas of the spine, thoracolumbar curves occurred considerably more frequently than cervicothoracic curves (**Table 4.5**). The percentage of the thoracolumbar curves observed in this study (**Table 4.5**) was less than that reported by Wong *et al.* (2005), Glassman *et al.* (2005) and Pouramat *et al.* (2007) (**Table 2.5**). These differences in results may be explained by differences in age of the subjects and different population groups compared to those in previous studies (**Table 2.5**).

Due to the lack of comprehensive radiological data in previous studies (on minor curves), comments on the comparison of findings between major and minor curves are limited to the observations in this study. The key differences between the major and minor curves are tabulated in **Table 5.1**

Table 5.1 A comparison of the major and minor curves

Parameter	Major curve	Minor curve
Mean (± SD)	21.3° (± 13.1°)	16.7° (± 5.4°)
Range	11.5° - 97°	10° - 37°
Most common location for apex Vertebra	T7/8	L1/2
Least common location of apex vertebra	T1/2 and L4/5	C7-T4 and T12 , L4/5
Most common spinal region	Thoracic	Thoracic
Least common spinal region	Upper thoracic and lower lumbar	Lumbar
Most common side	Right	Left
Least common side	Left	Right
Most common grade of pedicle rotation	Grade 1	Grade 0
Least common grade of pedicle rotation	Grade 4	Grade 3 and Grade 4

The lower limit of the ranges of both the curves was similar, but the upper limit was greater for the major curve (**Table 5.1**). The mean of the major curve was approximately five degrees greater than the minor curve. Even though the thoracic region was found to be the most common location for both the major and the minor curves, the most common location for the apex vertebra tended to be mid-thoracic for the major curve and the upper lumbar region for the minor curve. The side of convexity that was more common for each of the curves was also different. This difference in the side of convexity for both the curves is possibly a reflection of the compensatory nature of the minor curve that functions as an adaptation to maintain normal body alignment (Scoliosis Research Society, 2009).

Rotation of the vertebrae usually occurs during lateral deviation of the spine (Scoliosis Research Society, 2009). In this study 73.4% of the subjects presented with some degree of pedicle rotation, compared to 98% who participated in the study of Pouramat *et al*. (2007; **Table 2.7**). Since the majority of the major and minor curves were of mild severity, it is not surprising that pedicle rotation for the major curves was either Grade 1, Grade 0 or Grade 2 (in that order) (**Table 4.7**) and Grade 0, Grade 1 and Grade 2 for the minor curves (**Table 4.10, Table 5.1**).

The magnitude of the major curve observed in this study was compared to the magnitude of curves reported in previous studies (**Table 5.2**). Direct comparison of the result of this study with those of previous studies is difficult due to differences in the mean (and range) of the age of the subjects and different population groups (**Table 2.4**). Nonetheless, the mean (± SD) for the major curve was similar to the findings of Grameaux *et al.* (2008; **Table 2.4**). Furthermore, with the exception of the *de novo* degenerative scoliosis curve mean reported by Pouramat *et al*. (2007) and the observations of Grameaux *et al.* (2008), all the other previously reported curve means were higher than that observed in this study. There were also considerable differences between the range of the major curve observed in this study to those previously reported (**Table 5.2**). Pouramat *et al*. (2007) also included subjects with curves less than ten degrees which is outside the definition of scoliosis (Scoliosis Research Society, 2009). The majority of the subjects presented with curves of minor severity, then moderate severity and only two subjects had severe curves. The mean and range of the thoracic, thoracolumbar and lumbar curves (**Table 4.5**) were considerably less than that reported by Glassman *et al.* (2005; **Table 5.2**).

Table 5.2 Comparison of the magnitude of the major curve of this study to those reported in the literature

Reference	Mean age (range) (yrs)	Mean (range) Cobb angle of major curve	Comparison to this study
Arjani *et al.* (2000)	16 (N/A)	58º (N/A)	↑
Schwab *et al.* (2004)	68 (30-90)	30º (10º-109º)	↑
Asher *et al.* (2004)	15 (10-20)	63º (40º-147º)	↑
Glassman *et al.* (2005)	48 (18-87)	54º (30º-124º) – T	↑
		45º (30º-75º) – TL	↑
		51º (30º-110º) – L	↑
Pouramat *et al.* (2007)	37 (17-60)	37º (22º-52º) – ASA	↑
		20º (3º-35º) – DDS	↓
Grameaux *et al.* (2008)	62 (27-83)	23.1º (10º-75º)	↑

yrs = years; N/A = Not available; T = Thoracic; TL = Thoracolumbar; L = Lumbar, ↑ = results are more than findings in this study; ↓ = results are less than findings of this study; ASA = Adult scoliosis of adolescent onset; DDS = *de novo* degenerative scoliosis

Ethnicity and gender are not significant factors affecting curve magnitude or pedicle rotation as the results of this study showed no significant association between ethnicity or gender and the magnitude of the curve or grade of pedicle rotation (**Table 4.12**). In 1976, Thulborne and Gillespie (**Table 2.7**) also reported no correlation between the degree of scoliosis and vertebral rotation. But, in adolescents a correlation was found between axial rotation and Cobb angle (Villemure *et al*., 1999; **Table 2.7**)

