RACIAL VARIATIONS OF SELECTED THORACIC SPINE RADIOGRAPHIC PARAMETERS OF MALES IN THE GREATER DURBAN AREA.

By

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

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DEDICATION

I dedicate this dissertation to:

The Lord Almighty for granting me the opportunity to follow my dreams and for providing the strength that I needed to persevere and accomplish my goal.

My loving and supportive parents, Sagren and Alice Govender, for always encouraging me and supporting me throughout my chiropractic studies; and for teaching me the importance of hard work. Thank you for inspiring me and believing in me, I love you. To my dear sister, Ramona, for always having had the time to listen and offer advice; and for being a pillar of strength, I love you. To my Aunt Cheryl, for all your words of encouragement and for reminding me that through God all things are possible, I love you dearly. I am truly blessed to have all of you in my life, without whom none of this would have been possible. Thank you all so much.

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ABSTRACT

Aim: The aim of this study was to evaluate the normal selected radiographic parameters (thoracic kyphosis (TK), anterior vertebral body height (AVBH), posterior vertebral body height (PVBH), intervertebral disc height (IVDH) and interpedicular distance (IPD)) in young to middle-aged males across the four racial groups in Durban.

Participants: Eighty young to middle-aged apparently healthy males between the ages of 18-45 years from the White, Black, Indian and Coloured racial groups in Durban.

Methodology: After written informed consent was acquired, all participants underwent a case history, physical examination and thoracic orthopaedic examination. An AP and lateral radiograph of the thoracic spine was then obtained. The TK, AVBH, PVBH, IVDH and IPD were assessed using methods described previously. The IBM SPSS version 20 was utilized for the data analysis. Mean, standard deviation (SD) and range are reported for the TK, AVBH, PVBH and IPD for each of the four racial groups. For the IVDH, however, the median for the respective vertebral levels is given. ANOVA testing with Bonferroni *post-hoc* tests were used to determine overall inter-group variations and compare each group to the other. Pearson's correlation test was used to determine the relationship between the thoracic kyphosis and the other radiographic parameters that were assessed.

Results:

The mean, SD, minimum and maximum values of the thoracic kyphosis by racial group

Racial Group	*n*	Mean (°)	Standard Deviation	Minimum	Maximum
White	20	25.2	9.3	8.0	39.0
Black	20	20.1	7.4	4.0	33.0
Indian	20	23.4	8.2	10.0	43.0
Coloured	20	20.1	9.0	7.0	37.0

The mean (mm) and SD of the anterior vertebral body height of T5-T12 by racial group

Group		T5	T6	T7	T8	T9	T10	T11	T12
White	Mean	25.6	25.9	26.3	26.9	27.7	29.0	30.6	32.5
	SD	2.0	2.0	1.6	1.9	1.5	1.6	1.9	2.2
Black	Mean	23.9	24.2	24.7	25.1	26.6	28.3	29.5	31
	SD	1.9	1.9	1.9	2.0	2.0	2.0	2.4	2.7
Indian	Mean	23.9	24.6	25	25.5	26.7	28.1	29.2	31.1
	SD	1.6	1.7	1.7	2.0	2.2	3.0	2.4	2.2
Coloured	Mean	25.5	25.8	26.1	26.5	27.4	29.6	31	32.7
	SD	2.1	2.1	1.8	2.0	1.9	1.9	2.3	2.2

The mean (mm) and SD of the posterior vertebral body height of T5-T12 by racial group

Group		T5	T6	T7	T8	T9	T10	T11	T12
White	Mean	26.6	28.2	29.9	30.5	31.1	32.2	34	35.6
	SD	1.8	1.8	2.7	1.4	1.5	1.6	2.3	2.9
Black	Mean	25.6	26.8	27.5	28.0	28.8	29.9	31.3	33.3
	SD	2.5	2.4	2.0	1.8	2.0	2.4	2.5	3.0
Indian	Mean	25.7	26.8	27.4	28.4	29.0	30.1	32.2	33.6
	SD	1.6	1.5	1.3	1.7	1.6	2.2	2.0	2.1
Coloured	Mean	26.7	27.5	28.2	29	29.9	31.2	32.6	33.9
	SD	2.0	2.4	2.4	2.0	2.2	2.0	1.5	1.8

The median and geometric mean of the intervertebral disc height (mm)

Report

Group		T5-T6	T6-T7	T7-T8	T8-T9	T9-T10	T10-T11	T11-T12	T12-L1
White	Median	3.0	3.0	3.0	4.0	4.5	5.5	7.0	8.0
	Geometric mean	3.0	3.3	3.5	3.9	4.5	5.2	6.8	7.8
Black	Median	3.0	3.0	3.0	4.0	4.0	5.5	7.0	8.0
	Geometric mean	2.8	2.9	3.3	3.7	4.3	5.6	7.0	8.0
Indian	Median	3.0	3.0	3.0	4.0	4.0	5.0	6.5	8.0
	Geometric mean	2.9	3.0	3.4	3.7	4.3	5.2	6.6	7.7
Coloured	Median	3.0	4.0	4.0	4.5	5.0	6.0	8.0	8.0
	Geometric mean	3.1	3.6	4.0	4.5	4.9	6.3	7.6	8.2

The mean (mm) and SD of the interpedicular distance of T1-T12 by racial group

Report													
Group		**T1**	**T2**	**T3**	**T4**	**T5**	**T6**	**T7**	**T8**	**T9**	**T10**	**T11**	**T12**
White	Mean	26.2	22.3	20.4	19.4	18.5	18.5	18.5	18.7	18.9	19.5	21.5	24.2
	SD	1.1	0.9	1.0	1.2	1.5	1.3	1.3	1.4	1.6	1.5	3.5	2.7
Black	Mean	24.7	20.5	18.9	17.8	17.4	17.3	17.1	17.4	17.5	18	19.1	21.9
	SD	2.0	1.7	1.5	1.7	1.5	1.5	1.5	1.7	1.8	2.0	2.4	2.4
Indian	Mean	24.7	20.9	19.1	18.3	17.5	17.4	17.3	17.7	17.4	18.2	19.8	22.6
	SD	1.8	1.6	1.3	1.5	1.6	1.4	1.5	1.3	1.1	1.7	2.0	2.0
Coloured	Mean	25.6	21.7	19.8	18.9	18.2	18.2	18	18	18.5	19.1	20.6	24.3
	SD	2.2	2.0	1.9	1.8	1.8	2.0	2.0	2.3	2.4	2.8	2.6	3.4

There was no significant difference in the TK among the four race groups. Significant differences ($p < 0.05$) were observed in the AVBH, PVBH, IVDH and IPD between the White, Black, Indian and Coloured males at various thoracic levels.

Conclusion: The trends of the various radiographic parameters observed in this study support the argument that these parameters should be based on sex, age and geographic race. These values would be useful for South African spinal health care practitioners in the diagnosis and management of spinal disorders.

LIST OF SYMBOLS AND ABBREVIATIONS

=:	Results are the same as those of previous studies
>:	Greater than
<:	Less than
°:	Degrees
↑:	Increase
↓:	Decrease
A:	Anterior
ABCS:	Alignment, Bone, Cartilage and Soft tissue
ALL:	Anterior longitudinal ligament
ANOVA:	Analysis of variance
AVBH:	Anterior vertebral body height
AP:	Anteroposterior
B:	Black
BMI:	Body mass index
C:	Coloured
CDC:	Chiropractic Day Clinic
CT:	Computed tomography
DISH:	Diffuse idiopathic skeletal hyperostosis
DUT:	Durban University of Technology
F:	Female

I:	Indian
IBM:	International Business Machines
IVD:	Intervertebral disc
IVDs:	Intervertebral discs
IVDH:	Intervertebral disc height
IVF:	Intervertebral foramina
IPD:	Interpedicular distance
kg:	Kilogram
kV:	Kilovolt
kg.m^{-2}	Kilogram per metre squared
M:	Male
m:	Metres
mAs:	Milliamperes per second
mm:	Millimetres
MRI:	Magnetic resonance imaging
***n*:**	Sample size or count
N/A:	Not available
P:	Posterior
PLL:	Posterior longitudinal ligament
PVBH:	Posterior vertebral body height
SCD:	Sagittal canal diameter
SPSS:	Statistical Package for the Social Sciences
TK:	Thoracic kyphosis

VBH: Vertebral body height

viz: Namely

W: White

yoa: Years of age

yrs: Years

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CHAPTER ONE

INTRODUCTION

1.1 INTRODUCTION

Plain film radiographs are commonly utilized in clinical practice as investigative aids in the diagnosis and management of musculoskeletal conditions (Ory, 2003; Yochum and Rowe, 2005). It is important for a chiropractor and other health care professionals to not only have a systematic approach to evaluating spinal radiographs, but also to be acquainted with the normative reference values for the various radiographic parameters that are assessed (McAviney et al., 2005).

The plain-film radiograph is the preferred diagnostic imaging modality due to its accessibility, cost-effectiveness and ability to demonstrate the bony anatomy and landmarks (Yochum and Rowe, 2005). The main reasons for requesting spinal radiographs by primary health care practitioners include ruling out disease, confirmation of a suspected clinical diagnosis; and for follow-up or to aid in management of patients (Houben et al., 2006).

One preferred technique to evaluating the radiographs of the thoracic spine is the ABCS (**A** = **A**lignment, **B** = **B**one, **C** = **C**artilage and **S** =**S**oft tissue) method described by Yochum and Rowe (2005). The main advantage of this method is that it ensures that all significant structures are evaluated on the radiograph.

Despite the thoracic spine having a reported higher incidence of malignancy, infection and fractures compared to the cervical and lumbar region (Yochum and Rowe, 2005), it is surprising that more attention has not been focused on this region; resulting in limited available data (Edmondston and Singer, 1997; Goh et al., 2000). The key radiographic parameters that are evaluated in the thoracic spine include thoracic spine (TK), vertebral body height (VBH), intervertebral disc height (IVDH) and interpedicular distance (IPD) (Gelb et al., 1995; Manns et al., 1996; Harrison et al., 2003; Datir and Mitra, 2004). There are a few studies that have reported normal values of several parameters that are commonly assessed in the thoracic spine, but the results are often inconsistent mainly due to differences in methodologies and population characteristics such as sex and race (Tan et al., 2004).

A normal TK is necessary for the maintenance of proper posture (Edmondston and Singer, 1997). Changes in the normal TK could signify postural abnormalities, congenital anomalies and inflammatory and traumatic conditions (Fon et al., 1980; Edmondston and Singer, 1997). Despite its importance, there is debate amongst researchers as to what the normal range of kyphosis should be (Kolessar et al., 1996). Significant differences have been found in the thoracic spine between the sexes and various age groups (Fon et al., 1980; Bartynski et al., 2005). However, few studies have discussed differences between the various population groups (Stagnara et al., 1982; Korovessis et al., 1999). Variations in the vertebral morphology may affect the development of the vertebral bodies (VBs) (Scoles et al., 1988). The VBH and IVDH play a significant role in the development and maintenance of the normal kyphotic curve (Manns et al., 1996; Goh et al., 1999). A racial variation in the vertebral morphology of the thoracic spine has been observed by Lau et al. (1996).

A reduced IPD is strongly suggestive of spinal canal stenosis (Nirvan et al., 2005). Variation in pedicle morphology of the thoracic spine in different population groups has been observed (Datir and Mitra, 2004). Differences in IPD in the thoracic spine between the sexes and between males from different geographic locations have also been observed (Scoles et al., 1988; Ugur et al., 2001). Studies have also been conducted to determine the IPD between different racial populations. A common reference value cannot be applied to all racial groups as previous studies have reported variations in the IPD in the thoracic spine in various population groups (Scoles et al., 1988; Ugur et al., 2001; Datir and Mitra, 2004).

It is important to evaluate the selected radiographic parameters [TK, anterior and posterior vertebral body height (AVBH and PVBH), IVDH and IPD] of the thoracic spine as these measurements aid in the diagnosis of many congenital and acquired spinal disorders (Singer et al., 1994; Kolessar et al., 1999; Edmondston and Singer, 1997; Rajnics et al., 2001). The TK angle is essential in aiding the diagnoses of various postural disorders (Kolessar et al., 1996; Rajnics et al., 2001). The AVBH and IVDH play a significant role in the angle of the TK (Singer et al., 1994; Manns et al., 1996). The AVBH is also especially important in aiding in the diagnosis of compression fractures (Parizel et al., 2010). Racial and sex differences in the radiographic parameters of the cervical and lumbar spines have been reported by previous studies some of which included South African population groups (Eisenstein, 1977; Lim and Wong, 2004; Tatarek, 2005; Tossel, 2007; Naidoo, 2008; Roopnarian, 2011). It is, therefore, hypothesised that similar differences would be observed in the thoracic spine. Currently, there is a paucity of literature on the radiographic parameters of the thoracic spine in a South African population setting.

1.2 DEFINITIONS

For the purpose of this study the following definitions were applied:

Sex: Refers to the biological and physiology characteristics that define men and women (World Health Organization, 2014).

Gender: Refers to the socially constructed roles, behaviours, activities and attributes that a given society considers appropriate for men and women (World Health Organization, 2014).

Race: "a phenotypically and/or geographically distinctive sub-specific group, composed of individuals inhabiting a defined geographic and/or ecological region, and possessing characteristic phenotypic and gene frequencies that distinguish it from other such groups" (LaVeist, 1994).

Ethnicity: "embraces groups differentiated by colour, language and religion; it covers 'tribes', 'races', 'nationalities' and castes" (Chandra, 2006).

1.3 AIM AND OBJECTIVES

1.3.1 Aim

The aim of this study was to evaluate the normal selected thoracic spine radiographic parameters in young to middle-aged males across the four racial groups in Durban.

1.3.2 Objectives

1. To assess the selected radiographic parameters, viz. TK, AVBH, PVBH, IVDH and IPD in young to middle-aged males in White, Black, Indian and Coloured males.

2. To determine if there was a significant variation in the selected radiographic parameters within and between the four racial groups.

1.4 HYPOTHESIS OF THE STUDY

The Alternate Hypothesis (H_a) which was set stated that there will be a significant difference in the selected radiographic parameters between the racial groups.

1.5 SCOPE OF THE STUDY

Eighty apparently healthy, young to middle-aged White, Black, Indian and Coloured male participants were notified of the nature of this study by means of a letter of information. Written informed consent was obtained from each participant before a complete case history, physical examination and a thoracic spine orthopaedic examination was completed. Each participant then had an erect anteroposterior (AP) and lateral thoracic spine radiograph taken. These were then evaluated by the radiographer using the ABCS approach described by Yochum and Rowe (2005) and the methods described in **Table 3.2**. The results of the assessments are reported in this dissertation.

1.6 LIMITATIONS OF THE STUDY

Two examiners could have been utilized to ensure more accurate measurements. However, due to financial and time constraints, this was not feasible. The measurements were completed manually by the researcher on plain-film radiographs as opposed to using a digitised version with the relative software programmes.

The ages of the participants ranged from 18 to 45 years. The participants that were involved in this study had to be over the age of 18 to ensure adherence to the South African Medical Research Council (Medical Research Council Guidelines on Ethics for Medical Research, 2002). Participants over the age of 45 were not included in this study, due to degeneration reportedly commencing in the fifth decade (Mitra et al., 1996; Friedenberg and Miller 2010). These results cannot be generalized to females as only males were included in the study to maintain sample homogeneity. The two most common views requested for the thoracic spine are AP and lateral. Due to the superimposition of the scapula over the upper thoracic vertebrae, the TK was measured from T5 to T12 (Yochum and Rowe, 2005).

CHAPTER TWO

LITERATURE REVIEW

2.1 INTRODUCTION

Chiropractors may request plain-film radiographs to assist in the screening process for spinal pathology and to gain insight on particular anatomical abnormalities; as well as to accumulate information on the structural and functional grade of the muscular and skeletal systems (Brown, 2001). It is, therefore, imperative that chiropractors not only have a systematic approach to evaluating spinal radiographs, but also be acquainted with the normative reference values for the various radiographic parameters that are assessed (McAviney et al., 2005). Although there are a few studies that have reported normal values of several parameters that are commonly assessed in the thoracic spine, the results are often inconsistent; mainly due to differences in methodologies and population characteristics such as sex and race (Tan et al., 2004). This review will present an overview of the relevant anatomy of the thoracic region, together with the reported literature on the TK, AVBH, PVBH, IVDH and IPD of the thoracic spine.

2.2 AN OVERVIEW OF THE RELEVANT BONY AND SOFT TISSUE IN THE THORACIC SPINE

There are 12 thoracic vertebrae in an adult which are situated in the upper and mid-back, and one of their main roles is to provide attachment for the ribs (Moore and Dalley, 2006). The thoracic spine is rigid and this allows for less movement compared to the cervical and lumbar regions. The thoracic spine comprises of the bony vertebrae and soft tissues which include intervertebral discs (IVDs), muscles, ligaments, blood vessels and neural structures such as the spinal cord and nerves (Moore and Dalley, 2006).

2.2.1 THE TYPICAL THORACIC VERTEBRAE

The T5-T8 vertebrae are usually considered as the typical thoracic vertebrae and are heart-shaped (Moore and Dalley, 2006). The AP dimension of the VB increases from T5-T8, and the transverse sections are usually asymmetrical due to their left sides being impacted by the pressure of the thoracic aorta. An AP and lateral view of a typical thoracic vertebra is shown in **Figures 2.1** and **2.2**. The spinous processes of the thoracic vertebrae are long, slender and slope posteroinferiorly to the next vertebral level, resulting in an overlap. This forms an arc and allows for the greatest amount of rotation occurring within the vertebral column. The vertebral foramen is circular and the smallest when compared to the cervical and lumbar regions. The spinal canal is large and triangular in the cervical spine, and in the lumbar spine it is triangular; but not larger than the cervical spine. These differences in diameter are to accommodate the cervical and lumbar spinal cord enlargements (Crossman and Neary, 2005; Moore and Dalley, 2006). The transverse processes are long and strong extending posterolaterally, and include a costotuberular facet which allows for articulation with the corresponding rib (Moore and Dalley, 2006; Standring, 2008).

Figure 2.1 Anteroposterior view of a typical thoracic vertebra

Figure 2.2 Lateral view of a typical thoracic vertebra

2.2.2 ATYPICAL THORACIC VERTEBRAE

The following thoracic vertebrae are considered to be atypical: T1 and T9-T12 (Standring, 2005).

A) T1

The features of the first thoracic vertebra resemble the body of the cervical vertebra. There are round superior costal facets which allow for full articulation with the first rib. Also found are smaller semilunar inferior facets, which allow for articulation of the second rib at its demi-facet. As a result of the superior costal facet sometimes being incomplete, the first rib often articulates with the seventh cervical vertebra and it's IVD.

B) T9

The demi-facets are absent in the ninth thoracic vertebra. Therefore, it fails to articulate with the tenth rib. In all other aspects, it has features of a typical thoracic vertebra.

C) T10

Only superior facets are found on the body of the tenth thoracic vertebra because this vertebra only articulates with the tenth rib. Facets for the tubercle of the tenth ribs are sometimes found on this vertebra.

D) T11

The 11^{th} thoracic vertebra only articulates with the head of the 11^{th} rib. The superior, circular facets lie closely to the upper border of the body and extend onto the pedicles. The transverse processes do not contain articular facets, and the spinous processes are triangular in shape and are blunt at their apices.

E) T12

The 12^{th} thoracic vertebra only articulates with the head of the 12^{th} ribs. It has a large body and shares some features of the lumbar vertebra. Three small tubercles replace the transverse process. The lateral tubercle is a homologue for the transverse process. The superior tubercle which is the largest, corresponds to the lumbar mammillary process; and the inferior tubercle is a homologue of a lumbar accessory process.

2.2.3 FACET JOINTS

The facet joints are synovial-type joints which are covered in hyaline cartilage. The articulating surfaces are between the superior and inferior articular processes. Each of the facet joints are also covered by a joint capsule. The orientation of the facet joints from T1-T10 is in the coronal plane; at the levels of T11 and T12 the orientation changes to the oblique sagittal plane which is similar to the orientation of the facet joints in the lumbar spine (El-Khoury and Whitten, 1993). These joints allow for gliding movements between the articular processes; and the degree of movement is established by their orientation (Standring, 2005; Moore and Dalley, 2006).

2.2.4 VERTEBRAL ENDPLATES AND INTERVERTBRAL DISCS

The vertebral endplates comprise of hyaline and fibrocartilage, with the fibrocartilaginous aspect lying closer to the IVD (Standring, 2005). The IVDs comprise of an annulus fibrosis, which is an outer fibrous layer consisting of many layers of fibrocartilage and an inner nucleus pulposus which is a gelatinous, elastic substance (Moore and Dalley, 2006; Tortora and Derrickson, 2006). The IVDs strongly adhere to the VBs, uniting them and helping to form a rigid, continuous column (Moore and Dalley, 2006). The IVDs comprise 20%-33% of the height of the spinal column. In the cervical and lumbar regions of the spine the IVDs are thicker anteriorly; whereas in the thoracic spine the height is reported to be uniform (Standring, 2005). The chief functions of the IVDs include shock absorption and to aid in movement of the spine (White and Panjabi, 1990; Moore and Dalley, 2006).

2.2.5 INTERVERTEBRAL FORAMINA

The intervertebral foramina (IVF) are found on each side between adjacent vertebrae. The inferior vertebral notch of the pedicle above and the superior vertebral notch of the pedicle below aid in formation of the IVF. Posteriorly, the IVF is bordered by the facet joint of the vertebra above and below, and anteriorly it is bordered by the IVD and the two adjacent vertebrae. The main purpose of the IVF is to allow the entry and exit of blood vessels, and spinal nerves (Drake et al*.,* 2005).

2.2.6 THE SPINAL CANAL

The spinal canal encompasses the spinal cord. It is narrowest in the thoracic region compared to the cervical and lumbar region and is round in shape (El-Khoury and Whitten, 1993; Agur and Dalley, 2009). The spinal canal is widest at the levels of C3-T1 and L1-S3 so that it can accommodate the spinal enlargements that occur at these vertebral levels (Crossman and Neary, 2005). It is bounded anteriorly by the lamina and ligament flavum, laterally by the pedicles and posteriorly by the VBs and IVDs (Collins et al., 2005).

2.2.7 RELATED LIGAMENTOUS ANATOMY

A) Anterior Longitudinal Ligament

The anterior longitudinal ligament (ALL) is a broad, thick fibrous band that extends anteriorly from the base of the occiput to the superior aspect of the sacrum. It is broadest caudally, and in the thoracic spine it is thicker but narrower compared to the cervical and lumbar regions. It connects the anterolateral VBs, vertebral endplates and the IVDs (Kelley and Petersen, 2013). The ALL comprises of more than one layer which contributes to its strength; the superficial layer expands across three to four VBs, the intermediate layer expands over two to three VBs and the deepest layer expands from one VB to the next (Standring, 2005). The ALL provides stability to the spinal column by limiting hyperextension (Moore and Dalley, 2006; Kelley and Petersen, 2013).

B) Posterior Longitudinal Ligament (PLL)

The PLL is a narrower and weaker ligament than the ALL. It runs within the spinal canal, attaching to the IVDs more than the VBs themselves; and its primary function is to limit forward flexion (Moore and Dalley, 2006; Kelley and Petersen, 2013). It is wider and more uniform at the upper levels of the thoracic spine, whilst at the lower thoracic spine it expands broader over the IVDs and runs narrowly over the VBs (Kelley and Petersen, 2013).

C) Ligamenta Flavum

The ligamenta flavum is a yellow, elastic-type tissue that joins the laminae of adjacent vertebrae. The fibres attach to the capsule of the facet joint to the point at which the lamina fuses to form the spinous process. A delicate, smooth membrane covers the entire anterior aspect of the ligamentum flavum. It is thicker in the thoracic spine compared to the cervical region, but narrower when compared to the lumbar spine. The primary roles of this ligament are to resist the separation of the laminae when the spine is flexed, and to aid in restoring the spine to its neutral position following flexion (Standring, 2005; Kelley and Petersen, 2013).

2.2.8 MUSCLES OF THE MID-BACK

The key large muscles of the mid-back region are shown in **Table 2.1**. The erector spinae muscles consist of the iliocostalis, longissimus and the spinalis muscles. These act bilaterally to extend the thoracic spine, and when acting unilaterally they laterally flex the spine. The transversospinal consists of the semispinalis, multifidus and rotatores muscles and is responsible for extension of the thoracic spine and it also aids in the stabilisation of the spinal column. The interspinalis, which is the deepest layer, aids in the extension of the thoracic spine. The rectus abdominis and psoas major muscles are responsible for flexion of the trunk (Agur and Dalley, 2009). For further details, the reader is advised to consult the relevant anatomy texts such as Clinically Oriented Anatomy (Moore and Dalley, 2006) and Gray's Anatomy (Standring, 2005).

Table 2.1 Flexor and extensor muscles of the mid-back

Flexor Muscles	**Extensor Muscles**
Rectus Abdominis	Erector Spinae • Iliocostalis • Longissimus • spinalis
Psoas Major	Transversospinal • semispinalis • multifidus • rotatores
	Interspinalis

(Moore and Dalley, 2006)

2.3 CURVATURE OF THE THORACIC SPINE

In a foetus, the vertebrae consist of three osseous structures (centrum and two neural arches). At two years of age, the two halves of the neural arch begin to fuse, beginning at the lumbar spine and ending at the cervical spine. At seven years of age, the centrum and the neural arches begin to fuse; this begins at the cervical spine and ends at the lumbar spine (Agur and Dalley, 2009). The adult spine has four curvatures viz. cervical, thoracic, lumbar and sacral. The thoracic and sacral curves are concave anteriorly and are termed kyphotic curves. These are also known as the primary curves as they are present at birth and are formed due to the foetus being in a foetal position (Moore and Dalley, 2006). The posterior convexity of the thoracic spine is due to the PVBH being greater than the AVBH (Standring, 2005). The centre of gravity lies anterior to the thoracic curvature and the compressive forces are concentrated at the apex (T5-T8) of the thoracic spine (Goh et al., 1999; Goh et al., 2000; Masharawi et al., 2008). The cervical and lumbar curves, called the lordotic curves, are secondary in nature and form as a result of extension of the spine (Standring, 2005). The cervical lordosis begins to form when the child starts to lift the head and the lumbar lordosis begins to form when the child begins to sit up and walk (Agur and Dalley, 2009).

2.4 RADIOGRAPHIC EVALUATION OF THE THORACIC SPINE

2.4.1 The Role and Evaluation of Radiographs in Clinical Practice

Radiographs are commonly utilised in clinical practice as investigative aids in the diagnosis and management of musculoskeletal conditions (Ory, 2003; Yochum and Rowe, 2005). They are sensitive in identifying many conditions which include spinal malignancy, inflammatory arthropathies, infections and fractures; many of which present as or mimic non-pathological back pain (Brown, 2001). The plain-film radiograph is often the preferred initial diagnostic imaging modality due to its accessibility, cost-effectiveness and ability to demonstrate the bony anatomy and landmarks (Yochum and Rowe, 2005). Radiographs have shown to be relatively safe if the safety guidelines are adhered to (Levy et al., 1994). Plain-film radiographs are commonly used in emergency medicine, especially in trauma cases; and should precede any other investigative imaging as they provide quick and effective means to view the bony anatomy and to assess vertebral fractures and spinal deformity (El-Khoury and Whitten, 1993; Parizel et al., 2010).

This type of diagnostic imaging aids chiropractors and other primary health care practitioners in the diagnoses and decision-making of the appropriate management of spinal disorders in patients (Bussieres et al., 2007; Bussieres et al*.,* 2008). Common disorders diagnosed on spinal radiographs include: degenerative joint disease, osteopenia, soft tissue calcification, congenital anomalies, tumours and traumatic injury (El-Khoury and Whitten, 1993; Benneker et al., 2005). Combined with history and physical examination findings, radiographic examination is highly useful in aiding chiropractors in the diagnosis of numerous musculoskeletal disorders as well as ensuring that a patient is a candidate for spinal manipulative therapy (Brown, 2001).

Anteroposterior and lateral radiographs are the common primary views of the thoracic spine that are requested and are easily obtainable. The AP radiographs of the thoracic region are generally used to identify and evaluate the osseous structures of the spine and to ensure that there is no soft tissue swelling. The lateral radiographs assist in the evaluation of the VBH and IVDs and normal curve and alignment (El-Khoury and Whitten, 1993).

One preferred technique to evaluating the radiographs of the thoracic spine is the ABCS (**A** = **A**lignment, **B** = **B**one, **C** = **C**artilage and **S** = **S**oft tissue) method described by Yochum and Rowe (2005). On an AP radiograph, the thoracic spine is evaluated as follows:

- **A**: Scoliosis (side of the convexity and degree of the lateral deviation); the interspinous space, the IPD, the facet joint spaces and vertebral wedging (should not exceed two millimetres in adjacent segments)
- **B**: Each bony landmark should be visible and identified. These include the spinous processes, the transverse processes, pedicles and the vertebral end plates
- **C**: The intervertebral, costotransverse and costovertebral joints should be visible and identified
- **S**: The paravertebral soft tissues which include the heart, mediastinum, diaphragm and lung should be identified. The trachea should lie over the thoracic spine, and any deviation could be indicative of disease such as malignancy (Yochum and Rowe, 2005).

On a lateral radiograph of the thoracic spine, the following are usually evaluated:

- **A**: The TK, and the posterior VB line
- **B**: Bony landmarks such as the VB, vertebral end plates, pedicles, IVF, and facet joints should be identified. The scapula is often seen superimposed over the upper thoracic spine
- **C**: IVDH and facet joints should be identified
- **S**: The diaphragm should be visible, curving anteriorly and is higher on the right hand side

The ABCS method provides a simple, systematic approach to evaluating plain-film radiographs. It ensures that all important structures are assessed and prevents structures from being overlooked. This method also serves as a template to health care practitioners and allows for verification of the results if the radiographs are being assessed by more than one person.

2.4.2 Thoracic Kyphosis

The TK is a primary curve which originates from the level of the first thoracic vertebra to the 12th thoracic vertebra *in vivo*. It has a posterior convexity and lies between the cervical and lumbar lordosis (Standring, 2005). Assessing the TK is of considerable importance, as this angle is particularly helpful in aiding with the diagnosis of various spinal disorders. An increase in the thoracic angle has been associated with various pathologies in the thoracic spine such as degeneration, compensatory increased cervical and lumbar curves, impaired breathing patterns, and increased shoulder pathology, fractures and back pain (Tuzun et al., 1999; Goh et al., 2000; Harrison et al., 2001; Rajnics et al., 2001; Bartynski et al., 2005; Vialle et al., 2005). A decrease in TK angle has been associated with idiopathic adolescent scoliosis, impaired pulmonary function and cervical kyphosis (Harrison et al., 2001). A summary of the reported TK values in the literature is presented in **Table 2.2**.

Table 2.2 A summary of the reported thoracic kyphosis values

Reference	Sample Characteristics	Method	Level	Reported TK Value	
Fon et al. (1980)	316 2-79 yoa	Modified Cobb method; Retrospective lateral chest radiographs of healthy participants	N/A	(Mean) Males 29.9°	(Mean) Female 33.1°
Stagnara et al. (1982)	137 (62 French females, 75 French males) 20-29 yoa	Lateral radiographs of healthy participants	T4-T12	(Mean ± SD) 36°±10 ° in both males and females	
Voutsinas and MacEwen (1986)	670 (251 males 419 females) 5-20 yoa (Blacks and Whites)	Retrospective lateral spinal radiographs of healthy participants; Modified Cobb method	T2-T12	(Mean) Males 5-9: 35.8° 10-14: 37.6° 15-20: 39.4°	(Mean) Females 5-9: 37.4° 10-14: 37.5° 15-20: 37.9°
Singer et al. (1994)	22 (8 males, 14 females) 50-90 yoa	Modified Cobb method; Lateral chest radiographs (*in vivo*); Lateral spine radiographs of cadaveric specimens (*in vitro*)	N/A	(Mean) 49.4° (*in vivo*) , (Mean) 48.1° (*in vitro*) Combined results	
Jackson and McManus (1994)	100 (50 males, 50 females) 20-65 yoa	Modified Cobb method; Lateral radiograph of asymptomatic participants	T1-T12	(Mean) 42.1° Combined results	
Gelb et al. (1995)	100 (46 males 54 females)	Lateral spinal radiographs of asymptomatic participants;	T5-T12	(Mean ± SD) 34°±11° Combined results	

	57 years (mean) (race unknown)	Modified Cobb method		
Kolessar et al. (1996)	43 (20 males, 23 females) 10-17 yoa	Modified Cobb method; Retrospective radiographs	T5-T12	(Mean) 32°
Korovessis et al. (1999)	120 (Greek) 20-79 yoa	Modified Cobb method; Lateral radiograph of asymptomatic participants	T4-T12	(Mean ± SD) 42°±13° Combined results
Tuzun et al. (1999)	50 20-63 yoa	Modified Cobb method; Lateral radiograph of LBP patients	T1-T12	(Mean ± SD) 28°±10.7° Combined results
Jackson et al. (2000)	20 26-75 yoa	Modified Cobb method; Lateral radiographs of asymptomatic participants	T1-T12	(Mean ± SD) 45°±11.2°
Goh et al. (2000)	93	Modified Cobb method; CT and lateral radiographs	T4-T9	not reported
Harrison et al. (2001)	30 Sex not specified	Modified Cobb method; Retrospective lateral radiographs	T1-T12 T2-T11 T3-T11	45.6° mean 39.2° mean 32.7° mean
Boyle et al. (2002)	172 113 males (mean age: 48) 59 females (mean age: 54) Race Unknown	Modified Cobb method; Lateral spinal radiographs (Cadaveric specimens)	T1-T12	Males (mean): 18-29: 26.9°; 30-44: 32.9°; 45-59: 41.1°; 60-74: 53.5°; >75: 63.5° Females (mean): 18-29: 25.0°; 30-44: 33.3°; 45-59: 43.4°; 60-74: 51.8°; >75: 68.0°
Vaille et al. (2005)	300 190 males 110 females Mean age 35 Race unknown	Lateral digitized spinal radiographs of asymptomatic participants	T4-T12	(Mean ± SD) males 41.7° ± 10 (Mean ± SD) females 39° ± 10

***N/A Not Available   *yoa years of age   * LBP low back pain   *TK thoracic kyphosis**

When one examines the TK values reported in **Table 2.2**, it is immediately apparent that there is no single accepted mean value for TK. Rather, there appears to be a considerable range in the normal TK values. The discrepancies in the findings of the studies in **Table 2.2** may be attributed to several factors. These include: differences in sample size, age of the participants, and variations in the methods employed to determine the TK. It is imperative that a normative range of the TK be established as this could aid in the diagnosis and correct treatment protocols of postural conditions that occur in the thoracic spine.

The Cobb method was initially utilized to determine the magnitude of scoliosis and monitor its progression on AP radiographs (Cobb, 1948). This method was modified by Fon et al. (1980) to be used on lateral radiographs to assess the magnitude of spinal curvatures. The modified Cobb method is the most utilized method for determining the magnitude of the thoracic curve (Fon et al., 1980; Korovessis et al., 1999; Goh et al., 2000; Vialle et al., 2005) due to its ease of use (Singer et al., 1994; Korovessis et al., 1999; Jackson et al., 2000; Boyle et al., 2002). The modified Cobb method has, however, been criticised for various reasons such as difficulty in determining the cephalad endplate and increase in human error, due to four lines being required (Goh et al., 2000; Harrison et al., 2001). However, these may be overcome by the use of correct radiographic dosages, appropriate measuring tools and verification by more than one examiner to ensure accuracy of the results. Various landmarks were chosen by the different authors to determine the magnitude of the TK **(Table 2.2)**. Some authors were able to visualise the entire thoracic region by means of specialised screens and the concomitant use of copper filtration at the collimator (Harrison et al., 2001). However, other authors were unable to visualise the entire thoracic spine due to the superimposition of the scapula. Therefore, the levels T4-T12 and T5-T12 were selected as landmarks by these authors (Stagnara et al., 1982; Gelb et al., 1995; Kolessar et al., 1996; Korovessis et al., 1999; Vaille et al., 2005) **(Table 2.2)**. It was interesting to observe that although some authors only differed by one vertebral segment, a considerable difference can be observed in the results of the reported TK (Gelb et al., 1995; Kolessar et al., 1996; Korovessis et al., 1999; Vaille et al., 2005). Interestingly, the researchers that utilised similar vertebral levels, T4-T12; (Stagnara et al., 1982; Korovessis et al., 1999; Vaille et al., 2005) and T5-T12 (Gelb et al., 1995; Kolessar et al., 1996) have largely reported similar results despite considerable differences in the ages of the participants and sample sizes. This highlights the importance of selecting a consistent vertebral level for determining the TK when using the modified Cobb method.

A significant difference in the sample sizes of the various studies is apparent. These ranged from 20 to 670 as shown in **Table 2.2**. The age of the participants and the cadaveric specimens varied considerably; this ranged from two to 79 years of age. Various race groups and nationalities were also studied. These included: Black, White, French and Greek participants. This might have contributed to the discrepancy in the observed results. However, due to the large discrepancies in sample size and different methodologies a fair comparison of the TK values cannot be made between the studies.

Several studies shown in **Table 2.2** compared the differences of TK between sexes. It was observed that there were small differences in the TK between males and females. However, it is difficult to ascertain if there is a precise difference between the TK of males and females due to the unequal number of male and female participants that were utilised (Fon et al., 1980; Voutsinas and MacEwen, 1986; Boyle et al., 2002; Vaille et al., 2005).

Most authors utilised lateral radiographs of asymptomatic participants to determine the TK **(Table 2.2)**. Other authors chose to utilise cadaveric specimens, which would have included removal of all supporting structures such as the soft tissues (including muscles). This approach to determine the TK might also explain the differences in the results between the studies of those that employed plain-film radiographs and those that utilised cadaveric specimens.

Upon close examination of the results shown in **Table 2.2**, it is clearly evident that a single reference value of the TK cannot be applied to every population group. It is important to note that this range in TK is widely influenced by the various methodologies employed and also by factors such as sample size, age, and characteristics of the participants.

2.4.2.1 Factors that may influence the thoracic kyphosis

The TK is significantly influenced by the IVDs and the VBs particularly the anterior aspect (Itoi; 1991; Singer et al., 1994; Goh et al., 2000). The vertebrae of the thoracic spine demonstrate an asymmetrical shape; the AVBH is generally reduced in comparison to the PVBH. This asymmetry contributes to the anterior concavity of the thoracic curve (Tan et al., 2004; Bartynski et al., 2005). A significant correlation (p = 0.006) (r-value was not provided) has been observed between the magnitude of the thoracic curvature and height and weight in 636 asymptomatic growing males between the ages of 12 and 17 years. The TK was measured using a flexible ruler. No significant observation was made (p > 0.01) between the TK and body mass index (BMI) (Tizabi et al., 2012). In contrast, there was no correlation between the magnitude of the TK and the height and weight in patients with Scheuermann's disease and asymptomatic in participants. This finding suggests that the degree of kyphosis is independent of the height and weight of an individual; however, more studies are required to establish this observation. Furthermore, this result also needs to be viewed with caution as the mean age of the participants was 13 years, and full skeletal maturity had not yet been reached (Fotiadis et al., 2008). The centre of gravity usually lies anteriorly to the thoracic curve. As a result, there is an increase of mechanical loading on the anterior aspect of the thoracic VBs, especially at the apex. During the lifespan of an individual this could result in progression of the kyphotic deformity. This is often accentuated in osteoporotic patients (Goh et al., 1999).

Many conditions could alter the thoracic curvature such as an increase in age, osteoporosis, postural deformities, muscular disorders, cystic fibrosis and traumatic injury (Fon et al., 1980; Edmondston and Singer, 1997; Yochum and Rowe, 2005; Parizel et al., 2010). A study by Manns et al. (1996) reported that the TK is considerably reliant on the anterior wedging of the VBs in the thoracic spine and that laxity in the muscles and ligaments caused by advancing age will cause the TK to increase. According to Harrison et al. (2005), an increase in IVD loads and stresses may also contribute to the progression of the thoracic spine deformity.

2.4.3 Vertebral Body Height

The AVBH and the PVBH have been described as the distance between the superior and inferior aspect of the VB anteriorly and posteriorly respectively (Masharawi et al., 2008). The VBH plays a significant role in the normal spinal curvature and contributes to the TK of the spine (Manns et al., 1996; Goh et al., 1999). The greatest amount of anterior vertebral wedging is found at the apex of the thoracic curve which lies in the mid-thoracic region. A more significant correlation is found in females between the VBH and TK (Goh et al., 1999). A summary of the reported values of the AVBH and PVBH is shown in **Tables 2.3** and **2.4**.