5.3 CLINICAL PROFILE OF THE SUBJECTS

The results of this study support the observation that pain is a common clinical feature in adult patients with scoliosis (Armour *et al*., 1998; Pouramat *et al*., 2007). Pain was found to be commonly located in the thoracic and lumbar spinal regions (i.e. mid and low back regions) (**Table 4.2**). Furthermore, the location of the apex vertebra was the most likely site of pain in these spinal regions (**Table 4.17**). The majority of subjects reported pain of moderate severity followed by those who reported no pain (**Table 4.1**). Kostuik and Bentivoglio (1981) reported that individuals with scoliosis were more likely to report pain of mild or moderate rather than severe intensity. Pain was probably due to regional failure of the stabilizing structures or due to disproportionate loads in the muscle groups caused by the lateral deviation of the spine (Avikainen *et al*., 1999; Schwab *et al*., 2005; Morningstar and Joy, 2006). This asymmetrical muscle loading could lead to the development of myofascial trigger points and chronic inflammation caused by a compromise in circulation (Travell and Simons, 1999).

The percentage of subjects in this study (73.3%) that complained of some degree of pain at the time of presentation is similar to the findings of Schwab *et al*. (2002). They observed that 74% of 98 patients (mean age 20 years) with scoliosis complained of some degree of pain (**Table 2.4**). The results of this study were not similar to findings of Ramirez *et al*. (1997), who reported that only 23% of the 2 442 individuals (mean age 14 years) had back pain (**Table 2.4**). This is probably due to the observation that adolescents are more likely to be asymptomatic than adults or have higher pain tolerance levels (Armour *et al*., 1998; Pouramat *et al*., 2007).

The reports of pain and co-morbidities have been shown to be dissimilar in different ethnic groups (Njobvu, Hunt, Pope, Macfarlane, 1999). The trend in this study showed that Blacks were most likely to be asymptomatic and that Indians were likely to report pain of moderate to severe intensity (**Table 4.13**). This result may be explained by differences in pain threshold levels in different ethnic groups (Beck, 2000). The Indian/Asian adult population has been observed to have low pain threshold levels (Gillam, Jarman, White and Law, 1989; Zatzick and Dimsdale, 1990). In the United States however, the African/American population had a significantly lower pain tolerance in relation to Whites (Mechlin, Maixner, Light, Fisher and Girdler, 2005).

Although no significant association was observed between the gender of the subject and pain in this study, it was observed that more females reported pain of severe intensity while more males reported pain of mild and moderate intensity. It has been reported that generally, males have a higher pain tolerance than females (Woodrow, Friedman, Siegelaub and Collen, 1972)

In terms of clinical features, the majority of subjects in this study presented with shoulder height inequality, LLI, rib hump and pelvic obliquity (**Table 4.3**). Brooks *et al*. (1975) also observed that the rib hump and shoulder height inequality are common findings in patients with scoliosis. The clinical relevance of this observation is that the presence of these clinical features can aid the physician in the detection and diagnosis of scoliosis. The side of the shorter leg and elevated shoulder associated with LLI and shoulder height inequality respectively, was more commonly located on the left-side while the rib hump and pelvic obliquity were more commonly located on the right-side (**Table 4.4**). This supports the findings of Brooks *et al*. (1975) who reported a right-sided tendency for the presence of the rib hump and a left-sided tendency for the presence of the shoulder height inequality. However, Hoikka *et al.* (1989) found a tendency for the LLI to be located on the right-side.

Specht and De Boer (1991) reported that there was a tendency for individuals to have a scoliosis or some sort of spinal adaptation when the LLI was greater than 0.6 cm. The majority of subjects in this study (91.7%) presented with a LLI and the mean (± SD) for the LLI was 1.4 cm (± 0.7) (**Table 4.3**). A significant number (23.3%) of subjects had a LLI greater than 1.5 cm and 16.7% had a LLI of 1.5cm. This is dissimilar to the findings of Ramirez *et al.* (1997). They found that only 13% of subjects had a LLI greater than 1.5 cm. Again the difference in results here can be attributed to the difference in the sample studied.

5.4 THE ASSOCIATION BETWEEN SELECTED CLINICAL FEATURES AND RADIOGRAPHIC PARAMETERS

A significant association between LLI and pain was found (p = 0.034; Pearson's chi square test) (**Table 4.14**). Asymptomatic individuals were more likely not to have a LLI and the probability of pain increased as LLI increased. Leg length inequality results in asymmetrical loading of the vertebral column (Morscher, 1977) and joints of the lower extremities and pelvis which leads to stress, strain and altered biomechanical function. This can predispose these joints to early degeneration, leading to back pain (Defrin, Benyamin, Dov Aldubi and Pick, 2005). Another theory on the development of pain is that the abnormal loading caused by the LLI causes irritation of the nerve endings in the tissue of the sacroiliac joint which then triggers a reflex activation of the surrounding muscles which become painful over time (Indahl, Kaigle, Reikeras and Holm, 1999). The use of heel lifts has shown excellent results in the treatment of back pain associated with LLI. The lift reduces the asymmetry and strain on the sacroiliac and other joints, which decreases pain associated with muscle bracing (Indahl *et al*., 1999; Defrin *et al*., 2005). Therefore, LLI assessment is significant for clinicians who treat patients with back pain but may overlook evaluating LLI. This may be a significant contributor to back pain especially in patients who are not responding to standard treatment. Although, none of the other selected clinical features were significantly associated with pain in this study, it is the researcher's opinion that their diagnostic significance should be evaluated in future studies with larger cohorts.