Table 2.3 A summary of the reported thoracic anterior vertebral body height values

Reference	Sample	Method	AVBH	
Scoles et al. (1988)	50 Cadaveric specimens: (19 Black males 6 Caucasian males 16 Black females 9 Caucasian females) 20-40 yoa	Callipers	Males (mean): T1: 16.8 T3: 18.6 T6: 19.8 T9: 21.8 T12: 25.9 (races combined)	Females (mean): T1: 15.7 T3: 17.6 T6: 18.8 T9: 20.5 T12: 24.6 (races combined)
Harrison et al. (2003)	50 healthy participants Mean age: 28 years (sex and race unknown)	Retrospective lateral full spinal radiographs	Sex unspecified (mean): T1:17.1 T2: 18.2 T3: 18.3 T4: 19.1 T5: 19.2 T6: 19.1 T7: 19.1 T8: 19.6 T9: 20.7 T10: 22.6 T11: 23.7 T12: 25.4	
Tan et al. (2004)	10 Cadavers (Chinese Singaporean) 56-77 yoa (sex unknown)	Digitised co-ordinate system	Sex unspecified (mean): T1: 12.8 T2: 14.2 T3: 14.5 T4: 15.8 T5: 15.2 T6: 15.5	

			T7: 15.1 T8: 16.1 T9: 16.5 T10: 17.5 T11: 17.5 T12: 18.7	
Masharawi et al. (2008)	240 specimens: (60 Caucasian males 60 Caucasian females 60 African-American males 60 African-American females) 20-80 yoa	3D Digitiser	Males (mean ± SD) T1: 16.8 ± 1.8 Progressively increased (T2-T12 not reported) Race unspecified	Females (mean ± SD) T1: 15.1 ± 1.3 Progressively increased (T2-T12 not reported) Race unspecified
Singh et al. (2011)	100 vertebral specimens (Indian) (81 males 19 females) 22-70 yoa	Digital vernier callipers	Males (mean ± SD) T1: 15.1 ± 1.2 T2: 16.5 ± 1.6 T3:16.9 ± 1.4 T4: 17.3 ± 1.2 T5: 17.2 ± 1.3 T6: 17.9 ± 1.3 T7: 18.1 ± 1.4 T8: 19.1 ± 1.4 T9: 20.0 ± 1.5 T10: 20.5 ± 1.4 T11: 21.3 ± 1.8 T12: 22.3 ± 1.9	Females (mean ± SD) T1: 14.1 ± 1.4 T2: 15.3 ± 1.0 T3: 16.0 ± 0.8 T4: 16.5 ± 0.8 T5: 16.4 ± 1.0 T6: 17.0 ± 1.0 T7: 16.9 ± 0.9 T8:18.5 ± 1.0 T9: 19.4 ± 1.4 T10: 19.8 ± 1.4 T11: 21.0 ± 1.5 T12: 21.8 ± 1.6

*** AVBH values are given in mm   *yoa years of age**

Table 2.4 A summary of the reported thoracic posterior vertebral body height values

Reference	Sample	Method	PVBH
Panjabi et al. (1991)	12 whole spine specimens; 8 males 4 females 19-59 yoa (race unknown)	Lateral radiographs (whole spine) 3D Morphometer	Sex unspecified (mean) T1: 14.1 T2: 15.6 T3: 15.7 T4: 16.2 T5: 16.2 T6: 17.4 T7: 18.2 T8: 18.7

			T9: 19.3 T10: 20.2 T11: 21.3 T12: 22.7	
Harrison et al. (2003)	50 Healthy participants Mean age: 28 years (sex and race unknown)	Retrospective lateral full spinal radiographs	Sex unspecified (mean) T1: 17.5 T2: 18.2 T3: 19.2 T4: 20.0 T5: 20.6 T6: 20.8 T7: 21.5 T8: 21.9 T9: 22.5 T10: 24.0 T11: 26.4 T12: 28.1	
Tan et al. (2004)	10 Cadavers Chinese Singaporean 56-77 yoa (sex unknown)	Digitized co-ordinate system	Sex unspecified (mean) T1: 14.0 T2: 15.2 T3: 15.3 T4: 15.8 T5: 16.4 T6: 17.0 T7: 17.4 T8: 17.8 T9: 18.0 T10: 19.1 T11: 20.4 T12: 21.5	
Masharawi et al. (2008)	240 specimens (60 Caucasian males 60 Caucasian females 60 African American males 60 African American females) 20-80 yoa	3D Digitizer	Males (mean ± SD) T1: 19.5 ± 2.6 Progressively increased (T2-T12 not reported) Race unspecified	Females (mean ± SD) T1: 16.7 ± 1.5 Progressively increased (T2-T12 not reported) Race unspecified
Singh et al. (2011)	100 vertebral specimens (Indian) 81 males 19 females 22-70 yoa	Digital vernier callipers	Males (mean ± SD) T1: 16.1 ± 1.4 T2: 17.0 ± 1.5 T3: 17.3 ± 1.4 T4: 17.7 ± 1.3 T5: 18.4 ± 1.4 T6: 19.0 ± 1.3	Females (mean ± SD) T1: 14.6 ± 1.4 T2: 15.5 ± 1.1 T3: 16.3 ± 1.1 T4: 16.6 ± 1.0 T5: 17.6 ± 0.8 T6: 18.2 ± 0.9

	T7: 19.5 ± 1.3	T7: 18.4 ± 0.7
	T8: 20.0 ± 1.5	T8:18.8 ± 0.9
	T9: 20.6 ± 1.8	T9: 19.5 ± 1.1
	T10: 21.3 ± 1.7	T10: 20.2 ± 1.3
	T11: 36.3 ± 2.6	T11: 32.4 ± 3.0
	T12: 29.9 ± 5.0	T12: 29.4 ± 4.7

***PVBH values are given in mm *yoa years of age**

On close examination of the results of the studies shown in **Tables 2.3** and **2.4**, the trend in the VBH shows that the AVBH and PVBH progressively increase from the cephalic to the caudal levels of the thoracic spine. All the studies shown in **Table 2.3** and **Table 2.4** utilised a version of a digitised system to establish the AVBH and PVBH, with the exception of Scoles et al. (1988), who utilised callipers. A consistent trend has been observed between the AVBH and the PVBH; the AVBH is smaller than the PVBH at all levels **(Tables 2.3** and **2.4)**. This is as a result of the wedging that occurs on the anterior aspect of the VB which contributes to the TK and its anterior concavity (Manns et al., 1996; Goh et al., 1999).

The sample sizes and race of the participants and cadaveric specimens also varied considerably between the studies. This resulted in a significant range of normative values of the AVBH and PVBH. This observation supports the view that the AVBH and PVBH should be determined for races from different geographic locations. Interestingly, none of the studies in **Tables 2.3** and **2.4** reported on the height of the participants or the length of the cadaveric specimens and their correlation with the VB heights despite the report of Manns et al. (1996) who found a significant correlation between the height of an individual and the VBH.

Many of the studies combined or failed to report on the sex of their participants. A relatively small difference has been observed in the AVBH and PVBH between males and females. Panjabi et al. (1991) and Singh et al. (2011) assessed the AVBH and PVBH in both sexes, but the number of males and females in the studies were incongruent. Therefore, studies with larger sample sizes, with an equal number of males and females are needed to determine whether a significant difference exists between the sexes. In cadaveric studies, removal of the soft tissue, especially the endplates would significantly influence the results of the AVBH and PVBH. When examining the results of studies that utilised plain-film radiography, one has to take into consideration radiographic magnification (Blackley et al., 1999; Yue et al., 2001) and difficulty in establishing the endplates.

2.4.3.1 Factors that influence vertebral body height

Changes in the degree of wedging in the AVBH commonly occur in the mid-thoracic region with the common segments being T5-T8. This is not surprising as this region is the apex of the thoracic curve which is exposed to greater compressive loads (Goh et al., 1999; Goh et al., 2000; Masharawi et al., 2008). These changes commonly occur in the forth to fifth decades and occur more frequently in females than males. Anterior vertebral wedging occurs most frequently at the mid-thoracic region and is three times more common in White females due to their predisposition to decreased bone mineral density (osteoporosis). Osteoporosis and an increase in rotational forces occur more frequently in the lower thoracic spine which increases the susceptibility of the VBs to deformation (Goh et al., 1999; Goh et al., 2000).

A significant correlation has been observed between the height and weight ($p < 0.001$ and $p < 0.03$ respectively) of an individual and the height of the VB (Manns et al., 1996). As the spine ages, a natural decrease in the VBH will occur; which contributes to an overall decrease in the height of the individual (Manns et al., 1996). The transverse trabeculae of the VB become more thinned and perforated while the vertical trabeculae remain unchanged. This deterioration of the vertebral trabeculae makes it more unstable and more susceptible to buckling which lead to anterior wedge fractures (Snyder et al., 1993). In injuries such as a wedge compression, concave and crush fractures may decrease the anterior or posterior height of a vertebral segment (Parizel et al., 2010). The loss of VBH aids in the classification of vertebral fracture viz. Grade One: VBH is less than 75% of the normal height; Grade Two: VBH is between 50% and 75% of the normal height and Grade Three: VBH is less than 50% of the normal height (Parizel et al., 2010). The importance of the VBH and its relationship to the TK highlights its significance to spinal surgeons and chiropractors; especially if the surgical or conservative management is directed at normalising the TK.

2.4.4 Intervertebral Disc Height

The IVDH has been described as the distance between the adjacent endplates at the midpoint between the anterior and posterior body margins (Hurxthal et al., 1968; Yochum and Rowe; 2005). The IVDH is reported to play a significant role in the magnitude of the TK (Manns et al., 1996; Goh et al., 1999). A summary of the reported anterior and posterior IVDH is shown in **Table 2.5**.

Table 2.5 A summary of the reported thoracic intervertebral disc height values

Harrison et al. (2003)				
IVD Level	**Sample Size**	**Method**	**Anterior Height (mm)**	**Posterior Height (mm)**
T1-T2	50 healthy participants	Retrospective full lateral	3.7	3.5
T2-T3	Mean age: 28 years	spinal radiographs	3.8	3.3
T3-T4	(race and sex unknown)		3.6	2.6
T4-T5			3.8	2.9
T5-T6			3.9	2.8
T6-T7			4.3	3.3
T7-T8			4.3	3.9
T8-T9			4.4	4.2
T9-T10			4.4	4.5
T10-T11			4.9	5.5
T11-T12			5.2	6.6

Although many authors have discussed the importance and the relevance of the height of the IVD (Goh et al., 1999; Goh et al., 2000; Harrison et al., 2003; Masharawi et al., 2008), to date only Harrison and colleagues (2003) have reported the actual dimensions **(Table 2.5.)** An interesting observation is that the anterior IVDH is greater than the posterior IVDH, contrary to the assumption that the anterior IVDH would be slightly smaller than the posterior IVDH if one had to follow the trend of the VBs. The mid-IVDH has, however, not yet been reported in literature despite the method being described by Hurxthal and colleagues in 1968. According to the researcher's knowledge, this study would be the first to report on the mid-thoracic IVDH determined through a radiographic assessment.

2.4.4.1 Factors that influence the intervertebral disc height

The IVDs of the thoracic spine undergo the greatest change at the mid-thoracic level, and usually follow the trend of the VBs (Goh et al., 1999; Goh et al., 2000). According to Manns et al. (1996) and Goh et al. (1999), males have a higher prevalence of IVD degeneration especially after the age of 65 years. This may be attributed to an increase in micro-trauma which results in tears in the annulus fibrosis (Goh et al., 1999). The mid-thoracic spine also has the greatest rotational force; this predisposes this region to degenerative IVD disease which results in a decreased height. A loss of proteoglycans within the IVDs results in a subsequent loss of hydration and a decreased IVDH. This form of IVD degeneration is considered part of the normal aging process (Urban and Roberts, 2003). Smoking is another factor that has been shown to result in decreased oxygen supply to the IVDs and an increased degradation of the collagen components which results in degeneration of the IVDs, and eventual loss of IVDH (Abate et al., 2013).

2.4.5 Interpedicular Distance

The IPD is defined as the shortest distance between the inner convex cortical surfaces of the opposing segmental pedicles (Hinck et al., 1966; Yochum and Rowe, 2005). It is a dependable indicator of the size of the spinal canal as it assesses the transverse diameter of the spinal canal (Tacar et al., 2003; Nirvan et al., 2005). The largest dimensions of the canal are found at vertebral levels C3-T1 and L1-S3 to accommodate the enlargement of the spinal cord at these levels (Crossman and Neary, 2005). According to Panjabi et al. (1991) and Tacar et al. (2003) the narrowest dimensions of the IPD are usually observed at T4-T9, which also results in the least amount of blood flow to this region. This makes it more susceptible to spinal cord impingement. A summary of the reported IPD is presented in **Table 2.6**.

Table 2.6 A summary of the reported thoracic interpedicular distance values

Reference	Sample	Method	IPD	
Scoles et al. (1988)	Cadaveric specimens: 19 Black males 6 Caucasian males 16 Black females 9 Caucasian females 20-40 yoa	Callipers	Males (mean) T1: 21.2 T3: 17.4 T6:16.5 T9: 16.8 T12: 19.9 (races combined)	Females (mean) T1: 20.5 T3: 16.6 T6: 15.5 T9: 15.9 T12: 19.4 (races combined)
Panjabi et al. (1991)	12 whole spine specimens 8 males 4 females 19-59 yoa (Race unspecified)	AP Radiographs 3D Digitizer	Sex unspecified (mean) T1: 21.8 T2: 19.5 T3: 18.3 T4: 17.0 T5: 17.1 T6: 17.3 T7: 17.3 T8: 17.7 T9: 17.9 T10: 18.2 T11: 19.4 T12: 22.2	

Ebraheim et al. (1997)	15 Cadaveric specimens: (Caucasian) 6 males 9 females 42-75 yoa	Calliper and standard ruler	Sex unspecified (mean) T1: 13.8 T2: 14.4 T3: 14.5 T4: 13.9 T5: 13.9 T6: 14.4 T7: 14.6 T8: 14.9 T9: 15.5 T10: 15.5 T11: 16.1 T12: 16.6	
Ugur et al. (2001)	20 Cadaveric specimens: 14 males 6 females 24-72 yoa (race unknown)	Manual calibration	Males (mean) T1: 19.3 T2: 17.4 T3: 15.9 T4: 14.0 T5: 13.1 T6: 13.1 T7: 13.1 T8: 14.1 T9: 15.2 T10: 16.4 T11: 18.0 T12: 19.5	Females (mean) T1: 18.8 T2: 16.3 T3: 14.7 T4: 13.7 T5: 12.9 T6: 13.1 T7: 13.5 T8: 14.0 T9: 14.8 T10: 16.1 T11: 17.6 T12:19.2
Chaynes et al. (2001)	10 Cadaveric specimens (sex and race unknown)	Electronic digital calliper	Sex unspecified (mean) T1: 17.4 T2: 19.3 T3: 21.2 T4: 21.8 T5: 22.8 T6: 22.9 T7: 24.5 T8: 24.9 T9: 26.1 T10: 27.8 T11: 30.7	
Datir and Mitra (2004)	18 Indian male cadaveric specimens 30-74 yoa	AP radiographs; vernier callipers	Males (mean) T1: 21.3 T2: 22.3 T3: 22.7 T4: 23.0 T5: 23.5 T6: 23.7 T7: 24.9	

			T8: 25.7 T9: 26.8 T10: 28.1 T11: 29.0	
Tan et al. (2004)	10 Cadaveric specimens of Chinese Singaporeans 56-77 yoa	Digitized co-ordinate system	Sex unspecified (mean) T1: 17.7 T2: 15.2 T3: 14.2 T4: 13.5 T5: 13.6 T6: 13.8 T7: 13.9 T8: 14.1 T9: 14.2 T10: 14.2 T11: 15.3 T12: 17.9	
Singh et al. (2011)	100 vertebral specimens (Indian) 81 males 19 females (22-70 yoa)	Digital vernier callipers	Male (mean) T1: 19.8 T2: 17.1 T3: 16.2 T4: 15.8 T5: 15.4 T6: 15.5 T7: 15.7 T8: 15.8 T9: 15.9 T10: 15.9 T11: 16.9 T12: 18.6	Female (mean) T1: 19.7 T2: 17.1 T3: 16.3 T4: 15.9 T5: 15.8 T6: 15.8 T7: 15.7 T8: 16.2 T9: 16.2 T10: 16.4 T11: 17.4 T12: 19.5

***IPD values are given in millimetres (mm)   * yoa years of age**

The results of the studies reporting the IPD **(Table 2.6)** show that generally the IPD is widest in the upper thoracic spine, narrowing in the mid-thoracic region and then commencing to progressively increase at the caudal levels. Surprisingly, a different trend was observed by Chaynes et al. (2001) and Datir and Mitra (2004) who reported the IPD progressively increasing from superior to inferior and no narrowing in the mid-thoracic region. This conflicting trend may be attributed to the small sample size and the characteristics of the participants.

The sample sizes varied significantly between all the studies. Most studies did not use large enough sample sizes to establish valid normative reference values for the IPD. Several authors reported on the race of their participants and cadaveric specimens (Scoles et al., 1988;

Ebraheim et al., 1997; Datir and Mitra, 2004; Tan et al., 2004; Singh et al., 2011). In the studies where the IPD data of the different races were combined, or where the races were not specified, it made it impossible to establish if there were significant differences in IPD between races **(Table 2.6)**.

Comparisons of the IPD have been made between males and females **(Table 2.6)**. The males had a slightly wider IPD at the majority of the thoracic vertebral levels compared to females. An exception to this observation was the IPD between the Indian males and females (Singh et al., 2011; **Table 2.6**). This may be attributed to the unequal number of males and females in this study (Singh et al., 2011). These differences in the IPD between males and females may (with the possible exception of Indian females) indicate that females might be more susceptible to thoracic spinal stenosis. The findings of Singh et al. (2011) suggest that in Indian females larger IPD at most thoracic vertebral levels may be the norm rather than an exception.

Many of the studies presented in **Table 2.6** utilised cadaveric specimens, and digital callipers or a digitized system to determine the IPD. An advantage of this approach would be the removal of all soft tissue as this allows for a more accurate measurement of the IPD (Tan et al., 2004; Singh et al., 2011). It is important for authors that conduct cadaveric studies to also measure the sagittal canal diameter; as this is also implicated in spinal canal stenosis. It is observed that the interpedicular distances obtained through radiographic assessments were generally larger than the values obtained from cadaveric specimens. This may be attributed to factors such as radiographic magnification (Blackley et al., 1999; Yue et al., 2001) and removal of the soft tissue (Tan et al., 2004; Singh et al., 2011).

2.4.5.1 Factors affecting the interpedicular distance

Despite the numerous conditions (congenital and acquired) that can cause narrowing of the spinal canal which would result in a decreased IPD, spinal stenosis is quite rare in the thoracic spine compared to the cervical and lumbar regions (Palumbo et al., 2001). Common conditions and disorders known to cause narrowing include: aging and degeneration, hypertrophy of osseous structures, ossification of spinal ligaments, Paget's disease (which results in expansion of the VB and neural arch) and achondroplasia due to the thickening and shortening of the pedicles (Lee et al., 1995; Palumbo et al., 2001; Yochum and Rowe, 2005). Traumatic injury and disorders such as Marfan's syndrome may cause widening of the spinal canal leading to an increase in the IPD (El-Khoury and Whitten, 2003; Yochum and Rowe, 2005). Tumours such as neurofibromas, osteoblastoma and lytic metastases may also cause destruction of the pedicles with a resulting increase in the IPD (Yochum and Rowe, 2005).

The IPD is an important tool which is often utilised to diagnose spinal stenosis or spinal dilation (Palumbo et al., 2001; Nirvan et al., 2005). It is also especially important to surgeons performing transpedicular fixation in the thoracic spine to help provide stabilisation and minimise risk of injury to the spinal cord and nerve roots (Ebraheim et al., 1997; Ugur et al., 2001; Datir and Mitra, 2004).

2.5 CONCLUSION

The thoracic region is one of the most disregarded regions of the spine with previous studies focussing mainly on the cervical and lumbar spinal regions resulting in limited data being available on the thoracic spine (Edmondston and Singer, 1997; Goh et al., 2000; Harrison, 2009). On close appraisal of the literature, it is clearly apparent that a single reference value cannot be applied to any of the parameters (TK, AVBH, PVBH, IVDH and IPD) that were assessed. This is mainly attributed to the differences in sample sizes and characteristics such as race, age of the participants, use of cadaveric specimens and differences in the methods utilised to determine the various radiographic parameters. Finally, there is no current literature that provides the normative reference values of the selected radiographic parameters in the South African context.

CHAPTER THREE

MATERIALS AND METHODS

3.1 STUDY DESIGN

This research was designed as a quantitative, descriptive, non-interventional study. Approval to conduct the study was obtained from the Durban University of Technology's Faculty of Health Sciences Research Committee and the Institutional Research Ethics Committee **[Ethics Clearance Certificate No.: 038/12 (Appendix A)].**

3.2 RECRUITMENT

Potential participants were recruited through the use of pamphlets and advertisements **(Appendix B).** Permission was obtained from the relevant authorities of the libraries and surrounding shopping malls before any pamphlets were put up.

3.3 SAMPLE SIZE AND SAMPLING METHOD

The sample size for this study constituted 80 participants who were recruited through purposive sampling (Tongco, 2007). The participants were divided into four groups of 20 from each of the four main racial groups in the greater Durban area viz. Black, White, Indian and Coloured. All participants were between the ages of 18-45 years, in keeping with the inclusion criteria of the study. Financial, time and human resources were the main constraints in determining the final sample size. The sample size was greater than some of the previous studies (Singer et al., 1994; Kolessar et al., 1996; Mac-Thiong et al., 2007), but less than those of others (Fon et al., 1980; Goh et al., 2000).

3.4 INCLUSION AND EXCLUSION CRITERIA

3.4.1 Inclusion Criteria

- Participants of the study had to be between the ages of 18-45 years. The South African Medical Research Council recommends that participants under the age of 18 years should not be used in research studies (Medical Research Council Guidelines on Ethics for Medical Research, 2002). Participants over the age of 45 were excluded from the study as the degeneration process likely commences in the fifth decade (Friedenberg and Miller 2010). The average age of the commencement of degeneration in the thoracic spine is reported to be 48 years (Mitra et al., 1996).

- Participants had to be of the male sex. This was done to ensure sample homogeneity in terms of sex and in keeping with the aim of the study.
- All participants had to be asymptomatic (i.e. present with no mid-back pain or any other current medical complaints). This was determined by the outcome of their case history, physical and thoracic orthopaedic examination findings.
- The research participants had to be of the Black, White, and Indian or Coloured racial groups. For the purpose of this study the Coloured racial group was defined as individuals of mixed White and Black ethnic descent (Oxford Dictionaries, 2011)
- The participant had to have had a height of between 1.65m-1.8m, and a weight of between 70-90kg. This was done to ensure sample homogeneity in terms of height and weight.

3.4.2 Exclusion Criteria

- Participants that had radiographs of the mid-back region in the three months prior to participating in this study. This was to reduce the radiation exposure to the participants.
- Any mid-back injuries sustained by the participant between the initial consultation and the radiographic appointment.
- Any trauma such as fractures, injury or surgery to the mid-back region of the participant
- Any participant with a history of malignancy (e.g. prostate Ca) or inflammatory arthritide (e.g. rheumatoid arthritis) was excluded.
- Participants who had a thoracic scoliosis (i.e. a curve greater than 10˚ (Scoliosis Research Society, 2012)) or congenital anomalies in the thoracic spine region (e.g. hemivertebra).

3.5 RESEARCH PROCEDURE

3.5.1 Initial Telephonic Screening Questions

The questions presented in **Table 3.1** were utilised as a screening tool to ensure that the participants met the requirements for this study. Any participant that did not meet these criteria was not permitted to enrol in this study, as these could have potentially influenced the results.

If the participants answered “Yes” to Questions 1-3 and “No” to Questions 4-6, they were asked to present at the Chiropractic Day Clinic (CDC) for the initial consultation.

Table 3.1 Initial telephonic screening questions

Questions	Expected response	
	Yes	**No**
1. Are you between the ages 18-45 years?	✓	
2. Are you between 1.65m-1.8 m tall?	✓	
3. Do you weigh between 70-90 kg?	✓	
4. Do you have any midback pain?		✓
5. Have you been for any x-rays in the last three months?		✓
6. Have you had any surgery or injury to your midback?		✓

3.5.2 Phase One

Upon arrival at the CDC, the participant was given a combined letter of information and informed consent **(Appendix C)**, as well a verbal explanation of the study by the researcher. Thereafter, a complete case history **(Appendix D)**, physical examination **(Appendix E)**, and orthopaedic examination of the thoracic spine **(Appendix F)** was conducted. A data collection sheet **(Appendix G)** was used to record study-specific data e.g. race, age, height and weight. An appointment was then scheduled for the thoracic spine radiographs, which were taken at the Radiography Clinic (RC).

3.5.3 Phase Two

On the appointed date the participants then proceeded to the RC, on condition that they did not complain of mid-back pain or had not sustained any injury to the mid-back region. There was a minimum of one day and a maximum of seven days between the clinical assessment and the appointment at the RC. Upon arrival at the RC, the participant was asked to change into a gown and gonad protection (lead shield) was provided to the participant. The researcher explained the procedure to the participant and then proceeded to take the radiographs. The protocol of the RC was adhered to by the researcher and a qualified radiographer was present at all times to supervise the researcher. An erect AP and lateral (participants arms flexed to level above the head) radiograph of the thoracic spine were taken. For the AP erect radiograph, the participant stood bare-foot on a flat surface with the feet together and hands on the side. For the lateral radiographs, the participant stood bare-foot on the flat surface with the feet and legs together and the arms flexed above his head which is in keeping with the methods described by Yochum and Rowe (2005). An 18 x 43 cm plain-film was used for the AP radiograph and a 30 x 40 cm plain-film was used for the lateral radiograph. The recommended dosages for the AP and lateral radiographs were 77kV, 32mAS and 80kV, 63mAS respectively as per the Radiography Clinic's protocol (Moonsamy, 2011). All participants' identities were protected as identity codes were assigned to each individual participant. Once the radiographs were completed, the participants were told to get dressed and this concluded their participation in the study.

3.5.4 Phase Three

The ABCS method of evaluating a spinal radiograph was utilised to assess the thoracic spine radiographs. The specific radiographic parameters viz. the TK, IPD, AVBH, PVBH and IDH were assessed according to the methods described in **Table 3.2**.

Table 3.2 Methods for evaluating the specific radiographic parameters of the thoracic spine

Parameter	Description	Reference
Thoracic kyphosis	The anterior-concave curve was evaluated by a line drawn parallel to and through the superior endplate of the fifth thoracic vertebral body. A similar line was drawn through the inferior endplate of the 12th thoracic vertebral body. Perpendicular lines were then constructed and the angle was measured.	Gelb et al. (1995); Yochum and Rowe (2005)
Interpedicular distance	The shortest distance between the inner convex cortical surfaces of the opposing segmental pedicles.	Hinck et al. (1966); Yochum and Rowe (2005)
Anterior vertebral body height	The distance between the central borders of the anterior aspect of the superior and inferior vertebral body.	Masharawi et al. (2008)
Posterior vertebral body height	The distance between the central borders of the posterior aspect of the superior and inferior vertebral body.	Masharawi et al. (2008)
Intervertebral disc height	The distance between the opposing endplates at the midpoint between the anterior and posterior vertebral body margins were measured.	Hurxthal (1968); Yochum and Rowe (2005)

The same instruments were utilised throughout the study to ensure consistency and accuracy of the results. All measurements were checked twice by the researcher and verified by the supervisor to ensure no error had been made.

3.5.5 Instruments and tools utilised in this study

The instruments and tools utilised in this study included the following:

- An x-ray viewing box with adequate lighting. (The same viewing box was used throughout the research process to eliminate variations in lighting).
- A thin marker to draw the lines and mark the angles.
- A 30 cm ruler to draw straight lines.
- A protractor to measure angles.
- A T-square to ensure that the film was parallel to the horizontal plane.
- A divider to ensure accurate marking of two points.

3.6 STATISTICAL ANALYSIS

The IBM Statistical Package for the Social Sciences (SPSS) version 20 was utilised for the data analysis. Mean, standard deviation (SD) and range are reported for the TK, AVBH, PVBH and IPD for each of the four racial groups. ANOVA testing with Bonferroni *post-hoc* tests were used to determine overall inter-group variations and compare each group to the other. A p value of < 0.05 was considered as statistically significant. Pearson's correlation test was used to determine the relationship between the TK and the AVBH and IVDH as well as the height and weight of the participants. Non-parametric statistics was used to summarise the IVDH as these values were not normally distributed. The Kruskal-Wallis test was used to determine the significant variances in the IVDH (Esterhuizen, 2012).

3.7 ETHICAL CONSIDERATIONS

Gonad protection (lead shield) was used as a safety precaution to minimise exposure of the gonadal region to the dose of radiation. The correct exposure factors were utilised and only the area of interest was collimated. The participants of this study were exposed to a short radiation, which minimised the adverse effects of radiation (Ritenour, 1986; Wall et al., 2006). All safety protocols of the RC were adhered to, to minimise the radiation dosage to the participants and the researcher (Moonsamy, 2011). Confidentiality of all the participants was maintained by use of a code system to protect their identity; which is only known to the researcher and the supervisor.

CHAPTER FOUR

RESULTS

4.1 AGE AND SELECTED ANTHROPOMETRIC CHARACTERISTICS OF THE PARTICIPANTS

There were a total of 80 apparently-healthy male participants. The mean age, height, weight and BMI of all the participants are shown in **Table 4.1** by racial group and total. The age of the participants ranged from 18-45 years.

Table 4.1 Mean and SD of the age and selected anthropometric characteristics of the participants

Group		Age (yrs)	Height (m)	Weight (kg)	BMI ($kg.m^{-2}$)
White	Mean	23.2	1.8	78.2	25.0
	n	20	20	20	20
	SD	4.6	0.0	6.9	2.1
Black	Mean	24.8	1.7	72.8	24.7
	n	20	20	20	20
	SD	5.8	0.0	3.1	1.5
Indian	Mean	22.5	1.7	76.3	25.0
	n	20	20	20	20
	SD	3.9	0.0	6.1	2.1
Coloured	Mean	24.9	1.7	77.6	26.0
	n	20	20	20	20
	SD	4.5	0.1	7.7	1.6
Total	Mean	23.9	1.7	76.3	25.2
	n	80	80	80	80
	SD	4.7	0	6.0	1.8

4.2 THE SELECTED RADIOGRAPHIC PARAMETERS

4.2.1 Thoracic Kyphosis

The mean, standard deviation, minimum and maximum values of the TK are shown in **Tables 4.2** and **4.3** respectively. There were no significant differences between the racial groups (**Table 4.4**; *p* = 0.161) even with removal of the outlier values (**Table 4.5**; *p* = 0.065). The values that were considered outliers were 4˚, 7-10˚ and 43˚.

Table 4.2 The mean, SD, and range of the thoracic kyphosis by racial group

Racial Group	*n*	Mean (°)	SD	Minimum	Maximum
White	20	25.2	9.3	8.0	39.0
Black	20	20.1	7.4	4.0	33.0
Indian	20	23.4	8.2	10.0	43.0
Coloured	20	20.1	9.0	7.0	37.0
Total	**80**	**22.2**	**8.5**	**4.0**	**43.0**

Table 4.3 The mean, SD, and range of the thoracic kyphosis by racial group (excluding the outliers)

Racial Group	*n*	Mean (°)	SD	Minimum	Maximum
White	18	27.1	7.6	11.0	39.0
Black	19	21.0	6.6	12.0	33.0
Indian	18	23.0	6.5	12.0	38.0
Coloured	17	22.2	8.0	12.0	37.0
Total	**72**	**23.3**	**7.4**	**11.0**	**39.0**

Table 4.4 The ANOVA test to compare the mean thoracic kyphosis between the racial groups

Thoracic Kyphosis					
	Sum of squares	**df**	**Mean square**	**F**	***p* value**
Between groups	382.8	3	127.6	1.8	0.161
Within groups	5501.4	76	72.4		
Total	**5884.2**	**79**			

Table 4.5 The ANOVA test (excluding the outlier values) to compare the mean thoracic kyphosis between the racial groups

Thoracic Kyphosis					
	Sum of squares	**df**	**Mean square**	**F**	***p* value**
Between groups	387.5	3	129.2	2.5	0.065
Within groups	3485.8	68	51.3		
Total	**3873.3**	**71**			

4.2.2 Anterior Vertebral Body Height

The mean, standard deviation of the AVBH at the respective thoracic vertebral levels is shown in **Table 4.6**. It was observed that the AVBH increased in all the racial groups and overall from T5-T12 **(Table 4.6)**. There were significant differences in the AVBH between the race groups at levels T5-T8 and T11-T12 **(Table 4.7)**. When the Bonferroni *post-hoc* test was done **(Table 4.8)**, the following differences were observed:

- T5 between Whites and Blacks ($p = 0.039$)
- T5 between Whites and Indians ($p = 0.031$)
- T5 between Indians and Coloureds ($p = 0.049$)
- T7 between Whites and Blacks ($p = 0.023$)
- T8 between Whites and Blacks ($p = 0.047$)

Table 4.6 The mean and SD of the anterior vertebral body height of T5-T12 by racial group and overall

Group		**T5**	**T6**	**T7**	**T8**	**T9**	**T10**	**T11**	**T12**
White	Mean	25.6	25.9	26.3	26.9	27.7	29.0	30.6	32.5
	n	20	20	20	20	20	20	20	20
	SD	2.0	2.0	1.6	1.9	1.5	1.6	1.9	2.2
Black	Mean	23.9	24.2	24.7	25.1	26.6	28.3	29.5	31.0
	n	20	20	20	20	20	20	20	20
	SD	1.9	1.9	1.9	2.0	2.0	2.0	2.4	2.7
Indian	Mean	23.9	24.6	25.0	25.5	26.7	28.1	29.2	31.1
	n	20	20	20	20	20	20	20	20
	SD	1.6	1.7	1.7	2.0	2.2	3.0	2.4	2.2
Coloured	Mean	25.5	25.8	26.1	26.5	27.4	29.6	31.0	32.7
	n	20	20	20	20	20	20	20	20
	SD	2.1	2.1	1.8	2.0	1.9	1.9	2.3	2.2

Total	Mean	24.7	25.1	25.5	26.0	27.0	28.8	30.0	31.8
	n	80	80	80	80	80	80	80	80
	SD	2.1	2.0	1.9	2.0	2.0	2.2	2.3	2.4

Table 4.7 ANOVA testing to compare the anterior vertebral body height of T5-T12 between the racial groups

		ANOVA				
		Sum of squares	**df**	**Mean square**	**F**	***p* value**
T5	Between groups	56.238	3	18.746	5.085	0.003
	Within groups	280.150	76	3.686		
	Total	336.388	79			
T6	Between groups	43.050	3	14.350	3.791	0.014
	Within groups	287.700	76	3.786		
	Total	330.750	79			
T7	Between groups	39.338	3	13.113	4.285	0.008
	Within groups	232.550	76	3.060		
	Total	271.888	79			
T8	Between groups	38.900	3	12.967	3.339	0.024
	Within groups	295.100	76	3.883		
	Total	334.000	79			
T9	Between groups	17.837	3	5.946	1.586	0.200
	Within groups	284.850	76	3.748		
	Total	302.688	79			
T10	Between groups	29.700	3	9.900	2.071	0.111
	Within groups	363.300	76	4.780		
	Total	393.000	79			
T11	Between groups	44.550	3	14.850	2.978	0.037
	Within groups	379.000	76	4.987		
	Total	423.550	79			
T12	Between groups	46.837	3	15.612	2.885	0.041
	Within groups	411.350	76	5.413		
	Total	458.188	79			

Table 4.8 Bonferroni adjusted *post-hoc* test to assess inter-group variation of the anterior vertebral body height (T5-T12)

Multiple Comparisons							
Bonferroni							
Dependent variable	(I) Group	(J) Group	Mean difference(I-J)	Std Error	Sig.	95% Confidence level	
						Lower Bound	Upper bound
T5	White	Black	1.700*	.607	.039	.06	3.34
		Indian	1.750*	.607	.031	.11	3.39
		Coloured	.100	.607	1.000	-1.54	1.74
	Black	White	-1.700*	.607	.039	-3.34	-.06
		Indian	.050	.607	1.000	-1.59	1.69
		Coloured	-1.600	.607	.061	-3.24	.04
	Indian	White	-1.750*	.607	.031	-3.39	-.11
		Black	-.050	.607	1.000	-1.69	1.59
		Coloured	-1.650*	.607	.049	-3.29	-.01
	Coloured	White	-.100	.607	1.000	-1.74	1.54
		Black	1.600	.607	.061	-.04	3.24
		Indian	1.650*	.607	.049	.01	3.29
T6	White	Black	1.650	.615	.054	-.02	3.32
		Indian	1.350	.615	.188	-.32	3.02
		Coloured	.100	.615	1.000	-1.57	1.77
	Black	White	-1.650	.615	.054	-3.32	.02
		Indian	-.300	.615	1.000	-1.97	1.37
		Coloured	-1.550	.615	.083	-3.22	.12
	Indian	White	-1.350	.615	.188	-3.02	.32
		Black	.300	.615	1.000	-1.37	1.97
		Coloured	-1.250	.615	.274	-2.92	.42
	Coloured	White	-.100	.615	1.000	-1.77	1.57
		Black	1.550	.615	.083	-.12	3.22
		Indian	1.250	.615	.274	-.42	2.92
T7	White	Black	1.650*	.553	.023	.15	3.15
		Indian	1.350	.553	.102	-.15	2.85
		Coloured	.250	.553	1.000	-1.25	1.75
	Black	White	-1.650*	.553	.023	-3.15	-.15
		Indian	-.300	.553	1.000	-1.80	1.20
		Coloured	-1.400	.553	.081	-2.90	.10
	Indian	White	-1.350	.553	.102	-2.85	.15
		Black	.300	.553	1.000	-1.20	1.80
		Coloured	-1.100	.553	.302	-2.60	.40
	Coloured	White	-.250	.553	1.000	-1.75	1.25
		Black	1.400	.553	.081	-.10	2.90

		Indian	1.100	.553	.302	-.40	2.60
T8	White	Black	1.700*	.623	.047	.01	3.39
		Indian	1.350	.623	.200	-.34	3.04
		Coloured	.350	.623	1.000	-1.34	2.04
	Black	White	-1.700*	.623	.047	-3.39	-.01
		Indian	-.350	.623	1.000	-2.04	1.34
		Coloured	-1.350	.623	.200	-3.04	.34
	Indian	White	-1.350	.623	.200	-3.04	.34
		Black	.350	.623	1.000	-1.34	2.04
		Coloured	-1.000	.623	.676	-2.69	.69
	Coloured	White	-.350	.623	1.000	-2.04	1.34
		Black	1.350	.623	.200	-.34	3.04
		Indian	1.000	.623	.676	-.69	2.69
T11	White	Black	1.100	.706	.741	-.81	3.01
		Indian	1.400	.706	.306	-.51	3.31
		Coloured	-.400	.706	1.000	-2.31	1.51
	Black	White	-1.100	.706	.741	-3.01	.81
		Indian	.300	.706	1.000	-1.61	2.21
		Coloured	-1.500	.706	.221	-3.41	.41
	Indian	White	-1.400	.706	.306	-3.31	.51
		Black	-.300	.706	1.000	-2.21	1.61
		Coloured	-1.800	.706	.077	-3.71	.11
	Coloured	White	.400	.706	1.000	-1.51	2.31
		Black	1.500	.706	.221	-.41	3.41
		Indian	1.800	.706	.077	-.11	3.71
T12	White	Black	1.500	.736	.270	-.49	3.49
		Indian	1.400	.736	.365	-.59	3.39
		Coloured	-.150	.736	1.000	-2.14	1.84
	Black	White	-1.500	.736	.270	-3.49	.49
		Indian	-.100	.736	1.000	-2.09	1.89
		Coloured	-1.650	.736	.167	-3.64	.34
	Indian	White	-1.400	.736	.365	-3.39	.59
		Black	.100	.736	1.000	-1.89	2.09
		Coloured	-1.550	.736	.231	-3.54	.44
	Coloured	White	.150	.736	1.000	-1.84	2.14
		Black	1.650	.736	.167	-.34	3.64
		Indian	1.550	.736	.231	-.44	3.54

*** The mean difference is significant at the 0.05 level**

4.2.3 Posterior Vertebral Body Height

The mean, standard deviation of the PVBH at the respective thoracic vertebral levels is shown in **Table 4.9**. It was observed that the PVBH increased in all the racial groups and overall from T5-T12 **(Table 4.10)**. When the Bonferroni *post-hoc* test was done **(Table 4.11)**, the following differences were observed:

- T7 between Whites and Blacks ($p = 0.005$)
- T7 between Whites and Indians ($p = 0.004$)
- T8 between Whites and Blacks ($p = 0.000$)
- T8 between Whites and Indians ($p = 0.002$)
- T8 between Whites and Coloureds ($p = 0.048$)
- T9 between Whites and Blacks ($p = 0.001$)
- T9 between Whites and Indians ($p = 0.004$)
- T10 between Whites and Blacks ($p = 0.005$)
- T10 between Whites and Indians ($p = 0.013$)
- T11 between Whites and Blacks ($p = 0.001$)
- T12 between Whites and Blacks ($p = 0.027$)

Table 4.9 The mean and SD of the posterior vertebral body height of T5-T12 by racial group and overall