No correlation was observed between pain and the side of convexity (**Table 4.16**) even though the majority of thoracic curves were right-sided and lumbar curves were left-sided. The convex and concave side of the curve is subject to tension and compression forces respectively (Shea, Ford, Bloebaum, D'Austous and King, 2004). Therefore the side of curve will not influence the degree of pain since the effects of the lateral deviation would be similar for both sides.

There was no significant association between the location of the major curve and pain. This is dissimilar to the findings of Kostuik and Bentivoglio (1981) and Grameaux *et al.* (2008) who observed that pain was reported to be more severe when curves are located in the lumbar spine. A possible explanation for this is that pain has been found to have a correlation with a decrease in sagital balance associated with the lumbar spine (Glassman *et al.,* 2005) (**Table 2.4**) and most of the curves in this study were located in the thoracic region. This location for curves has also been linked to better postural control (Gauchard *et al*., 2001). If postural control is enhanced then there would consequently be a lesser degree of asymmetry leading to degeneration in the lumbar spine (Travell and Simons, 1999), which is associated with pain. Kirkaldy-Willis and William (1999) also state that the possibility of degeneration is greater with older individuals whom this study excluded, and this could be a likely explanation for the difference in results.

None of the selected clinical features were found to have an association with the magnitude of the curve. Since the majority of the curves were mild to moderate and seeing that half of the subjects presented with a double curve, the degree of bodily compensation would be minimal as the overall postural control and symmetry would be better (Gauchard *et al*., 2001). The mean values (± SD) for each of the clinical features were relatively close to each other (**Table 4.3**). It appears that the magnitude of the curve does not proportionately influence the magnitude of the LLI, pelvic obliquity or shoulder height inequality.

The magnitude of the major curve in this study also did not correlate with the degree of pain (**Figure 4.3**). This is similar to the findings of Ramirez *et al* (1997) and Glassman *et al.* (2005). However Jackson *et al.* (1983) reported that pain increased with the degree of curvature, especially for curves greater than 40º. Interestingly, they also reported that pain correlated well with the age of the patient in that the level of pain increased with an increase in age. The differences in results could therefore be explained by the relatively younger population group that is represented in this study and that there were only two individuals with curves greater than 40º. The finding that the degree of pain does not correlate with the magnitude of the curve is an important consideration in the treatment of scoliosis, as optimal treatment requires the attending clinician to decide if he/she is going to address the clinical symptoms or the deformity alone (Djurasovic and Glassman, 2005). It is therefore suggested that if the primary aim of treatment is to treat the deformity and reduce the magnitude of the curve, it is not likely to have an impact on the degree of pain that the individual is experiencing.

The rotational transformation of the spine that occurs with the lateral bending associated with scoliosis is responsible for the creation of a rib hump (Armour *et al.*, 1998). This study also observed that as the degree of pedicle rotation increased, so did the rib hump and that the probability of a rib hump increased with an increase in the magnitude of the curve. Villemure *et al.* (1999) and Krawczynski *et al.* (2006) also found a correlation between the magnitude of the curve, axial rotation (pedicle rotation) and the angle of trunk rotation (rib hump) respectively. Jackson *et al*. (1989) also observed that there was a correlation between vertebral rotation and the degree of scoliosis ($r = 0.70$) and they reported that the radiographic parameter that had the highest correlation to pain was the vertebral rotation. Grameaux *et al*. (2008) also found there was a good correlation between these two variables ($p < 0.05$). In this study the rib hump is the only clinical parameter that was found to have a significant correlation to the degree of curvature. This is important as it suggests that radiation doses could be reduced if curves are monitored by nature of the rib hump in cases where progression of the curve is likely. Therefore it can be concluded that the presence of a rib hump on Adams Forward Bend Test is a good clinical indicator of the presence of scoliosis.

CHAPTER SIX

CONCLUSION AND RECOMMENDATIONS

6.1 CONCLUSION

The majority of the subjects (96.7%) presented with mild to moderate scoliosis of idiopathic origin. Half of the subjects presented with a double curve. A family history of scoliosis was reported by 23.3% of subjects. Most of the subjects complained of some degree of pain at the time of presentation and subjects were most likely to experience pain at the location of the apex vertebrae. The thoracic and lumbar regions were common areas of complaint in symptomatic subjects. A significant association between LLI and pain was found ($p = 0.034$) but none of the other selected clinical features were associated with pain. The side of convexity and the location and magnitude of the major curve did not have any correlation to the degree of pain experienced by the subjects. The only clinical feature that had an association with the degree of curvature was the rib hump ($p = 0.049$) but none of the other selected clinical features (shoulder height inequality, LLI and pelvic obliquity) were associated with the degree of curvature.

In terms of specific hypotheses that were set out at the onset of the study:

The Null Hypothesis (H_0) which stated that there would be no significant association between pain and the location of the curve was accepted.

The Null Hypothesis (H_0) which stated that there would be no significant association between pain and the direction of the curve was accepted.

The Null Hypothesis (H_0) which stated that there would be no significant association between pain and the magnitude of the curve was accepted.

The Null Hypothesis (H_0) which stated that there would be no significant association between LLI and the magnitude of the curve was accepted.

The Null Hypothesis (H_0) which stated that there would be no significant association between the degree of pedicle rotation and the height of the clinically detectable rib hump was not accepted.

The Null Hypothesis (H_0) which stated that there would be no significant association between the height of the clinically detectable rib hump and the degree of curvature was not accepted.

6.2 RECOMMENDATIONS

Recommendations for future studies include the following:

- Randomized well-controlled studies investigating the clinical and biomechanical effects of LLI, shoulder height inequality and pelvic obliquity.
- Include a lateral spine x-ray and evaluate the effect of scoliosis on the various radiographic parameters observable on the lateral spinal view such as intervertebral disc height and lumbar lordosis.
- A larger sample size to investigate pain in relation to the apex vertebra.

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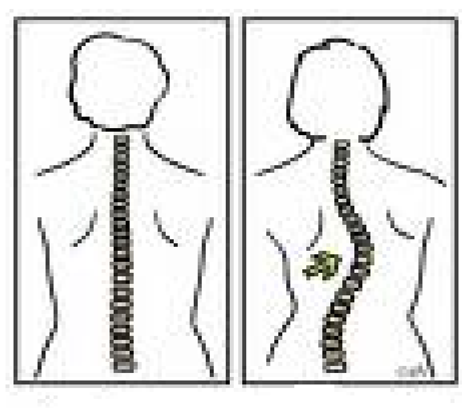
APPENDIX A

ARE YOU BETWEEN THE AGES OF
18-45
WITH A DIAGNOSED

SCOLIOSIS

If YES, you could qualify for a
FREE CLINICAL ASSESSMENT
and X-RAY of your spine



Research is being conducted at the
CHROPRACTIC DAY CLINIC at
The DURBAN UNIVERSITY OF TECHNOLOGY

Please call
Shethal (Researcher):0733267485

Chiropractic Day Clinic:031-3732512/2205

APPENDIX B

DURBAN UNIVERSITY of TECHNOLOGY
Making Knowledge Useful

Letter of Information and Consent

Title of the Research Study:

Radiographic and Clinical Analyses of Scoliosis of Adult Subjects in the Greater Durban Area.

Principle Investigator: Shethal Gajeerajee (031 – 3732512)
Supervisor: Dr. J. Shaik (M.Tech.Chiro; M.Med.Sci.(SM)
(031 – 3732588)

DEAR PARTICIPANT,
Welcome to my research project. You have been selected to take part in the clinical and radiological analysis of Scoliosis of Subjects in the greater Durban area.

Purpose:
Scoliosis refers to a side bending of the spine. A radiological and clinical analysis of Scoliosis would aid health care professionals, (e.g. Spinal surgeons and chiropractors) in the diagnosis and decision making, with regards to the spinal deformity. This will ultimately add to the quality of patient care. The study will look at the commonality of features of scoliosis in addition to other aspects. One of the aims of this study would be to determine if the radiological profiles and clinical examination findings in patients with scoliosis in the greater Durban area are in keeping with what literature states about it. This study will also aim to find if there is any correlation between the clinical examination findings and the findings on x-ray, and its association with pain.

Procedure:
You will be given a letter of information to read and should you agree to participate in this study you will have to sign the consent form. You will then have a case history and physical examination as well as an assessment of the cervical/thoracic/and lumbar spines done. You will then be evaluated for the signs and symptoms of scoliosis. All the information gathered will be strictly confidential. The examinations will be done once off (Phase One) and should take no more than 2 hrs.
If all of the inclusion criteria have been met, then only will you go through to phase two of the research. You will have an appointment made for you by the researcher at the Radiographic clinic. You will have an erect A-P view of the entire spine done by the researcher according to the Clinic's protocol. This concludes your participation in the study.

Risks or Discomforts to the Subject:
You will be exposed to standard doses of radiation. According to various studies the risk to radiation is very minimal in keeping with the accepted exposure dosage.

Benefits:
The results from this study will add to the growing body of knowledge of scoliosis and it will help spinal health care professionals with a more accurate evaluation and diagnosis of the spinal disorder. This will ultimately increase the quality of patient care. The results of this study will be made available at the Steve Biko library (DUT) in the form of a dissertation.
You may be removed from this study without your consent for the following reasons:

a) If you are a female who is pregnant or suspect that you may be pregnant.

b) You will be excluded from the study if you do not sign the informed consent form (Appendix B)

c) If you had x-rays (of any region of the body within one month prior to the commencement of this study.

You will not be awarded any remuneration for taking part in this study
Your participation in this research is free of charge.
Your participation is voluntary and refusal to participate will not result in any adverse consequences.

All data received form this study will be coded to ensure that confidentiality is maintained.
Please don't hesitate to ask questions. Your full co-operation will help the chiropractic profession in expanding its knowledge of scoliosis. You are free to withdraw form this study at any time.

If you have any queries or questions about the study, please feel free to contact my supervisor.

Do not sign the consent form unless all your questions have been answered to your satisfaction.