Group		T5	T6	T7	T8	T9	T10	T11	T12
White	Mean	26.6	28.2	29.9	30.5	31.1	32.2	34.0	35.6
	n	20	20	20	20	20	20	20	20
	SD	1.8	1.8	2.7	1.4	1.5	1.6	2.3	2.9
Black	Mean	25.6	26.8	27.5	28.0	28.8	29.9	31.3	33.3
	n	20	20	20	20	20	20	20	20
	SD	2.5	2.4	2.0	1.8	2.0	2.4	2.5	3.0
Indian	Mean	25.7	26.8	27.4	28.4	29.0	30.1	32.2	33.6
	n	20	20	20	20	20	20	20	20
	SD	1.6	1.5	1.3	1.7	1.6	2.2	2.0	2.1
Coloured	Mean	26.7	27.5	28.2	29.0	29.9	31.2	32.6	33.9
	n	20	20	20	20	20	20	20	20
	SD	2.0	2.4	2.4	2.0	2.2	2.0	1.5	1.8
Total	Mean	26.1	27.3	28.2	29.0	29.7	30.8	32.5	34.0
	n	80	80	80	80	80	80	80	80
	SD	2.0	2.0	2.3	2.0	2.0	2.3	2.3	2.7

Table 4.10 ANOVA testing to compare the posterior vertebral body height between the racial groups

		ANOVA				
		Sum of Squares	**df**	**Mean square**	**F**	***p* value**
T5	Between groups	18.250	3	6.083	1.499	0.222
	Within groups	308.500	76	4.059		
	Total	326.750	79			
T6	Between groups	27.700	3	9.233	2.213	0.093
	Within groups	317.100	76	4.172		
	Total	344.800	79			
T7	Between groups	78.538	3	26.179	5.544	0.002
	Within groups	358.850	76	4.722		
	Total	437.388	79			
T8	Between groups	74.138	3	24.713	8.139	0.000
	Within groups	230.750	76	3.036		
	Total	304.888	79			
T9	Between groups	66.500	3	22.167	6.731	0.000
	Within groups	250.300	76	3.293		
	Total	316.800	79			
T10	Between groups	67.538	3	22.513	5.133	0.003
	Within groups	333.350	76	4.386		
	Total	400.888	79			
T11	Between groups	72.838	3	24.279	5.315	0.002
	Within groups	347.150	76	4.568		
	Total	419.987	79			
T12	Between groups	66.250	3	22.083	3.430	0.021
	Within groups	489.300	76	6.438		
	Total	555.550	79			

Table 4.11 Bonferroni adjusted *post-hoc* test to assess inter-group variation of the posterior vertebral body height

			Multiple Comparisons				
Bonferroni Dependent variable	**(I) Group**	**(J) Group**	**Mean difference(I-J)**	**Std Error**	**Sig.**	**95% Confidence level**	
						Lower Bound	Upper bound
T7	White	Black	2.400*	.687	.005	.54	4.26
		Indian	2.450*	.687	.004	.59	4.31
		Coloured	1.700	.687	.094	-.16	3.56

	Black	White	-2.400*	.687	.005	-4.26	-.54
		Indian	.050	.687	1.000	-1.81	1.91
		Coloured	-.700	.687	1.000	-2.56	1.16
	Indian	White	-2.450*	.687	.004	-4.31	-.59
		Black	-.050	.687	1.000	-1.91	1.81
		Coloured	-.750	.687	1.000	-2.61	1.11
	Coloured	White	-1.700	.687	.094	-3.56	.16
		Black	.700	.687	1.000	-1.16	2.56
		Indian	.750	.687	1.000	-1.11	2.61
T8	White	Black	2.550*	.551	.000	1.06	4.04
		Indian	2.100*	.551	.002	.61	3.59
		Coloured	1.500*	.551	.048	.01	2.99
	Black	White	-2.550*	.551	.000	-4.04	-1.06
		Indian	-.450	.551	1.000	-1.94	1.04
		Coloured	-1.050	.551	.363	-2.54	.44
	Indian	White	-2.100*	.551	.002	-3.59	-.61
		Black	.450	.551	1.000	-1.04	1.94
		Coloured	-.600	.551	1.000	-2.09	.89
	Coloured	White	-1.500*	.551	.048	-2.99	-.01
		Black	1.050	.551	.363	-.44	2.54
		Indian	.600	.551	1.000	-.89	2.09
T9	White	Black	2.350*	.574	.001	.80	3.90
		Indian	2.050*	.574	.004	.50	3.60
		Coloured	1.200	.574	.239	-.35	2.75
	Black	White	-2.350*	.574	.001	-3.90	-.80
		Indian	-.300	.574	1.000	-1.85	1.25
		Coloured	-1.150	.574	.292	-2.70	.40
	Indian	White	-2.050*	.574	.004	-3.60	-.50
		Black	.300	.574	1.000	-1.25	1.85
		Coloured	-.850	.574	.856	-2.40	.70
	Coloured	White	-1.200	.574	.239	-2.75	.35
		Black	1.150	.574	.292	-.40	2.70
		Indian	.850	.574	.856	-.70	2.40
T10	White	Black	2.300*	.662	.005	.51	4.09
		Indian	2.100*	.662	.013	.31	3.89
		Coloured	1.050	.662	.702	-.74	2.84
	Black	White	-2.300*	.662	.005	-4.09	-.51
		Indian	-.200	.662	1.000	-1.99	1.59
		Coloured	-1.250	.662	.378	-3.04	.54
	Indian	White	-2.100*	.662	.013	-3.89	-.31
		Black	.200	.662	1.000	-1.59	1.99

		Coloured	-1.050	.662	.702	-2.84	.74
	Coloured	White	-1.050	.662	.702	-2.84	.74
		Black	1.250	.662	.378	-.54	3.04
		Indian	1.050	.662	.702	-.74	2.84
T11	White	Black	2.650*	.676	.001	.82	4.48
		Indian	1.750	.676	.069	-.08	3.58
		Coloured	1.350	.676	.296	-.48	3.18
	Black	White	-2.650*	.676	.001	-4.48	-.82
		Indian	-.900	.676	1.000	-2.73	.93
		Coloured	-1.300	.676	.349	-3.13	.53
	Indian	White	-1.750	.676	.069	-3.58	.08
		Black	.900	.676	1.000	-.93	2.73
		Coloured	-.400	.676	1.000	-2.23	1.43
	Coloured	White	-1.350	.676	.296	-3.18	.48
		Black	1.300	.676	.349	-.53	3.13
		Indian	.400	.676	1.000	-1.43	2.23
T12	White	Black	2.350*	.802	.027	.18	4.52
		Indian	2.050	.802	.076	-.12	4.22
		Coloured	1.700	.802	.224	-.47	3.87
	Black	White	-2.350*	.802	.027	-4.52	-.18
		Indian	-.300	.802	1.000	-2.47	1.87
		Coloured	-.650	.802	1.000	-2.82	1.52
	Indian	White	-2.050	.802	.076	-4.22	.12
		Black	.300	.802	1.000	-1.87	2.47
		Coloured	-.350	.802	1.000	-2.52	1.82
	Coloured	White	-1.700	.802	.224	-3.87	.47
		Black	.650	.802	1.000	-1.52	2.82
		Indian	.350	.802	1.000	-1.82	2.52

*** The mean difference is significant at the 0.05 level.**

4.2.4 Intervertebral Disc Height

Non-parametric statistics were used to summarise this test variable as it was not normally distributed. The median, 25th and 75th percentiles are presented in **Table 4.12**. The IVDH was observed to increase in all four race groups from T5-T12 **(Table 4.12)**. The Kruskal-Wallis test (one-way ANOVA) was used to determine significant variances as shown in **Table 4.13**. Significant differences between the racial groups were observed at the following levels:

- T6 (p = 0.008)
- T7 (p = 0.008)

- T8 (p = 0.007)
- T10 (p = 0.003)
- T11 (p = 0.003)

Table 4.12 Median, 25th and 75th percentiles of the intervertebral disc height from T5-T6 to T12-L1 by racial group and overall

		Report							
Group		**T5-T6**	**T6-T7**	**T7-T8**	**T8-T9**	**T9-T10**	**T10-T11**	**T11-T12**	**T12-L1**
White	Median	3.0	3.0	3.0	4.0	4.5	5.5	7.0	8.0
	Mean	3.0	3.4	3.6	4.0	4.6	5.4	6.9	7.9
	Geometric mean	3.0	3.3	3.5	3.9	4.5	5.2	6.8	7.8
	25th percentile	3.0	3.0	3.0	3.0	4.0	5.0	6.0	7.0
	75th percentile	3.0	4.0	4.0	5.0	6.0	6.0	8.0	9.0
Black	Median	3.0	3.0	3.0	4.0	4.0	5.5	7.0	8.0
	Mean	2.9	3.0	3.4	3.8	4.4	5.6	7.1	8.1
	Geometric mean	2.8	2.9	3.3	3.7	4.3	5.6	7.0	8.0
	25th percentile	2.0	3.0	3.0	3.0	4.0	5.0	7.0	8.0
	75th percentile	3.0	3.0	4.0	4.0	5.0	6.0	8.0	9.0
Indian	Median	3.0	3.0	3.0	4.0	4.0	5.0	6.5	8.0
	Mean	2.9	3.1	3.4	3.8	4.4	5.4	6.6	7.8
	Geometric mean	2.9	3.0	3.4	3.7	4.3	5.2	6.6	7.7
	25th percentile	3.0	3.0	3.0	3.0	4.0	5.0	6.0	7.0
	75th percentile	3.0	3.0	4.0	4.0	5.0	6.0	7.0	9.0
Coloured	Median	3.0	4.0	4.0	4.5	5.0	6.0	8.0	8.0
	Mean	3.2	3.7	4.1	4.6	5.0	6.3	7.7	8.2
	Geometric mean	3.1	3.6	4.0	4.5	4.9	6.3	7.6	8.2
	25th percentile	3.0	3.0	4.0	4.0	4.0	6.0	7.0	8.0
	75th percentile	4.0	4.0	5.0	5.0	6.0	7.0	8.0	9.0
Total	Median	3.0	3.0	3.5	4.0	4.5	6.0	7.0	8.0
	Mean	3.0	3.3	3.6	4.1	4.6	5.7	7.1	8.0
	Geometric mean	2.9	3.2	3.5	4.0	4.5	5.6	7.0	7.9
	25th percentile	3.0	3.0	3.0	3.0	4.0	5.0	6.0	8.0
	75th percentile	3.0	4.0	4.0	5.0	5.0	6.0	8.0	9.0

Table 4.13 Hypothesis test summary

	Null Hypothesis	Test	Sig.	Decision
1	The distribution across categories of group of T5-T6 is the same	Independent-Samples Kruskal-Wallis Test	0.271	Retain the null hypothesis
2	The distribution across categories of group of T6-T7 is the same	Independent-Samples Kruskal-Wallis Test	0.008	Reject the null hypothesis

3	The distribution across categories of group of T7-T8 is the same	Independent-Samples Kruskal-Wallis Test	0.008	Reject the null hypothesis
4	The distribution across categories of group of T8-T9 is the same	Independent-Samples Kruskal-Wallis Test	0.007	Reject the null hypothesis
5	The distribution across categories of group of T9-T10 is the same	Independent-Samples Kruskal-Wallis Test	0.148	Retain the null hypothesis
6	The distribution across categories of group of T10-T11 is the same	Independent-Samples Kruskal-Wallis Test	0.003	Reject the null hypothesis
7	The distribution across categories of group of T11-T12 is the same	Independent-Samples Kruskal-Wallis Test	0.003	Reject the null hypothesis
8	The distribution across categories of group of T12-L1 is the same	Independent-Samples Kruskal-Wallis Test	0.619	Retain the null hypothesis

Asymptotic significances are displayed. The significance level is 0.05

4.2.5 Interpedicular Distance

The mean and SD of the IPD for T1-T12 is shown in **Table 4.14**. The IPD in the Whites decreased from T1-T6, and then increased from T7-T12; in Blacks the IPD decreased from T1-T7 and then increased from T8-T12; in Indians the IPD decreased from T1-T7, increased at T8, decreased at T9 and then increased again from T10-T12, and in Coloureds the IPD decreased from T1-T8 and then increased from T9-T12 **(Table 4.14)**. Significant differences in the IPD were observed between the four race groups **(Table 4.15).** When the Bonferroni *post-hoc* test was done **(Table 4.16)**, the following differences were observed:

- T2 between Whites and Blacks (p = 0.004)
- T3 between Whites and Blacks (p = 0.010)
- T4 between Whites and Blacks (p = 0.007)
- T7 between Whites and Blacks (p = 0.043)
- T11 between Whites and Blacks (p = 0.042)
- T12 between Whites and Blacks (p = 0.040)
- T2 between Whites and Indians (p =0.032)
- T3 between Whites and Indians (p = 0.035)
- T12 between Blacks and Coloureds (p = 0.034)

Table 4.14 The mean and SD of the interpedicular distance T1-T12 by racial group and overall

Report													
Group		**T1**	**T2**	**T3**	**T4**	**T5**	**T6**	**T7**	**T8**	**T9**	**T10**	**T11**	**T12**
White	Mean	26.2	22.3	20.4	19.4	18.5	18.5	18.5	18.7	18.9	19.5	21.5	24.2
	n	20	20	20	20	20	20	20	20	20	20	20	20
	SD	1.1	0.9	1.0	1.2	1.5	1.3	1.3	1.4	1.6	1.5	3.5	2.7
Black	Mean	24.7	20.5	18.9	17.8	17.4	17.3	17.1	17.4	17.5	18.0	19.1	21.9
	n	20	20	20	20	20	20	20	20	20	20	20	20
	SD	2.0	1.7	1.5	1.7	1.5	1.5	1.5	1.7	1.8	2.0	2.4	2.4
Indian	Mean	24.7	20.9	19.1	18.3	17.5	17.4	17.3	17.7	17.4	18.2	19.8	22.6
	n	20	20	20	20	20	20	20	20	20	20	20	20
	SD	1.8	1.6	1.3	1.5	1.6	1.4	1.5	1.3	1.1	1.7	2.0	2.0
Coloured	Mean	25.6	21.7	19.8	18.9	18.2	18.2	18.0	18.0	18.5	19.1	20.6	24.3
	n	20	20	20	20	20	20	20	20	20	20	20	20
	SD	2.2	2.0	1.9	1.8	1.8	2.0	2.0	2.3	2.4	2.8	2.6	3.4
Total	Mean	25.3	21.3	19.6	18.6	17.9	17.8	17.7	18.0	18.0	18.7	20.2	23.2
	n	80	80	80	80	80	80	80	80	80	80	80	80
	S D	2.0	1.7	1.5	1.6	1.6	1.6	1.7	1.8	1.9	2.1	2.8	2.8

Table 4.15 ANOVA test to compare interpedicular distance between the racial groups

ANOVA						
		Sum of squares	**df**	**Mean square**	**F**	**Sig.**
T1	Between Groups	32.400	3	10.800	3.199	.028
	Within Groups	256.600	76	3.376		
	Total	289.000	79			
T2	Between Groups	39.250	3	13.083	5.118	.003
	Within Groups	194.300	76	2.557		
	Total	233.550	79			
T3	Between Groups	28.200	3	9.400	4.476	.006
	Within Groups	159.600	76	2.100		
	Total	187.800	79			
T4	Between Groups	31.450	3	10.483	4.424	.006
	Within Groups	180.100	76	2.370		
	Total	211.550	79			
T5	Between Groups	19.050	3	6.350	2.491	.067
	Within Groups	193.700	76	2.549		

	Total	212.750	79			
T6	Between Groups	19.050	3	6.350	2.560	.061
	Within Groups	188.500	76	2.480		
	Total	207.550	79			
T7	Between Groups	25.837	3	8.612	3.364	.023
	Within Groups	194.550	76	2.560		
	Total	220.388	79			
T8	Between Groups	18.538	3	6.179	2.114	.105
	Within Groups	222.150	76	2.923		
	Total	240.688	79			
T9	Between Groups	34.138	3	11.379	3.536	.019
	Within Groups	244.550	76	3.218		
	Total	278.688	79			
T10	Between Groups	31.638	3	10.546	2.487	.067
	Within Groups	322.250	76	4.240		
	Total	353.888	79			
T11	Between Groups	62.650	3	20.883	2.900	.040
	Within Groups	547.300	76	7.201		
	Total	609.950	79			
T12	Between Groups	85.650	3	28.550	4.016	.010
	Within Groups	540.300	76	7.109		
	Total	625.950	79			

Table 4.16 Bonferroni adjusted *post-hoc* test to assess inter-group variation of the interpedicular distance

Multiple Comparisons

Bonferroni

Dependent Variable	**(I) group**	**(J) group**	**Mean Difference (I-J)**	**Std. Error**	**Sig.**	**95% Confidence Interval**	
						Lower Bound	**Upper Bound**
T1	White	Black	1.500	.581	.071	-.07	3.07
		Indian	1.500	.581	.071	-.07	3.07
		Coloured	.600	.581	1.000	-.97	2.17
	Black	White	-1.500	.581	.071	-3.07	.07
		Indian	.000	.581	1.000	-1.57	1.57
		Coloured	-.900	.581	.753	-2.47	.67
	Indian	White	-1.500	.581	.071	-3.07	.07
		Black	.000	.581	1.000	-1.57	1.57
		Coloured	-.900	.581	.753	-2.47	.67

	Coloured	White	-.600	.581	1.000	-2.17	.97
		Black	.900	.581	.753	-.67	2.47
		Indian	.900	.581	.753	-.67	2.47
T2	White	Black	1.800*	.506	.004	.43	3.17
		Indian	1.450*	.506	.032	.08	2.82
		Coloured	.650	.506	1.000	-.72	2.02
	Black	White	-1.800*	.506	.004	-3.17	-.43
		Indian	-.350	.506	1.000	-1.72	1.02
		Coloured	-1.150	.506	.155	-2.52	.22
	Indian	White	-1.450*	.506	.032	-2.82	-.08
		Black	.350	.506	1.000	-1.02	1.72
		Coloured	-.800	.506	.707	-2.17	.57
	Coloured	White	-.650	.506	1.000	-2.02	.72
		Black	1.150	.506	.155	-.22	2.52
		Indian	.800	.506	.707	-.57	2.17
T3	White	Black	1.500*	.458	.010	.26	2.74
		Indian	1.300*	.458	.035	.06	2.54
		Coloured	.600	.458	1.000	-.64	1.84
	Black	White	-1.500*	.458	.010	-2.74	-.26
		Indian	-.200	.458	1.000	-1.44	1.04
		Coloured	-.900	.458	.319	-2.14	.34
	Indian	White	-1.300*	.458	.035	-2.54	-.06
		Black	.200	.458	1.000	-1.04	1.44
		Coloured	-.700	.458	.785	-1.94	.54
	Coloured	White	-.600	.458	1.000	-1.84	.64
		Black	.900	.458	.319	-.34	2.14
		Indian	.700	.458	.785	-.54	1.94
T4	White	Black	1.650*	.487	.007	.33	2.97
		Indian	1.150	.487	.124	-.17	2.47
		Coloured	.500	.487	1.000	-.82	1.82
	Black	White	-1.650*	.487	.007	-2.97	-.33
		Indian	-.500	.487	1.000	-1.82	.82
		Coloured	-1.150	.487	.124	-2.47	.17
	Indian	White	-1.150	.487	.124	-2.47	.17
		Black	.500	.487	1.000	-.82	1.82
		Coloured	-.650	.487	1.000	-1.97	.67
	Coloured	White	-.500	.487	1.000	-1.82	.82
		Black	1.150	.487	.124	-.17	2.47
		Indian	.650	.487	1.000	-.67	1.97
T7	White	Black	1.400*	.506	.043	.03	2.77
		Indian	1.250	.506	.094	-.12	2.62

		Coloured	.500	.506	1.000	-.87	1.87
	Black	White	-1.400*	.506	.043	-2.77	-.03
		Indian	-.150	.506	1.000	-1.52	1.22
		Coloured	-.900	.506	.476	-2.27	.47
	Indian	White	-1.250	.506	.094	-2.62	.12
		Black	.150	.506	1.000	-1.22	1.52
		Coloured	-.750	.506	.854	-2.12	.62
	Coloured	White	-.500	.506	1.000	-1.87	.87
		Black	.900	.506	.476	-.47	2.27
		Indian	.750	.506	.854	-.62	2.12
T9	White	Black	1.450	.567	.075	-.09	2.99
		Indian	1.500	.567	.060	-.04	3.04
		Coloured	.400	.567	1.000	-1.14	1.94
	Black	White	-1.450	.567	.075	-2.99	.09
		Indian	.050	.567	1.000	-1.49	1.59
		Coloured	-1.050	.567	.408	-2.59	.49
	Indian	White	-1.500	.567	.060	-3.04	.04
		Black	-.050	.567	1.000	-1.59	1.49
		Coloured	-1.100	.567	.337	-2.64	.44
	Coloured	White	-.400	.567	1.000	-1.94	1.14
		Black	1.050	.567	.408	-.49	2.59
		Indian	1.100	.567	.337	-.44	2.64
T11	White	Black	2.350*	.849	.042	.05	4.65
		Indian	1.700	.849	.292	-.60	4.00
		Coloured	.850	.849	1.000	-1.45	3.15
	Black	White	-2.350*	.849	.042	-4.65	-.05
		Indian	-.650	.849	1.000	-2.95	1.65
		Coloured	-1.500	.849	.487	-3.80	.80
	Indian	White	-1.700	.849	.292	-4.00	.60
		Black	.650	.849	1.000	-1.65	2.95
		Coloured	-.850	.849	1.000	-3.15	1.45
	Coloured	White	-.850	.849	1.000	-3.15	1.45
		Black	1.500	.849	.487	-.80	3.80
		Indian	.850	.849	1.000	-1.45	3.15
T12	White	Black	2.350*	.843	.040	.07	4.63
		Indian	1.600	.843	.369	-.68	3.88
		Coloured	-.050	.843	1.000	-2.33	2.23
	Black	White	-2.350*	.843	.040	-4.63	-.07
		Indian	-.750	.843	1.000	-3.03	1.53
		Coloured	-2.400*	.843	.034	-4.68	-.12
	Indian	White	-1.600	.843	.369	-3.88	.68

	Black	.750	.843	1.000	-1.53	3.03
	Coloured	-1.650	.843	.324	-3.93	.63
Coloured	White	.050	.843	1.000	-2.23	2.33
	Black	2.400*	.843	.034	.12	4.68
	Indian	1.650	.843	.324	-.63	3.93

***. The mean difference is significant at the 0.05 level.**

4.3 THE COEFFICIENT OF VARIATION (%) OF THE THORACIC KYPHOSIS, ANTERIOR AND POSTERIOR VERTEBRAL BODY HEIGHTS AND INTERVERTEBRAL DISC HEIGHT BETWEEN THE RACIAL GROUPS

The coefficient of variation of the TK is comparatively larger **(Table 4.17)** than the other parameters that were evaluated **(Tables 4.18-4.20)**. This was expected as the SD of the TK values was significantly higher than those of other parameters.