Statement of Agreement to Participate in the Research Study:
I,…………………………………………..…., ID number……………………………………….., have read this document in its entirety and understand its contents. Where I have had any questions or queries, Shethal Gajeerajee has explained these to me to my satisfaction. Furthermore, I fully understand that I may withdraw from this study at any stage without any adverse consequences and my future health care will not be compromised. I, therefore, voluntarily agree to participate in this study.

Subject's name (print):.………………………………….

Subject's signature:…………………………..…………. Date:……………..…

Researcher's name (print):……………………..………...

Researcher's signature:……………………..………… Date:...........…............

Witness name (print)…………………………………….

Witness signature: …………...................………..……… Date:………………….…

APPENDIX C

DURBAN UNIVERSITY OF TECHNOLOGY
CHIROPRACTIC DAY CLINIC
CASE HISTORY

Patient: ____ Date: __________

File # : ____________ Age: __________

Sex : __________ Occupation: ________________________________

Intern : ______________________________ Signature: _______________________

FOR CLINICIANS USE ONLY:
Initial visit
Clinician: Signature :

Case History:

Examination:
Previous: Current:

X-Ray Studies:
Previous: Current:

Clinical Path. lab:
Previous: Current:

CASE STATUS:

PTT:	Signature:	Date:

CONDITIONAL:
Reason for Conditional:

Signature: Date:

Conditions met in Visit No:	Signed into PTT:	Date:
Case Summary signed off:		Date:

Intern’s Case History:

1. **Source of History:**

2. **Chief Complaint : (patient’s own words):**

3. **Present Illness:**

	Complaint 1	**Complaint 2**
< Location		
< Onset : Initial:		
Recent:		
< Cause:		
< Duration		
< Frequency		
< Pain (Character)		
< Progression		
< Aggravating Factors		
< Relieving Factors		
< Associated S & S		
< Previous Occurrences		
< Past Treatment		
< Outcome:		

4. **Other Complaints:**

5. **Past Medical History:**

< General Health Status

< Childhood Illnesses

< Adult Illnesses

< Psychiatric Illnesses

< Accidents/Injuries

< Surgery

< Hospitalizations

6. Current health status and life-style:

< Allergies

< Immunizations

< Screening Tests incl. x-rays

< Environmental Hazards (Home, School, Work)

< Exercise and Leisure

< Sleep Patterns

< Diet

< Current Medication
Analgesics/week:
< Tobacco

< Alcohol

< Social Drugs

7. Immediate Family Medical History:

< Age
< Health
< Cause of Death
< DM
< Heart Disease
< TB
< Stroke
< Kidney Disease
< CA
< Arthritis
< Anaemia
< Headaches
< Thyroid Disease
< Epilepsy
< Mental Illness
< Alcoholism
< Drug Addiction
< Other

8. Psychosocial history:

< Home Situation and daily life
< Important experiences
< Religious Beliefs

9. Review of Systems:

< General

< Skin

< Head

< Eyes

< Ears

< Nose/Sinuses

< Mouth/Throat

< Neck

< Breasts

< Respiratory

< Cardiac

< Gastro-intestinal

< Urinary

< Genital

< Vascular

< Musculoskeletal

< Neurologic

< Haematologic

< Endocrine

< Psychiatric

APPENDIX D

Durban University of Technology

PHYSICAL EXAMINATION: SENIOR

Patient Name : ________________________________ **File no :**__________

Date : ________

Student : **Signature :**

VITALS:					
Pulse rate:			Respiratory rate:		
Blood pressure:	R	L	Medication if hypertensive:		
Temperature:			Height:		
Weight:	Any recent change? Y / N		If Yes: How much gain/loss	Over what period	

GENERAL EXAMINATION:		
General Impression		
Skin		
Jaundice		
Pallor		
Clubbing		
Cyanosis (Central/Peripheral)		
Oedema		
Lymph nodes	Head and neck	
	Axillary	
	Epitrochlear	
	Inguinal	
Pulses		
Urinalysis		

SYSTEM SPECIFIC EXAMINATION:
CARDIOVASCULAR EXAMINATION
RESPIRATORY EXAMINATION
ABDOMINAL EXAMINATION
NEUROLOGICAL EXAMINATION
COMMENTS

Clinician: **Signature :**

APPENDIX E

DURBAN UNIVERSITY OF TECHNOLOGY
REGIONAL EXAMINATION - CERVICAL SPINE

Patient: .... File No: ....

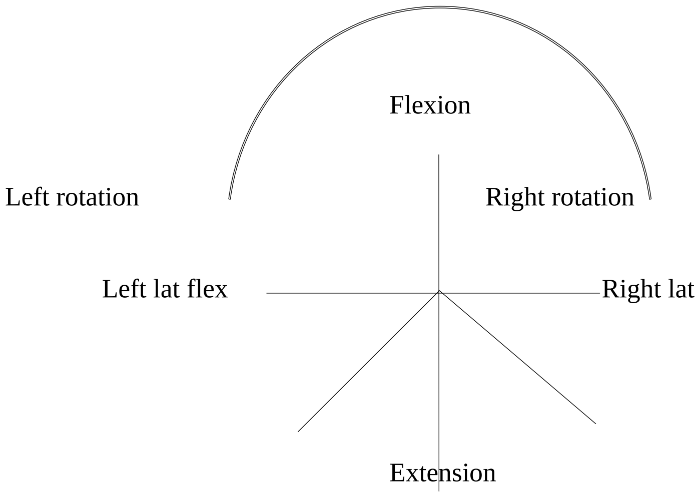
Date: .... Student: ....