Table 4.17 The coefficient of variation (%) of the thoracic kyphosis within the racial groups

Racial Group	Thoracic kyphosis	Thoracic kyphosis (excl. outliers)
White	37	28
Black	37	31
Indian	35	28
Coloured	45	36

Table 4.18 The coefficient of variation (%) of the anterior vertebral body height of T5-T12 within the racial groups

Racial Group	AVBHT5	AVBHT6	AVBHT7	AVBHT8	AVBHT9	AVBHT10	AVBHT11	AVBHT12
White	8	8	6	7	5	6	6	7
Black	8	8	8	8	8	7	8	9
Indian	7	7	7	8	8	11	8	7
Coloured	8	8	7	7	7	6	7	7

Table 4.19 The coefficient of variation (%) of the posterior vertebral body height of T5-T12 within the racial groups

Racial Group	PVBHT5	PVBHT6	PVBHT7	PVBHT8	PVBHT9	PVBHT10	PVBHT11	PVBHT12
White	7	6	9	5	5	5	7	8
Black	10	9	8	6	7	8	8	9

Indian	6	6	5	6	6	7	7	6
Coloured	8	9	9	7	7	7	4	5

Table 4.20 The coefficient of variation (%) of the interpedicular distance of T1-T12 within the racial groups

Racial Group	IPDT1	IPDT2	IPDT3	IPDT4	IPDT5	IPDT6	IPDT7	IPDT8	IPDT9	IPDT10	IPDT11	IPDT12
White	4	4	5	6	8	7	7	8	8	8	16	11
Black	8	8	8	9	9	9	9	10	10	11	13	11
Indian	7	8	7	8	9	8	9	7	7	9	10	9
Coloured	8	9	9	9	10	11	11	13	13	15	13	14

4.4 THE CORRELATION BETWEEN THE THORACIC KYPHOSIS AND THE ANTERIOR VERTEBRAL BODY AND INTERVERTEBRAL DISC HEIGHTS

4.4.1 The Correlation between the Thoracic Kyphosis and the Anterior Vertebral Body Heights

There was a significant inverse correlation between the AVBH and TK ($p < 0.05$) at T8-T11 as shown in **Table 4.21**. The greatest level of significance was observed at T11.

Table 4.21 The correlation between the thoracic kyphosis and anterior vertebral body height

		TK
AVBH T5	Pearson Correlation	-.213
	Sig. (2-tailed)	0.058
	n	80
AVBH T6	Pearson Correlation	-.278*
	Sig. (2-tailed)	0.013
	n	80
AVBH T7	Pearson Correlation	-.219
	Sig. (2-tailed)	0.051
	n	80
AVBH T8	Pearson Correlation	-.303**
	Sig. (2-tailed)	0.006
	n	80
AVBH T9	Pearson Correlation	-.347**
	Sig. (2-tailed)	0.002
	n	80
AVBH T10	Pearson Correlation	-.302**
	Sig. (2-tailed)	0.006

	n	80
AVBH T11	Pearson Correlation	-.355**
	Sig. (2-tailed)	0.001
	n	80
AVBH T12	Pearson Correlation	-.123
	Sig. (2-tailed)	0.279
	n	80

***. Correlation is significant at the 0.05 level (2-tailed).**

****. Correlation is significant at the 0.01 level (2-tailed).**

4.4.2 The Correlation between the Thoracic Kyphosis and the Intervertebral Disc Heights

Moderate to strong correlations were observed at T6-T7 and T8-T9 levels. A general trend was observed between the TK and the IVD heights in all race groups. The weakest correlation between the TK and IVD heights was observed in Blacks, while the highest correlation between the TK and the IVD heights was observed in Indians as presented in **Table 4.22.**

Table 4.22 The correlation between the thoracic kyphosis and the intervertebral disc heights by racial group

Racial Group	IVD level							
	T5-T6	**T6-T7**	**T7-T8**	**T8-T9**	**T9-T10**	**T10-T11**	**T11-T12**	**T12-L1**
W	0.10 Weak positive	0.81 Strong positive	0.76 Strong positive	0.57 Moderate positive	0.70 Strong positive	0.68 Moderate positive	0.58 Moderate positive	0.54 Moderate positive
B	0.02 Weak positive	0.89 Strong positive	0.64 Moderate positive	0.57 Moderate positive	0.46 Weak positive	0.33 Weak positive	0.27 Weak positive	0.40 Weak positive
I	0.05 Weak positive	0.82 Strong positive	0.76 Strong positive	0.69 Moderate positive	0.75 Strong positive	0.72 Strong positive	0.81 Strong positive	0.84 Strong positive
C	-0.26 Weak inverse	0.69 Moderate positive	0.73 Strong positive	0.65 Moderate positive	0.60 Moderate positive	0.50 Moderate positive	0.68 Moderate positive	0.73 Strong positive

W = White; B = Black; I = Indian; C = Coloured

4.5 THE CORRELATION BETWEEN THE THORACIC KYPHOSIS, WEIGHT, HEIGHT AND BODY MASS INDEX OF THE PARTICIPANTS

4.5.1The Correlation between the Weight of the Participants and the Thoracic Kyphosis

The correlation between the weight of the participants and the TK is shown in **Table 4.23**. A weak inverse correlation was observed between the weight and TK of the White, Black and Coloured participants (i.e. as the weight increases, the TK decreases). Interestingly, a positive correlation, albeit weak, was observed between the weight and TK of the Indian participants (i.e. as the weight increases, the TK increases).

Table 4.23 The correlation between the weight of the participants and the thoracic kyphosis

Racial Group	Pearson Correlation
W	-0.08 Weak inverse
B	-0.01 Weak inverse
I	0.22 Weak positive
C	-0.22 Weak inverse

W = White; B = Black; I = Indian; C = Coloured

4.5.2 The Correlation between the Height of the Participants and the Thoracic Kyphosis

The correlation between the height of participants and the TK is shown in **Table 4.24.** A positive albeit weak correlation is observed between the height of participants and the TK. This demonstrates that the height of an individual has a weak influence on the magnitude of the TK.

Table 4.24 The correlation between the height of the participants and the thoracic kyphosis

Racial Group	Pearson Correlation
W	0.14 Weak positive
B	0.23 Weak positive
I	0.18 Weak positive
C	0.06 Weak positive

W = White; B = Black; I = Indian; C = Coloured

4.5.3 The Correlation between the Thoracic Kyphosis and Body Mass Index

The correlation between the BMI of the participants and the TK is shown in **Table 4.25**. A weak inverse correlation was observed between the TK and the BMI of the White, Black and Coloured participants (i.e. as the BMI increases, the TK decreases). Interestingly, a positive correlation, albeit weak, was observed between the BMI and TK of the Indian participants (i.e. as the weight increases, the BMI increases).

Table 4.25 The correlation between the body mass index and thoracic kyphosis

Racial Group	Pearson Correlation
W	-0.17 Weak inverse
B	-0.21 Weak inverse
I	0.08 Weak positive
C	-0.38 Weak inverse

W = White; B = Black; I = Indian; C = Coloured

4.6 THE CORRELATION BETWEEN THE INTERVERTEBRAL DISC HEIGHT AND THE WEIGHT, HEIGHT AND BODY MASS INDEX OF THE PARTICIPANTS

4.6.1 The Correlation between the Weight of the Participants and the Intervertebral Disc Height

An overall positive weak correlation was observed between the height of the participant and the IVDH. At the level of T8-T9 a moderate correlation was observed in all race groups except the Indians. At the level of T11-T12, a moderate correlation was observed in all race groups with the exception of Blacks.

Table 4.26 The correlation between the weight of participants and the intervertebral disc height

Racial Group	Level							
	T5-T6	**T6-T7**	**T7-T8**	**T8-T9**	**T9-T10**	**T10-T11**	**T11-T12**	**T12-L1**
W	0.23 Weak positive	0.20 Weak positive	-0.47 Weak inverse	0.65 Moderate positive	0.61 Moderate positive	0.54 Moderate positive	0.53 Moderate positive	0.04 Weak positive
B	0.19 Weak positive	0.02 Weak positive	0.15 Weak positive	0.61 Moderate positive	0.39 Weak positive	0.24 Weak positive	-0.15 Weak inverse	-0.20 Weak inverse
I	-0.30 Weak inverse	-0.23 Weak inverse	0.22 Weak positive	0.37 Weak positive	0.76 Moderate positive	0.42 Weak positive	0.50 Moderate positive	0.68 Moderate positive
C	0.30 Weak positive	0.43 Weak positive	-0.23 Weak inverse	0.54 Moderate positive	0.48 Weak positive	0.49 Weak positive	0.54 Moderate positive	0.26 Weak positive

W = White; B = Black; I = Indian; C = Coloured

4.6.2 The Correlation between the Height of the Participants and the Intervertebral Disc Height

The correlation between the height of the participants and the IVDH is shown in **Table 4.27**.An overall weak positive correlation was observed between the height of the participants and the IVDH.

Table 4.27 The correlation between the height of the participants and the intervertebral disc height

Racial Group	Level							
	T5-T6	T6-T7	T7-T8	T8-T9	T9-T10	T10-T11	T11-T12	T12-L1
W	0.14 Weak positive	0.18 Weak positive	0.06 Weak positive	-0.34 Weak inverse	0.63 Moderate positive	0.48 Weak positive	0.26 Weak positive	0.06 Weak positive
B	0.06 Weak positive	0.05 Weak positive	-0.09 Weak inverse	0.24 Weak inverse	0.44 Weak positive	0.08 Weak positive	-0.08 Weak inverse	-0.07 Weak inverse
I	0.34 Weak positive	0.08 Weak positive	-0.07 Weak inverse	0.18 Weak positive	0.52 Moderate positive	0.36 Weak positive	0.45 Weak positive	0.60 Moderate positive
C	0.28 Weak positive	0.55 Moderate positive	0.41 Weak positive	-0.15 Weak inverse	0.47 Weak positive	0.65 Moderate positive	0.55 Moderate positive	0.11 Weak positive

W = White; B = Black; I = Indian; C = Coloured

4.6.3 The Correlation between the Body Mass Index of the participants and Intervertebral Disc Height

The correlation between the IVDH and BMI is shown in **Table 4.28**. There was a strong correlation between the BMI and IVDH at the level of T8 (r = 0.83) in Whites, and in Indians, there was a strong association between the BMI and IVD height at the levels of T11 (r = 0.74) and T12 (r = 0.72). A weak to moderate correlation between the BMI and IVDH was observed in Blacks and Coloureds **(Table 4.28)**.

4.28 The correlation between the body mass index and the intervertebral disc height

Racial Group	Level							
	T5-T6	T6-T7	T7-T8	T8-T9	T9-T10	T10-T11	T11-T12	T12-L1
W	0.16 Weak positive	-0.36 Weak inverse	0.50 Moderate positive	0.83 Strong positive	0.52 Moderate positive	0.49 Weak positive	0.57 Moderate positive	0.31 Weak positive
B	0.08 Weak positive	0.11 Weak positive	0.67 Moderate positive	0.60 Moderate positive	0.26 Weak positive	0.04 Weak positive	-0.43 Weak inverse	-0.02 Weak inverse
I	-0.51 Moderate inverse	-0.04 Weak inverse	0.61 Moderate positive	0.52 Moderate positive	0.58 Moderate positive	0.66 Moderate positive	0.74 Strong positive	0.72 Strong positive
C	0.18 Weak positive	-0.24 Weak inverse	0.60 Moderate positive	0.40 Weak positive	0.51 Moderate positive	0.35 Weak positive	0.53 Moderate positive	0.52 Moderate positive

W = White; B = Black; I = Indian; C = Coloured

CHAPTER FIVE

DISCUSSION

5.1 AGE AND ANTHROPOMETRIC CHARACTERISTICS OF THE PARTICIPANTS

The participants of this study were young to middle-aged males between 18 and 45 years of age which was in keeping with the aim of the study. This minimised the inclusion of the participants with degenerative joint disease of the thoracic spine which may have influenced the results. The mean age of the participants of this study **(Table 4.1)** was lower than that reported by Singer et al. (1994), Jackson and McManus (1994) and Harrison et al. (2001), but higher than that reported by Kolessar et al. (1996). The mean height of the participants **(Table 4.1)** was higher than that reported by Panjabi et al. (1991) and Singer et al. (1994), but lower than that reported by Harrison et al. (2001). The mean weight of the participants of this study **(Table 4.1)** was higher than that reported by Panjabi et al. (1991), Singer et al. (1994), and Harrison et al. (2001). The mean BMI of all the participants **(Table 4.1)** marginally exceeded the limit of the normal mean BMI ($18.5kg.m^{-2}$-$25kg.m^{-2}$) (World Health Organisation Global Data Base on Body Mass Index, 2011) which indicates that some of the participants were slightly overweight. It was possible that these anthropometric characteristics could have impacted on the results of certain radiographic parameters that were assessed. Therefore, correlation analyses were done between the height, weight and BMI of the participants, and the TK, AVBH, IVDH. These findings are discussed later in this chapter.

5.2 SELECTED RADIOGRAPHIC PARAMETERS OF THE THORACIC SPINE

5.2.1 Thoracic Kyphosis

The mean TK (22.2°, **Table 4.2**) observed in this study is reported here for the first time as a possible reference value for the TK in males of South Africa. Even the removal of the outlier values did not significantly influence the results of the TK **(Table 4.3)**. A relatively small non-significant difference ($p > 0.05$) in the mean TK was observed in this study between the four main race groups. Despite these findings, it is important that a future study be conducted on a national level with a much larger sample and with more sensitive assessment tools in order to confirm the range of the TK observed in this study as a normative reference value for the TK in males in South Africa.

When one compares the mean TK of the four races and overall as observed in this study to that reported by Stagnara et al. (1982) and Korovessis et al. (1999) **(Table 5.1)**, it is immediately apparent that a distinct difference is present between the mean TK of the South Africans compared to the French and Greek populations. At first glance, this finding suggests that there may be differences in the TK in individuals from the same race (Stagnara et al., 1982; Korovessis et al., 1999), but from different geographic locations. On the other hand, there were no significant differences in the mean TK of the four racial groups in South Africa. It is also possible that these differences may be attributed to the different vertebral levels selected for measurement of the TK, differences in sample size and variances in the ages of the participants **(Table 2.2)**.

When compared to the TK values of previous studies **(Table 5.2)**, it is apparent that the magnitude of the TK of the current study is lower. These discrepancies may be attributed to the various landmarks selected, different methodologies, and different sample characteristics **(Table 2.2)**. Even when similar anatomical landmarks were used for determining the TK **(Table 2.2, Table 5.2)**, the mean TK observed in this study is still lower. This confirms the previous observation that there is no universal normal TK value. It is clearly shown in **Table 5.2** that the South African population does not follow trends observed in other studies of different races and geographic locations. Therefore, normative TK values should be based on race, sex and age. It is imperative for spinal physicians in South Africa to be acquainted with the normative reference values of the TK as this curve is helpful in aiding with the diagnosis of various spinal disorders. It is also important for these spinal health care practitioners to be aware of the South African population-specific normal TK values if conservative or surgical management is directed towards restoration of the normal TK.

Table 5.1 A comparison of the mean thoracic kyphosis to those of French and Greek participants of previous studies

Mean TK of the CS	French (Stagnara et al., 1982)	Greek (Korovessis et al., 1999)
W: 25.2°	↑10.8°	↑16.8°
B: 20.1°	↑15.9°	↑21.9°
I: 23.4°	↑12.6°	↑18.6°
C: 20.1°	↑15.9°	↑21.9°
Overall: 22.2°	**↑13.8°**	**↑19.8°**

***CS= Current study * W = White; B = Black; I = Indian; C = Coloured *↑ = an increase of**

Table 5.2 Comparison of the mean TK of this study to those of previous studies

Reference	Level	Reported Mean	Observed Differences
Current study	T5-T12	22.2°	
Stagnara et al. (1982)	T4-T12	36°	↑13.8°
Voutsinas and MacEwen (1986)	T2-T12	39.4°	↑17.2°
Jackson and McManus (1994)	T1-T12	42.1°	↑19.9°
Gelb et al. (1995)	T5-T12	34°	↑11.8°
Kolessar et al. (1996)	T5-T12	32°	↑9.8°
Korovessis et al. (1999)	T4-T12	42°	↑19.8°
Tuzun et al. (1999)	T1-T12	28°	↑5.8°
Jackson et al. (2000)	T1-T12	45°	↑22.8°
Harrison et al. (2001)	T1-T12	45.6°	↑23.4°
Boyle et al. (2002)	T1-T12	29.9°	↑7.7°
Vaille et al. (2005)	T4-T12	41.7°	↑19.5°

***↑ an increase of**

5.2.2 Anterior vertebral body height

The AVBH progressively increased from T1 to T12 as shown in **Table 4.6.** Significant differences (p < 0.05) were observed between the race groups of this study, which is shown in **Table 4.8**. These results suggest that there is a difference in AVBH within the four main race groups in South Africa, especially between the Whites and the Blacks.

Overall, the largest AVBH was observed in the South African participants compared to that of participants in previous studies, as shown in **Table 5.3.** The most significant difference was observed between the South Africans and the Chinese Singaporeans who had the smallest vertebral dimensions. A maximum difference of 14 mm of the AVBH was observed at the level of T12 (Tan et al., 2004). On closer inspection it should be noted that Tan et al. (2004) combined the data of males and females.

It is interesting to observe that the South African Whites and Blacks have a higher AVBH in comparison to the cadaveric specimens of Caucasians and Blacks studied by Scoles et al. (1988). This discrepancy may be attributed to the difference in sample size and the use of cadaveric specimens rather than radiographs of healthy participants. A difference ranging from 6.4mm to 8.8mm in the AVBH was observed between the Indian male cadaveric specimens (Singh et al., 2011) and the South African Indian participants of the current study.

The AVBH is of considerable importance as it plays a significant role in the magnitude of the thoracic curve. The results of this study are in keeping with other studies that observed that the AVBH plays a significant role in determining the TK as shown in **Table 4.21**. The greatest amount of change in the morphology of the AVBH occurs at the mid-thoracic region which is the apical region. This is as a result of the greatest amount of compressive loading that occurs in this region. An increase in the compressive loading is directly proportional to the prevalence of wedge fractures, especially in females due to their predisposition of decreased bone mineral density (Goh et al., 1999). A significantly reduced AVBH in comparison to the PVBH could be indicative of hyperkyphosis (Bruno et al., 2012). Therefore, it is imperative that South African spinal physicians be acquainted with the normative reference values of the AVBH.

Table 5.3 A comparison of the AVBH of this study to those of previous studies

Vertebral Level	Current Study Mean (mm)	Scoles et al. (1988) (M)	(F)	Harrison et al. (2003) (Sex combined)	Tan et al. (2004) (Sex Combined)	Singh et al. (2011) (M)	(F)
T5	W:25.6	*	*	↓6.4	↓10.4	↓8.4	↓9.2
	B:23.9	*	*	↓4.7	↓8.7	↓6.7	↓7.5
	I:23.9	*	*	↓4.7	↓8.7	↓6.7	↓7.5
	C:25.5	*	*	↓6.3	↓10.3	↓8.3	↓9.1
T6	W:25.9	↓9.1	↓7.1	↓6.8	↓10.4	↓8.0	↓8.9
	B:24.2	↓4.4	↓5.1	↓5.1	↓8.7	↓6.3	↓7.2
	I:24.6	↓4.8	↓5.8	↓5.5	↓9.1	↓6.7	↓7.6
	C:25.8	↓6.0	↓7.0	↓6.7	↓10.3	↓7.9	↓8.8
T7	W:26.3	*	*	↓7.2	↓11.2	↓8.2	↓9.4
	B:24.7	*	*	↓5.6	↓9.6	↓6.6	↓7.8
	I:25.0	*	*	↓5.9	↓9.9	↓6.9	↓8.1
	C:26.1	*	*	↓7.0	↓11.0	↓8.0	↓9.2
T8	W:26.9	*	*	↓7.3	↓10.8	↓7.8	↓8.4
	B:25.1	*	*	↓5.5	↓9.0	↓6.0	↓6.6
	I:25.5	*	*	↓5.9	↓9.4	↓6.4	↓7.0
	C:26.5	*	*	↓6.9	↓10.4	↓7.4	↓8.0
T9	W:27.7	↓ 5.9	↓7.2	↓7.0	↓11.2	↓7.7	↓8.3
	B:26.6	↓4.8	↓6.1	↓5.9	↓10.1	↓6.6	↓7.2
	I:26.7	↓4.9	↓6.2	↓6.0	↓10.2	↓6.7	↓7.3
	C:27.4	↓5.6	↓6.9	↓6.7	↓10.9	↓7.4	↓8.0
T10	W:29.0	*	*	↓6.4	↓11.5	↓8.5	↓9.2
	B:28.3	*	*	↓5.7	↓10.8	↓7.8	↓8.5
	I:28.1	*	*	↓5.5	↓10.6	↓7.6	↓8.3
	C:29.6	*	*	↓7.0	↓12.1	↓9.1	↓9.8
T11	W:30.6	*	*	↓6.9	↓13.1	↓9.3	↓9.6
	B:29.5	*	*	↓5.8	↓12.0	↓8.2	↓8.5
	I:29.2	*	*	↓5.5	↓11.7	↓7.9	↓8.2
	C:31.0	*	*	↓7.3	↓13.5	↓9.7	↓10.0
T12	W:32.5	↓6.6	↓7.9	↓6.1	↓13.8	↓10.2	↓10.7
	B:31.0	↓5.1	↓6.4	↓5.6	↓12.3	↓8.7	↓9.2
	I:31.1	↓5.2	↓6.5	↓5.7	↓12.4	↓8.8	↓9.3
	C:32.0	↓6.8	↓8.1	↓7.3	↓14.0	↓10.4	↓10.9

***W = White; B = Black; I = Indian; C = Coloured *↓= a decrease of**

5.2.3 Posterior vertebral body height

The largest PVBH was observed in Whites and the smallest in Blacks. A significant difference ($p < 0.05$) in the PVBH was observed from the level of T7 to T12 between Whites and Blacks. The most significant difference ($p < 0.000$) was observed at the level of T8. There was also a significant difference ($p < 0.05$) between the Whites and the Indians from the level of T7 to T10. The greatest significance ($p = 0.002$) was at the level of T8. These findings suggest that there may be racial differences in the PVBH.

The mean height of the posterior VB progressively increased from T5 to T12 which is consistent with previous studies **(Table 2.4.)**. However, the PVBH of the South African participants of this study was larger than that described by previous researchers in different settings **(Table 5.4)**. An exception was noted by Singh et al. (2011) who observed a decrease in the PVBH at the level of T11 and then an increase at T12. The largest difference (14.1mm) was found at the level of T12 between the South African White males and the Chinese Singaporeans.

Although Indian males were included by Singh et al. (2011) and in this study, it is interesting to observe a difference in PVBH of the two groups which ranged from 3.8mm to 8.8mm from T1-T12. The difference in Indian males between the two studies clearly supports that the parameters evaluated in the current study should not be limited to a single populace or geographic location.

Table 5.4 A comparison of the PVBH of this study to those of previous studies

Vertebral level	Current Study Mean (mm)	Panjabi et al. (1991) Sex Combined	Harrison et al. (2003) Sex Combined	Tan et al. (2004) Sex Combined	Singh et al. (2011) M	Singh et al. (2011) F
T5	W: 26.6	↓10.4	↓6.0	↓10.2	↓8.2	↓9.0
	B: 25.6	↓9.4	↓5.0	↓9.2	↓7.2	↓8.0
	I: 25.7	↓9.5	↓5.1	↓9.3	↓7.3	↓8.1
	C: 26.1	↓9.9	↓5.5	↓9.7	↓7.7	↓8.5
T6	W: 28.2	↓10.8	↓7.4	↓11.2	↓9.2	↓10.0
	B: 26.8	↓9.4	↓6.0	↓9.8	↓7.8	↓8.6
	I: 26.8	↓9.4	↓6.0	↓9.8	↓7.8	↓8.6
	C: 27.3	↓9.9	↓6.5	↓10.3	↓8.3	↓9.1
T7	W: 29.9	↓11.7	↓8.4	↓12.5	↓10.4	↓11.5
	B: 27.5	↓9.3	↓6.0	↓10.1	↓8.0	↓9.1
	I: 27.4	↓9.2	↓5.9	↓10.0	↓7.9	↓9.0
	C: 28.2	↓10.0	↓6.7	↓10.8	↓8.7	↓9.8
T8	W: 30.5	↓11.8	↓8.6	↓12.7	↓10.5	↓11.7

	B: 28.0	↓9.3	↓6.1	↓10.2	↓8.0	↓9.2
	I: 28.4	↓9.7	↓6.5	↓10.6	↓8.4	↓9.6
	C: 29.0	↓10.3	↓7.1	↓11.2	↓9.0	↓10.2
T9	W: 31.1	↓11.8	↓8.6	↓13.1	↓10.5	↓11.6
	B: 28.8	↓9.5	↓6.3	↓10.8	↓8.2	↓9.3
	I: 29.0	↓9.7	↓6.5	↓11.0	↓8.4	↓9.5
	C: 29.7	↓10.4	↓7.2	↓11.7	↓9.1	↓10.2
T10	W: 32.2	↓12.0	↓8.2	↓13.1	↓10.9	↓12.0
	B: 29.9	↓9.7	↓5.9	↓10.8	↓8.6	↓9.7
	I: 30.1	↓9.9	↓6.1	↓11.0	↓8.8	↓9.9
	C: 30.8	↓10.6	↓6.8	↓11.7	↓9.5	↓10.6
T11	W: 34.0	↓12.7	↓7.6	↓13.6	↑2.3	↓1.6
	B: 31.3	↓10.0	↓4.9	↓10.9	↑5.0	↑1.1
	I: 32.2	↓10.9	↓5.8	↓11.8	↑4.1	↑0.2
	C: 32.5	↓11.2	↓6.1	↓12.1	↑3.8	↓0.1
T12	W: 35.6	↓12.9	↓7.5	↓14.1	↓5.7	↓6.2
	B: 33.3	↓10.6	↓5.2	↓11.8	↓3.4	↓3.9
	I: 33.6	↓10.9	↓5.5	↓12.1	↓3.7	↓4.2
	C: 34.0	↓11.3	↓5.9	↓12.5	↓4.1	↓4.6

***W = White; B = Black; I = Indian; C = Coloured   *↓= a decrease of   *↑= an increase of**

5.2.4 Intervertebral disc height

The IVDH progressively increased from T5 to T12 **(Table 4.12)**. The largest IVDH was observed in Coloureds in comparison to the other race groups. The progressive increase of the anterior and posterior IVD heights from the cephalad to caudal levels was reported by Harrison et al. (2003) **(Table 2.5)**. A proper comparison **(Table 5.5)** however, could not be made as the central IVDH was measured in this study, while Harrison et al. (2003) assessed only the anterior and posterior IVD heights. Despite a thorough search for literature no other study was found which evaluated the central IVDH in the thoracic spine. It is the researcher’s view that the IVD heights in the thoracic spine should be evaluated by clinicians as they also influence the thoracic curve (Itoi, 1991; Singer et al., 1994; Goh et al., 2000).

Table 5.5 A comparison of the IVDH of this study to those of a previous study

IVD Level	Current Study	Harrison et al. (2003) A	P
T5-T6	W: 3.0	↑0.9	↓0.2
	B: 2.8	↑1.1	=
	I: 2.9	↑1.0	↓0.1
	C: 3.1	↑0.8	↓0.3
T6-T7	W: 3.3	↑1.0	=
	B: 2.9	↑1.4	↑0.4
	I: 3.0	↑1.3	↑0.3
	C: 3.6	↑0.7	↓0.3
T7-T8	W: 3.5	↑0.8	↑0.4
	B: 3.3	↑1.0	↑0.6
	I: 3.4	↑0.9	↑0.5
	C: 4.0	↑0.3	↓0.1
T8-T9	W: 3.9	↑0.5	↑0.3
	B: 3.7	↑0.7	↑0.5
	I: 3.7	↑0.7	↑0.5
	C: 4.4	↓0.1	↓0.3
T9-T10	W: 4.4	↓0.1	=
	B: 4.3	↑0.1	↑0.2
	I: 4.3	↑0.1	↑0.2
	C: 4.9	↓0.5	↓0.4
T10-T11	W: 5.3	↓0.4	↑0.2
	B: 5.6	↓0.7	↓0.1
	I: 5.2	↓0.3	↑0.3
	C: 6.2	↓1.4	↓0.8
T11-T12	W: 6.8	↓1.6	↓0.2
	B: 7.0	↓1.8	↓0.4
	I: 6.6	↓1.4	=
	C: 7.6	↓2.4	↓1.0
T12-L1	W: 7.8	*	*
	B: 8.0	*	*
	I: 7.7	*	*
	C: 8.1	*	*

***W = White; B = Black; I = Indian; C = Coloured *↓= a decrease of *↑= an increase of *= equal to *A= anterior *P=posterior**

5.2.5 Interpedicular distance

The trend of a progressive increase in IPD, then a decrease at the mid-thoracic region followed by an increase to the level of T12 was observed. This is in agreement with previous studies (Scoles et al., 1988; Ebraheim et al., 1997; Singh et al., 2011), but is in contradiction to the findings of Chaynes et al. (2001) and Datir and Mitra (2004). The trend in the IPD observed in this study is in keeping with accommodating the spinal cord in the thoracic region (Scoles et al., 1988; Ebraheim et al., 1997; Crossman and Neary, 2005; Singh et al., 2011). Significant differences ($p < 0.05$) in the IPD were observed between Whites and Blacks. The greatest significance ($p = 0.004$) was at T2. This suggests that the South African Blacks are more prone to spinal canal stenosis in comparison to the other race groups.

A comparison of the IPD observed in this study to that reported in previous studies is shown in **Tables 5.6** and **5.7**. The widest IPD was observed in the Indian males (Datir and Mitra, 2004) followed by the IPD of the participants of this study. It was interesting to observe that although Indian males were assessed by Datir and Mitra (2004) and in this study, differences in the IPD were observed. A considerable difference was also observed between the Caucasian cadaveric specimens assessed by Ebraheim et al. (1997) and the White participants of this study.

Table 5.6 A comparison of the IPD of this study and combined cohorts of previous studies

Vertebral Level	Current Study Mean(mm)	Panjabi et al. (1991)	Ebraheim et al. (1997) Caucasian	Chaynes et al. (2001)	Tan et al. (2004)
T1	W: 26.1	↓4.4	↓12.4	↓8.8	↓8.5
	B: 24.7	↓2.9	↓10.9	↓7.3	↓7.0
	I: 24.7	↓2.9	↓10.9	↓7.3	↓7.0
	C: 25.6	↓3.8	↓11.8	↓8.2	↓7.9
T2	W: 22.3	↓2.8	↓7.9	↓3.0	↓7.1
	B: 20.5	↓1.0	↓6.1	↓1.2	↓5.3
	I: 20.9	↓1.4	↓6.4	↓1.6	↓5.7
	C: 21.7	↓2.2	↓7.3	↓2.4	↓6.5
T3	W: 20.4	↓2.1	↓5.9	↑0.8	↓6.2
	B: 18.9	↓0.6	↓4.4	↑2.3	↓4.7
	I: 19.1	↓0.8	↓4.6	↑2.1	↓4.9
	C: 19.8	↓1.5	↓5.3	↑1.4	↓5.6
T4	W: 19.4	↓2.4	↓5.5	↑2.4	↓5.9
	B: 17.8	↓0.8	↓3.9	↑4.0	↓4.3
	I: 18.3	↓1.3	↓4.4	↑3.5	↓4.8
	C: 18.9	↓1.9	↓5.0	↑2.9	↓5.4

T5	W: 18.5	↓1.4	↓4.6	↑4.3	↓4.9
	B: 17.4	↓0.3	↓3.5	↑5.4	↓3.8
	I: 17.5	↓0.4	↓3.6	↑5.3	↓3.9
	C: 18.2	↓1.1	↓4.3	↑4.6	↓4.6
T6	W: 18.5	↓1.2	↓4.1	↑4.4	↓4.7
	B: 17.3	=	↓2.9	↑5.6	↓3.5
	I: 17.4	↓0.1	↓3.0	↑5.5	↓3.6
	C: 18.2	↓0.9	↓3.8	↑4.7	↓4.4
T7	W: 18.5	↓1.2	↓3.9	↑6.0	↓4.6
	B: 17.1	↑0.2	↓2.5	↑7.4	↓3.2
	I: 17.3	=	↓2.7	↑7.2	↓3.4
	C: 18.0	↓0.7	↓3.4	↑6.5	↓4.1
T8	W: 18.7	↓1.0	↓3.8	↑6.2	↓4.6
	B: 17.4	↑0.3	↓2.5	↑7.5	↓3.3
	I: 17.7	=	↓2.8	↑7.2	↓3.6
	C: 18.0	↓0.3	↓3.1	↑6.9	↓3.9
T9	W: 18.9	↓1.0	↓3.4	↑7.2	↓4.7
	B: 17.5	↑0.4	↓2.0	↑8.6	↓3.3
	I: 17.4	↑0.5	↓1.9	↑8.7	↓3.2
	C: 18.5	↓0.6	↓3.0	↑7.6	↓4.3
T10	W: 19.5	↓1.3	↓4.0	↑8.3	↓5.3
	B: 18.0	↑0.2	↓2.5	↑9.8	↓3.8
	I: 18.1	=	↓2.7	↑9.6	↓4.0
	C: 19.1	↓.9	↓3.6	↑8.7	↓4.9
T11	W: 21.5	↓2.1	↓5.4	↑9.2	↓6.2
	B: 19.1	↑0.3	↓3.0	↑11.6	↓3.8
	I: 19.8	↓0.4	↓3.7	↑10.9	↓4.5
	C: 20.6	↓1.2	↓4.5	↑10.1	↓5.3
T12	W: 24.2	↓2.0	↓7.6	*	↓6.3
	B: 21.9	↑0.3	↓5.3	*	↓4.0
	I: 22.6	↓0.4	↓6.0	*	↓4.7
	C: 24.3	↓2.1	↓7.7	*	↓6.4

***W = White; B = Black; I = Indian; C = Coloured *↓= a decrease of *↑= an increase of *= equal to**

Table 5.7 A comparison of the IPD of this study to those of previous studies

Vertebral Level	Current Study	Scoles et al. (1988)		Ugur et al. (2001)		Datir and Mitra (2004) Indian	Singh et al. (2011) Indian	
	Mean IPD (mm)	**M**	**F**	**M**	**F**	**M**	**M**	**F**
T1	W: 26.1	↓4.9	↓5.6	↓6.9	↓7.4	↓4.9	↓6.4	↓6.5
	B: 24.7	↓3.5	↓4.2	↓5.4	↓5.9	↓3.4	↓4.9	↓5.0
	I: 24.7	↓3.5	↓4.2	↓5.4	↓5.9	↓3.4	↓4.9	↓5.0
	C: 25.6	↓4.4	↓5.1	↓6.3	↓6.8	↓4.3	↓5.8	↓5.9
T2	W: 22.3	*	*	↓4.9	↓6.0	=	↓5.2	↓5.2
	B: 20.5	*	*	↓3.1	↓4.2	↑1.8	↓3.4	↓3.4
	I: 20.9	*	*	↓3.5	↓4.6	↑1.4	↓3.8	↓3.8
	C: 21.7	*	*	↓4.3	↓5.4	↑0.6	↓4.6	↓4.6
T3	W: 20.4	↓3.0	↓3.8	↓4.5	↓5.7	↑2.3	↓4.2	↓4.1
	B: 18.9	↓1.5	↓2.3	↓3.0	↓4.2	↑3.8	↓2.7	↓2.6
	I: 19.1	↓1.7	↓2.5	↓3.2	↓4.4	↑3.6	↓2.9	↓2.8
	C: 19.8	↓2.4	↓3.2	↓3.9	↓5.1	↑2.9	↓3.6	↓3.5
T4	W: 19.4	*	*	↓5.4	↓5.7	↑3.6	↓3.6	↓3.5
	B: 17.8	*	*	↓3.8	↓4.1	↑5.2	↓2.0	↓1.9
	I: 18.3	*	*	↓4.3	↓4.6	↑4.7	↓2.5	↓2.4
	C: 18.9	*	*	↓4.9	↓5.2	↑4.1	↓3.1	↓3.0
T5	W: 18.5	*	*	↓5.4	↓5.6	↑5.0	↓3.1	↓2.7
	B: 17.4	*	*	↓4.3	↓4.5	↑6.1	↓2.0	↓1.6
	I: 17.5	*	*	↓4.4	↓4.6	↑6.0	↓2.1	↓1.7
	C: 18.2	*	*	↓5.1	↓5.3	↑5.3	↓2.8	↓2.4
T6	W: 18.5	↓2.0	↓3.0	↓5.4	↓5.4	↑5.2	↓3.0	↓2.7
	B: 17.3	↓0.8	↓1.8	↓4.2	↓4.2	↑6.4	↓1.8	↓1.5
	I: 17.4	↓0.9	↓1.9	↓4.3	↓4.3	↑6.3	↓1.9	↓1.6
	C: 18.2	↓1.7	↓2.7	↓5.1	↓5.1	↑5.5	↓2.7	↓2.4
T7	W: 18.5	*	*	↓5.4	↓5.0	↑6.4	↓2.8	↓2.8
	B: 17.1	*	*	↓4.0	↓3.6	↑7.8	↓1.4	↓1.4
	I: 17.3	*	*	↓4.2	↓3.8	↑7.6	↓1.6	↓1.6
	C: 18.0	*	*	↓4.9	↓4.5	↑6.9	↓2.3	↓2.3
T8	W: 18.7	*	*	↓4.6	↓4.7	↑7.0	↓2.9	↓2.5
	B: 17.4	*	*	↓3.3	↓3.4	↑8.3	↓1.6	↓1.2
	I: 17.7	*	*	↓3.6	↓3.7	↑8.0	↓1.9	↓1.5
	C: 18.0	*	*	↓3.9	↓4.0	↑7.7	↓2.2	↓1.8

T9	W: 18.9	↓2.1	↓3.0	↓3.7	↓4.1	↑7.9	↓3.0	↓2.7
	B: 17.5	↓0.7	↓1.6	↓2.3	↓2.7	↑9.3	↓1.6	↓1.3
	I: 17.4	↓0.6	↓1.5	↓2.2	↓2.6	↑9.4	↓1.5	↓1.2
	C: 18.5	↓1.7	↓2.6	↓3.3	↓3.7	↑8.3	↓2.6	↓2.3
T10	W: 19.5	*	*	↓3.1	↓3.4	↑8.6	↓3.6	↓3.1
	B: 18.0	*	*	↓1.6	↓1.9	↑10.1	↓2.1	↓1.6
	I: 18.1	*	*	↓1.8	↓2.1	↑9.9	↓2.3	↓1.8
	C: 19.1	*	*	↓2.7	↓3.0	↑9.0	↓3.2	↓2.7
T11	W: 21.5	*	*	↓3.5	↓3.9	↑7.5	↓4.6	↓4.1
	B: 19.1	*	*	↓1.1	↓1.5	↑9.9	↓2.2	↓1.7
	I: 19.8	*	*	↓1.8	↓2.2	↑9.2	↓2.9	↓2.4
	C: 20.6	*	*	↓2.6	↓3.0	↑8.4	↓3.7	↓3.2
T12	W: 24.2	↓4.3	↓4.8	↓4.7	↓5.0	*	↓5.6	↓4.7
	B: 21.9	↓2.0	↓2.5	↓2.4	↓2.7	*	↓3.3	↓2.4
	I: 22.6	↓2.7	↓3.2	↓3.1	↓3.4	*	↓4.0	↓3.1
	C: 24.3	↓4.4	↓4.9	↓4.8	↓5.1	*	↓5.7	↓4.8

***W = White; B = Black; I = Indian; C = Coloured *↓= a decrease of *↑= an increase of *= equal to (=) *M= Male *F= Female**

Spinal canal stenosis is quite rare in the thoracic spine in comparison to the cervical and lumbar regions (Palumbo et al., 2001). There are a few conditions that have been identified for causing a decreased IPD viz. Paget's disease and achondroplasia. The narrowest IPD was observed in Blacks which could indicate that they are more predisposed to developing spinal canal stenosis in comparison to the other race groups. A cadaveric study with a larger sample size of each race group is required to establish a more accurate and significant difference between the race groups that exist in South Africa. A digitised system could also be utilised to ensure validity and reliability of the results.