Clinician: .... Sign: ....

OBSERVATION:
Posture
Swellings
Scars, discolouration
Hair line
Body and soft tissue contours

Shoulder position
Left :
Right :
Shoulder dominance (hand):
Facial expression:

RANGE OF MOTION:
Extension (70º):
L/R Rotation (70º):
L/R Lat flex (45º):
flex
Flexion (45º):



PALPATION:
Lymph nodes
Thyroid Gland
Trachea

ORTHOPAEDIC EXAMINATION:

Tenderness		Right	Left
Trigger Points:	SCM		
	Scalenii		
	Post Cervicals		
	Trapezius		
	Lev scapular		

	Right	Left		Right	Left
Doorbell sign			Cervical compression		
Kemp’s test			Lateral compression		
Cervical distraction			Adson’s test		
Halstead’s test			Costoclavicular test		
Hyper-abduction test			Eden’s test		
Shoulder abduction test			Shoulder compression test		
Dizziness rotation test			Lhermitte’s sign		

Brachial plexus test					

NEUROLOGICAL EXAMINATION:

Dermatones	**Left**	**Right**	**Myotomes**	**Left**	**Right**	**Reflexes**	**Left**	**Right**
C2			C1			C5		
C3			C2			C6		
C4			C3			C7		
C5			C4					
C6			C5					
C7			C6					
C8			C7					
T1			C8					
			T1					

Cerebellar tests:	Left	Right
Disdiadochokinesis		

VASCULAR:	**Left**	**Right**		**Left**	**Right**
Blood pressure			Subclavian arts.		
Carotid arts.			Wallenberg's test		

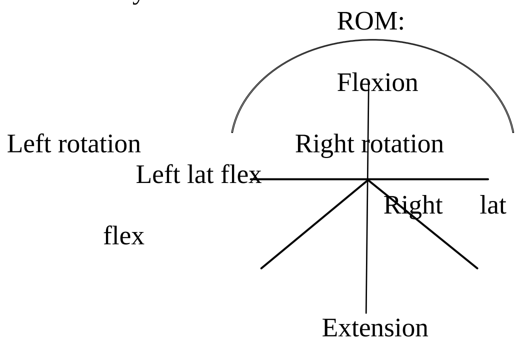
MOTION PALPATION & JOINT PLAY:
Left: Motion Palpation:
Joint Play:
Right: Motion Palpation:
Joint Play:

BASIC EXAM: SHOULDER:
Case History:

ROM: Active:
Passive:
RIM:
Orthopaedic:

Neuro:
Vascular:

BASIC EXAM: THORACIC SPINE:
Case History:



Motion Palpation:	
Orthopaedic:	
Neuro:	
Vascular:	
Observ/Palpation:	
Joint Play:	

APPENDIX F

DURBAN UNIVERSITY *of* TECHNOLOGY

THORACIC SPINE REGIONAL EXAMINATION

Patient:____File:____________ Date:______________

Intern:____Signature:__________________________

Clinician: ____Signature:__________________________

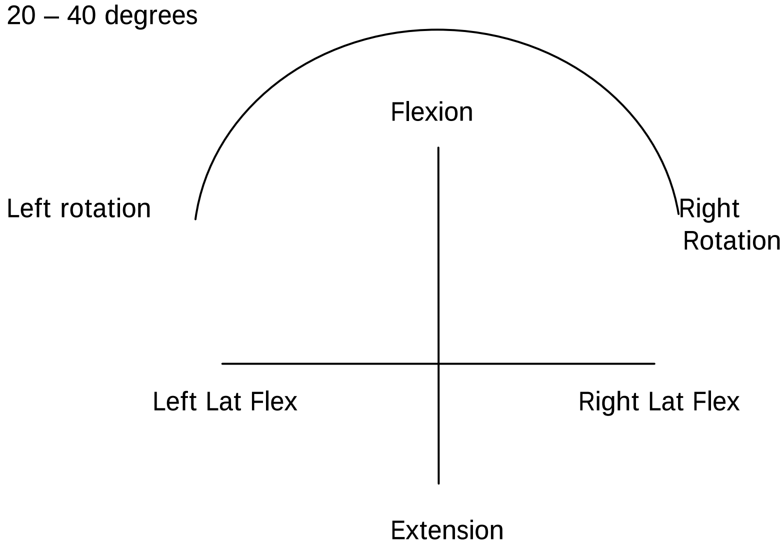
STANDING:

Posture (incl. L/S & C/S)
Muscle tone
Skyline view – Scoliosis
Spinous Percussion
Breathing (quality, rate, rhythm, effort)
Deep Inspiration

Scars
Chest deformity
(pigeon, funnel, barrel)

RANGE OF MOTION:

Forward Flexion	20 – 45 degrees (15cm from floor)
Extention	25 – 45 degrees
L/R Rotation	35 – 50 degrees
L/R Lat Flex	20 – 40 degrees



RESISTED ISOMETRIC MOVEMENTS: (in neutral)

Forward Flexion
Extension
L/R Rotation
L/R Lateral Flexion

SEATED:

Palpate Auxillary Lymph Nodes
Palpate Ant/Post Chest Wall
Costo vertebral Expansion (3 – 7cm diff. at 4th intercostal space)
Slump Test (Dural Stretch Test)

SUPINE:

Rib Motion (Costo Chondral joints)
Soto Hall Test (#, Sprains)
SLR
Palpate abdomen

PRONE:
Passive Scapular Approximation
Facet Joint Challenge
Vertebral Pressure (P-A central unilateral, transverse)
Active myofascial trigger points:

	Latent	Active	Radiation Pattern		Latent	Active	Radiation Pattern
Rhomboid Major				Rhomboid Minor			
Lower Trapezius				Spinalis Thoracic			
Serratus Posterior				Serratus Superior			
Pectoralis Major				Pectoralis Minor			
Quadratus Lumborum							

COMMENTS:____

NEUROLOGICAL EXAMINATION:

DERMATOMES												
	T 1	T 2	T 3	T 4	T 5	T 6	T 7	T 8	T 9	T 10	T 11	T 12
Left												
Right												

Basic LOWER LIMB neuro:

Myotomes	
Dermatomes	
Reflexes	

KEMP'S TEST:

MOTION PALPATION:

			Right	Left
Thoracic Spine				
Ribs	Calliper (Costo-transverse joints)			
	Bucket Handle	Opening		
		Closing		
Lumbar Spine				
Cervical Spine				

BASIC EXAM	History	ROM	Neuro/Ortho
LUMBAR			
CERVICAL			

APPENDIX G

DURBAN UNIVERSITY of TECHNOLOGY

REGIONAL EXAMINATION - LUMBAR SPINE AND PELVIS

Patient:__________________________________ File#:______Date:_________
Intern\Resident:___________________________ Clinician:______________

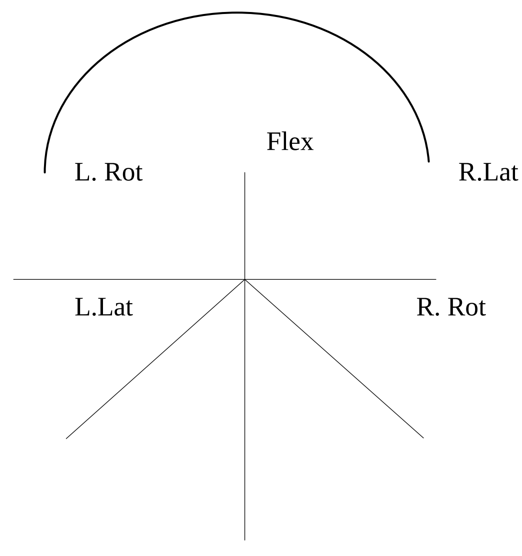
STANDING:

Posture– scoliosis, antalgia, kyphosis
Body Type
Skin
Scars
Discolouration

Minor's Sign
Muscle tone
Spinous Percussion
Scober's Test (6cm)
Bony and Soft Tissue Contours

GAIT:

Normal walking
Toe walking
Heel Walking
Half squat



ROM:

Forward Flexion = 40-60° (15 cm from floor)
Extension = 20-35°
L/R Rotation = 3-18°

L/R Lateral Flexion = 15-20°
Flex Flex

Which movt. reproduces the pain or is the worst?

- Location of pain
- Supported Adams: Relief? (SI)
- Aggravates? (disc, muscle strain)

SUPINE:

Observe abdomen (hair, skin, nails)
Palpate abdomen\groin
Pulses - abdominal
- lower extremity
Abdominal reflexes

		Degree	LBP?	Location	Leg pain	Buttock	Thigh	Calf	Heel	Foot	Braggard
SLR	**L**										
	R										

	L	R
Bowstring		
Sciatic notch		
Circumference (thigh and calf)		
Leg length: actual -		

apparent -		
Patrick FABERE: pos\neg – location of pain?		
Gaenslen's Test		
Gluteus max stretch		
Piriformis test (hypertonicity?)		
Thomas test: hip \ psoas? \ rectus femoris?		
Psoas Test		

SITTING:

Spinous Percussion
Valsalva
Lhermitte

		Degree	LBP?	Location	Leg pain	Buttock	Thigh	Calf	Heel	Foot	Braggard
TRIPOD Sl, +, ++	**L**										
	R										

Slump 7 test	**L**										
	R										

LATERAL RECUMBENT:

	L	R
Ober's		
Femoral n. stretch		
SI Compression		

PRONE:

	L	R
Gluteal skyline		
Skin rolling		
Iliac crest compression		
Facet joint challenge		
SI tenderness		
SI compression		
Erichson's		
Pheasant's		

MF tp's	**Latent**	**Active**	**Radiation**
QL			
Paraspinal			
Glut Max			
Glut Med			
Glut Min			
Piriformis			
Hamstring			
TFL			
Iliopsoas			
Rectus Abdominis			
Ext/Int Oblique muscles			

NON ORGANIC SIGNS:

Pin point pain
Axial compression

Trunk rotation
Burn's Bench test

Flip Test
Hoover's test

Ankle dorsiflexion test
Repeat Pin point test

NEUROLOGICAL EXAMINATION

Fasciculations

Plantar reflex

level	Tender?	Dermatomes		DTR		
		L	R		L	R
T12				Patellar		
L1				Achilles		
L2						
L3				Proproception		
L4						
L5						
S1						
S2						
S3						

MYOTOMES

Action	Muscles	Levels	L	R	
Lateral Flexion spine	Muscle QL				
Hip flexion	Psoas, Rectus femoris				5+ Full strength
Hip extension	Hamstring, glutes				4+ Weakness
Hip internal rotat	Glutmed, min;TFL, adductors				3+ Weak against grav
Hip external rotat	Gluteus max, Piriformis				2+ Weak w\o gravity
Hip abduction	TFL, Glut med and minimus				1+ Fascic w\o gross movt
Hip adduction	Adductors				0 No movement
Knee flexion	Hamstring,				
Knee extension	Quad				W - wasting
Ankle plantarflex	Gastroc, soleus				
Ankle dorsiflexion	Tibialis anterior				
Inversion	Tibialis anterior				
Eversion	Peroneus longus				
Great toe extens	EHL				

BASIC THORACIC EXAM

History
Passive ROM
Orthopedic

BASIC HIP EXAM

History
ROM: Active
Passive : Medial rotation : A) Supine (neutral) If reduced - hard \ soft end feel
B) Supine (hip flexed): - Trochanteric bursa

Upper Thoracics		
Lumbar Spine		
Sacroiliac Joint		

APPENDIX H

Clinical Information Data Sheet

Number												
Code												
Age												
Gender	**M**			**M**			**M**			**M**		
	F			**F**			**F**			**F**		
Ethnicity												
Family history of scoliosis	**YES**			**YES**			**YES**			**YES**		
	NO			**NO**			**NO**			**NO**		
Any known or detectable urogenital anomaly	**YES**			**YES**			**YES**			**YES**		
	NO			**NO**			**NO**			**NO**		
Presenting complaint or is the subject asymptomatic												
Location of pain if present												
NRS – Pain Rating												
Presence of leg length inequality and recording of short side of leg		**R**	**L**		**R**	**L**		**R**	**L**		**R**	**L**
	YES			YES			YES			YES		
	NO			NO			NO			NO		
Measurement of leg length inequality												
Presence of shoulder height inequality and recording of the elevated shoulder		**R**	**L**		**R**	**L**		**R**	**L**		**R**	**L**
	YES			YES			YES			YES		
	NO			NO			NO			NO		
Shoulder height inequality in cm												
Presence of pelvic obliquity and recording of elevated side		**R**	**L**		**R**	**L**		**R**	**L**		**R**	**L**
	YES			YES			YES			YES		
	NO			NO			NO			NO		
Pelvic Obliquity in cm												
Presence of rib hump, recording of side that it appears		**R**	**L**		**R**	**L**		**R**	**L**		**R**	**L**
	YES			YES			YES			YES		
	NO			NO			NO			NO		

APPENDIX I

Radiological information Data Sheet

Number					
Code					
Side of convexity					
Location of curve					
Classification according to aetiology / cause on x-ray					
Presence of more than one curve					
Location and direction of secondary curves					
Location of apex vertebrae					
Cobb angle of inclination					
Degree of pedicle rotation					

APPENDIX J

DURBAN UNIVERSITY of TECHNOLOGY

Faculty of Health Sciences

ETHICS CLEARANCE CERTIFICATE

Student Name	Shethal Gajeerajee	**Student No**	20300539
Ethics Reference Number	FHSEC 026/09	**Date of FRC Approval**	09/06/09
Research Title:	Radiographic and Clinical Analyses of Scoliosis of Adult Subjects in the Greater Durban Area.		

In terms of the ethical considerations for the conduct of research in the Faculty of Health Sciences, Durban University of Technology, this proposal meets with Institutional requirements and confirms the following ethical obligations.

1. The researcher has read and understood the research ethics policy and procedures as endorsed by the Durban University of Technology, has sufficiently answered all questions pertaining to ethics in the DUT 186 and agrees to comply with them.
2. The researcher will report any serious adverse events pertaining to the research to the Faculty of Health Sciences Research Ethics Committee.
3. The researcher will submit any major additions or changes to the research proposal after approval has been granted to the Faculty of Health Sciences Research Committee for consideration.
4. The researcher, with the supervisor and co-researchers will take full responsibility in ensuring that the protocol is adhered to.
5. ***The following section must be completed if the research involves human participants:***

	YES	NO	N/A
❖ Provision has been made to obtain informed consent of the participants	X		
❖ Potential psychological and physical risks have been considered and minimised	X		
❖ Provision has been made to avoid undue intrusion with regard to participants and community	X		
❖ Rights of participants will be safe-guarded in relation to: - Measures for the protection of anonymity and the maintenance of Confidentiality.	X		
- Access to research information and findings.	X		
- Termination of involvement without compromise	X		
- Misleading promises regarding benefits of the research	X		

SIGNATURE OF STUDENT/RESEARCHER — 09/06/09 DATE

SIGNATURE OF SUPERVISOR/S — 9 June 2009 DATE

SIGNATURE OF HEAD OF DEPARTMENT — 9/6/09 DATE

SIGNATURE/ CHAIRPERSON OF RESEARCH ETHICS COMMITTEE — 9/6/09 DATE