5.3 THE CORRELATION BETWEEN HEIGHT, WEIGHT, BODY MASS INDEX, INTERVERTEBRAL DISC HEIGHT, ANTERIOR VERTEBRAL BODY HEIGHT AND THE THORACIC KYPHOSIS

A Pearson's correlation test was performed by the researcher to establish if an association existed between the height, weight, BMI and the TK. The results of this study support the findings by Fotiadis et al. (2008) who concluded that there was no strong correlation between height, weight, BMI and the TK. A moderate to strong correlation was observed between the IVDH and TK in all the race groups, with the exception of the Blacks in whom a weak to moderate correlation was observed **(Table 4.22)**. The strongest correlations in each race group were as follows:

White: *r = 0.81* (T6-T7 IVD level)

Black: *r = 0.89* (T6-T7 IVD level)

Indian: *r = 0.82* (T6-T7 IVD level) and *r* = 0.84 (T12-L1 IVD level)

Coloured: *r = 0.73* (T7-T8 IVD level)

These values strongly support the view that the apex of the thoracic curve lies between the T6 and T8 vertebral levels (Bernhardt and Bridwell, 1984; Boyle et al., 2002; Masharawi et al., 2008). The AVBH also demonstrates a strong correlation with the TK, which shows that the curve of the thoracic spine is heavily reliant on the degree of anterior wedging of the VB. The significance was highest at the level of T11 (p = 0.001) followed by T9 (p = 0.002). These results strongly support the results of previous studies (Itoi et al., 1991; Singer et al., 1994; Manns et al., 1996; Goh et al., 2000).

5.4 THE CORRELATION BETWEEN THE WEIGHT, HEIGHT AND THE INTERVERTEBRAL DISC HEIGHT

A weak to moderate correlation was observed between the weight of the participants and the IVDH. There was a moderate correlation between the IVDH of T8-T9 and the weight of all race groups except Indians. An overall weak correlation was observed between the height of the participants and IVDH. These results, however, do not depict the true relationship between weight or height of the participants and IVDH. Since the weight and height of the participants were restricted as per the inclusion criteria, a study with a large sample size which includes participants with varying weights and heights is needed to establish a more accurate correlation between these factors and IVDH. There was a strong correlation between the BMI and IVDH at T8 (Whites) and T11, T12 (Indians). In Blacks and Coloureds, however, a weak correlation was observed between the BMI and the IVDH **(Table 4.28)**. These findings suggest that generally weight may affect the IVDH more than the height of an individual. In Whites and Indians, the BMI is also a major influencing factor in determining the IVDH. The clinical relevance of this observation is that overweight individuals (i.e. high BMI with weight as the major contributing factor) are more likely to develop thoracic IVD degeneration than individuals within the normal BMI range.

5.5 ETHICAL CONSIDERATION

The only reason asymptomatic individuals were selected for this study was because symptomatic participants might have influenced the results, as the aim of the study was to establish normative radiographic parameters. Although the entire radiographic procedure and exposure factors were in keeping with the accepted practice, it is not without risk to the participants as they were exposed to radiation. It is, therefore, recommended that other approaches be utilised to establish normative reference values where participants are not exposed to radiation (e.g. MRI) or even cadaveric studies.

CHAPTER SIX

CONCLUSION AND RECOMMENDATIONS

6.1 CONCLUSION

An overall mean (± SD) of 22.2° (± 8.5°) for the TK was observed. There were no significant (p > 0.05) differences in the TK between the four race groups. The mean (± SD) of the AVBH, PVBH and the IPD for the various thoracic vertebral levels is shown in **Tables 4.6, 4.9, 4.14**. The median (IQR) of the IVDH at the respective thoracic levels is shown in Table 4.12. This is the first study that has reported on the mid-IVDH for the thoracic spine for any race or sex. Significant differences were observed in the AVBH **(Table 4.7)**, PVBH **(Table 4.10)**, IVDH **(Table 4.13)** and IPD **(Table 4.15)**. The Alternate Hypothesis (H_a) is, therefore, rejected for the TK, but partially accepted for the other thoracic radiographic parameters.

When one examines the results of this study, it is immediately clear that there are differences in certain selected radiographic parameters between the races in South Africa. Considerable differences are also observed between South African males and other race groups from different geographic locations. This implies that reference values should be age, sex and geographic race-specific. These normative reference values are especially important to South African health care professionals that focus and specialise in the diagnoses and treatment of various spinal conditions and disorders.

6.2 RECOMMENDATIONS

The major recommendations arising from the results of this study are:

- This study should be conducted with female participants of the four main race groups in South Africa. A digitised system should be utilised to minimise human error and to ensure accuracy of the results.

- A study using a larger sample size should be considered to determine the intra-examiner and inter-examiner reliability of the radiographic parameters.

- This study should be made available to other health care professionals such as, medical doctors, radiologists and spinal and orthopaedic surgeons so as to provide more knowledge with regards to the diversity of various parameters between the different race groups of the South African populace.

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APPENDIX A

DURBAN UNIVERSITY *of* TECHNOLOGY

INSTITUTIONAL RESEARCH ETHICS COMMITTEE (IREC)

8 October 2012

IREC Reference Number: **REC 40/12**

Ms D Govender
26 Iduma Close
Izinga Ridge
Umhlanga Rocks

Dear Ms Govender

Racial variations of selected thoracic spine radiographic parameters of males in the greater Durban area

I am pleased to inform you that Full Approval has been granted to your proposal REC 40/12.

The ethical requirements have been met by the researcher however; the following correction is required:

- Section C (ethics): 'category 2 (expedited review) should be selected as opposed to 'full ethics review.'

The Proposal has been allocated the following Ethical Clearance number IREC 038/12. Please use this number in all communication with this office.

Approval has been granted for a period of one year, before the expiry of which you are required to apply for safety monitoring and annual recertification. Please use the Safety Monitoring and Annual Recertification Report form which can be found in the Standard Operating Procedures [SOP's] of the IREC. This form must be submitted to the IREC at least 3 months before the ethics approval for the study expires.

Any adverse events [serious or minor] which occur in connection with this study and/or which may alter its ethical consideration must be reported to the IREC according to the IREC SOP's. In addition, you will be responsible to ensure gatekeeper permission.

Please note that any deviations from the approved proposal require the approval of the IREC as outlined in the IREC SOP's.

Yours Sincerely

[redacted]

Dr D F Naude
Chairperson: IREC

APPENDIX B

MIDBACK X-RAYS

IF YOU ARE MALE

- **BETWEEN THE AGES OF 18-45 YEARS**
- **1.65m-1.8m Tall AND**
- **WEIGH 70-90kgs**

YOU MAY BE ELIGIBLE TO PARTICIPATE IN MY RESEARCH.

IF YOU ARE INTERESTED CONTACT: DERUSHA OR THE CHIROPRACTIC DAY CLINIC, DURBAN UNIVERSITY OF TECHNOLOGY

076 707 3927/031 – 373 2205

Appendix C

INSTITUTIONAL RESEARCH ETHICS COMMITTEE (IREC)
LETTER OF INFORMATION AND CONSENT

Title of the Research Study: Racial variations of selected thoracic spine radiographic parameters of males in the greater Durban area.

Principle Investigator/s/researcher: Derusha Govender

Co-Investigator/s/supervisor/s: Dr J. Shaik

Brief Introduction and Purpose of the Study: You have been selected to be part of my study. X-rays are used by chiropractors to look for disease or fracture of bones. This may include the spine. For a chiropractor to effectively diagnose conditions on x-rays he needs to know what the normal spinal x-ray looks like and what the normal spinal measurements are. In the midback region also known as the thoracic spine, there is not much research on what the normal values should be. Some researchers have shown that race and sex may play important roles in working out what normal values should be. Therefore, I am doing this research which will try and work out what normal values for the thoracic spine should be for Whites, Indians, Coloureds and Blacks in the greater Durban area. I will require 20 male participants for each of the 4 main racial groups.

Outline of the Procedures:
First I will explain the study to you and you must read this document. If you are willing to take part in the study, you must sign an informed consent form. By signing this form, you agree to voluntarily take part in my study. Secondly, I will take a complete case history and perform a physical examination together with an orthopaedic examination of your midback region this will take approximately 3 hours. If there are no problems and you meet the criteria for taking part in this study, you will be included otherwise you will not be eligible to take any further part in the study. Finally, I will make an appointment for you to take x-rays of your midback region at the Radiography Clinic. You must come to the Radiography Clinic on your appointment day and time and I will take the x-rays this will take approximately 30 minutes. <u>It is very important that you are punctual for all your appointments</u>. If you develop midback pain or injury to this area between the time of the initial consult and the day of your x-ray, you will be excluded from the study and referred to the Chiropractic Day Clinic. Your name will not appear in the actual x-rays or in my dissertation or any research article. I will use a code instead of your name. This ends your participation in the study. I will then evaluate the x-rays according to my study protocol and report the results in my dissertation and/or in a journal. The x-rays from this study will also be used for teaching purposes; however your identity will be blocked and not revealed.

To be part of this study you must:
Be male and between the ages of 18-45 years.
Be between 1.65m-1.8m tall and weigh between 70-90kgs.
Give informed consent in writing to participate in the research.
Be of Black, White, Coloured or Indian racial origin (this is purely for research purposes and is not in any way prejudicial to you).

You will not be eligible to take part in this study if you

Had any x-rays within a month before the study begins

Have arthritic disease in the midback, surgery or trauma to the spine determined in the initial consultation at the Chiropractic Day Clinic.

Any midback injuries sustained to the back between the initial consultation and the radiographic appointment (i.e. the appointment when x-rays of your midback are taken)

Have had any injury, trauma or surgery to your back prior to your taking part in this study

Risks or Discomforts to the Subject:

You will be exposed to ionised radiation (x-rays) for a very short duration. There are reports that exposure to x-rays could be put one at risk of genetic disorders or cancers but the risks are minimal. It, is however, anticipated that no adverse effects from this study are anticipated.

Benefits:

You will have a full medical history, physical examination and thoracic spine orthopaedic assessment performed.
You will receive a set of your thoracic spine x-rays free of charge.
You will be eligible for a voucher for the Chiropractic Day Clinic should you develop neck, back pain, shoulder, knee or any extremity pain to be used within three years of your first consultation at the Chiropractic Day Clinic consultation.
An x-ray report together with a summary of the results of this study will be sent to you via post or e-mail once this study is completed. You must let me know which you would prefer.

Reason/s why the Subject May Be Withdrawn from the Study:

If you sustain any injuries to the back during the initial consultation and the radiographic appointment
You become ill during your participation in this study

Remuneration:

There is no remuneration for participating in the study. You will, however receive a voucher for the Chiropractic Day Clinic should you develop neck, back pain, shoulder, knee or any extremity pain to be used within three years of your first consultation at the Chiropractic Day Clinic consultation. The voucher must be presented to the reception staff when you come to the Chiropractic Day Clinic for your free conservative treatment.

Costs of the Study:

You will not need to pay for any of the research consultations or the x-rays. Unfortunately, due to financial constraints, we cannot cover your transport costs to get to the Chiropractic Day Clinic or the Radiography Clinic for your appointments.

Confidentiality:

All personal details and relevant information gathered through the research process will only be accessible by me and my supervisor. Once all the relevant data has been gathered and analyzed, it will be disposed of in a professional manner, not being made available to the general public. Your name will not appear in the actual x-rays or in my dissertation or any research article. The x-rays will be used for teaching purposes however your personal details will not be available.

Research-related Injury:

You will not be compensated for should a research-related injury or adverse reaction occur (it is highly unlikely you will be injured or have an adverse reaction during your participation in this study). However if there are any research-related injuries or adverse effects during the period of this study, these will be reported to the Institutional Research Ethics Committee (Lavisha Deonarian- 031 373 2900). By being x-rayed, you are being exposed to radiation. However, the dose is minimal and there are no anticipated side-effects.

Persons to Contact in the Event of Any Problems or Queries: (Supervisor and details; HOD and details)
Dr J. Shaik (031) 373 2588
Dr A. Docrat (031) 373 2589
Ms Lavisha Deonarian, Faculty of Health Sciences Officer, (031) 373 2900

Statement of Agreement to Participate in the Research Study:
(I,…………………………………………………………………………(subject's full name), ID number…………………………………………, have read this document in its entirety and understand its contents. Where I have had any questions or queries, these have been explained to me by ……………………………………….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's name (print): ....Witness's signature..

Date: …………………

DUT DURBAN UNIVERSITY OF TECHNOLOGY — DEPARTMENT OF CHIROPRACTIC AND SOMATOLOGY

CHIROPRACTIC PROGRAMME

CHIROPRACTIC DAY CLINIC CASE HISTORY

Patient: ______________________________ Date: __________

File #: __________ Age: __________

Sex: __________ Occupation: ______________________________

Student: ______________________ 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:

<u>Student's Case History:</u>

1. Source of History:

2. Chief Complaint: (patient's own words):

3. Present Illness:

	Complaint 1(principle complaint)	**Complaint 2 (additional or secondary complaint)**
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:
- Other (please list):

Tobacco
Alcohol
Social Drugs

7. Immediate Family Medical History:

Age of all family members
Health of all family members
Cause of Death of any family members

	Noted	Family member		Noted	Family member
Alcoholism			Headaches		
Anaemia			Heart Disease		
Arthritis			Kidney Disease		
CA			Mental Illness		
DM			Stroke		
Drug Addiction			Thyroid Disease		
Epilepsy			TB		
Other (list)					

8. Psychosocial history:

Home Situation and daily life
Important experiences
Religious Beliefs

9. Review of Systems (please highlight with an asterisk those areas that are a problem for the patient and require further investigation)

General

Skin

Head

Eyes

Ears

Nose/Sinuses

Mouth/Throat

Neck

Breasts

Respiratory

Cardiac

Gastro-intestinal

Urinary

Genital

Vascular

Musculoskeletal

Neurologic

Haematological

Endocrine

Psychiatric

CHIROPRACTIC PROGRAMME

Chiropractic DAY CLINIC
PHYSICAL EXAMINATION

Patient:_______________________________File#:__________Date:_______

Clinician:____________________________Signature:__________________

Student:_____________________________Signature:__________________

1. VITALS

Pulse rate:
Respiratory rate:
Blood pressure: R L Medication if hypertensive:
Temperature:
Height:
Weight: Any change Y/N If Yes: how much gain/loss

Over what period

2. GENERAL EXAMINATION

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

Urinalysis:

3. CARDIOVASCULAR EXAMINATION

1) Is this patient in **Cardiac Failure**?
2) Does this patient have signs of **Infective Endocarditic**?
3) Does this patient have **Rheumatic Heart Disease?**

Inspection
- Scars
- Chest deformity:
- Precordial bulge:
- Neck -JVP:

Palpation:
- Apex Beat (character + location):
- Right or left ventricular heave:
- Epigastric Pulsations:
- Palpable P2: Palpable A2:

Pulses:
- General Impression:
- Radio-femoral delay:
- Carotid:
- Radial:
- Dorsalis pedis:
- Posterior tibial:
- Popliteal:
- Femoral:

Percussion: - borders of heart

Auscultation: - heart valves (mitral, aortic, tricuspid, pulmonary)
- Murmurs (timing, systolic/diastolic, site, radiation, grade).

4. RESPIRATORY EXAMINATION

1) Is this patient in **Respiratory Distress**?

Inspection
- Barrel chest:
- Pectus carinatum/cavinatum:
- Left precordial bulge:
- Symmetry of movement:
- Scars:

Palpation
- Tracheal symmetry:
- Tracheal tug:
- Thyroid Gland:
- Symmetry of movement (ant + post)
- Tactile fremitus:

Percussion
- Percussion note:
- Cardiac dullness:
- Liver dullness:

Auscultation
- Normal breath sounds bilateral:
- Adventitious sounds (crackles, wheezes, crepitations)
- Pleural frictional rub:
- Vocal resonance - Whispering pectoriloquy:
- Bronchophony:
- Egophony:

5. ABDOMINAL EXAMINATION

1) Is this patient in **Liver Failure**?

Inspection
- Shape:
- Scars:
- Hernias:

Palpation
- Superficial:
- Deep = Organomegally:
- Masses (intra- or extramural)
- Aorta:

Percussion
- Rebound tenderness:
- Ascites:
- Masses:

Auscultation
- Bowel sounds:
- Arteries (aortic, renal, iliac, femoral, hepatic)

Rectal Examination
- Perianal skin:
- Sphincter tone & S4 Dermatome:
- Obvious masses:
- Prostate:
- Appendix:

6. G.U.T EXAMINATION

External genitalia**:**
Hernias:
Masses:
Discharges:

7. NEUROLOGICAL EXAMINATION

Gait and Posture
- Abnormalities in gait:
- Walking on heels (L4-L5):
- Walking on toes (S1-S2):
- Romberg's test (Pronator Drift):

Higher Mental Function
- Information and Vocabulary:
- Calculating ability:
- Abstract Thinking:

G.C.S.:
- Eyes:
- Motor:
- Verbal:

Evidence of head trauma:

Evidence of Meningism:
- Neck mobility and Brudzinski's sign:
- Kernig's sign:

Cranial Nerves:

I Any loss of smell/taste:
Nose examination:

II External examination of eye:
- Visual Acuity:
- Visual fields by confrontation:
- Pupillary light reflexes = Direct:
  = Consensual:
- Fundoscopy findings:

III Ocular Muscles:
Eye opening strength:

IV Inferior and Medial movement of eye:

V
a. Sensory
- Ophthalmic:
- Maxillary:
- Mandibular:

b. Motor
- Masseter:
- Jaw lateral movement:

c. Reflexes
- Corneal reflex
- Jaw jerk

VI Lateral movement of eyes

VII
a. Motor
- Raise eyebrows:
- Frown:
- Close eyes against resistance:
- Show teeth:
- Blow out cheeks:

b. Taste
- Anterior two-thirds of tongue:

VIII General Hearing:
Rinne's = L: R:
Weber's lateralisation:
Vestibular function - Nystagmus:
- Romberg's:
- Wallenberg's:
Otoscope examination:

IX & X Gag reflex:
Uvula deviation:
Speech quality:

XI Shoulder lift:
S.C.M. strength:

XII Inspection of tongue (deviation):

Motor System:

a. Power
- Shoulder = Abduction & Adduction:
  = Flexion & Extension:
- Elbow = Flexion & Extension:
- Wrist = Flexion & Extension:
- Forearm = Supination & Pronation:
- Fingers = Extension (Interphalangeals & M.C.P's):
- Thumb = Opposition:
- Hip = Flexion & Extension:
  = Adduction & Abduction:
- Knee = Flexion & Extension:
- Foot = Dorsiflexion & Plantar flexion:
  = Inversion & Eversion:
  = Toe (Plantarflexion & Dorsiflexion):

b. Tone
- Shoulder:
- Elbow:
- Wrist:
- Lower limb - Int. & Ext. rotation:
- Knee clonus:
- ankle clonus:

c. Reflexes
- Biceps:
- Triceps:
- Supinator:
- Knee:
- Ankle:
- Abdominal:
- Plantar:

Sensory System:

a.	Dermatomes	- Light touch:
		- Crude touch:
		- Pain:
		- Temperature:
		- Two point discrimination:
b.	Joint position sense	- Finger:
		- Toe:
c.	Vibration:	- Big toe:
		- Tibial tuberosity:
		- ASIS:
		- Interphalangeal Joint:
		- Sternum:

Cerebellar function:

Obvious signs of cerebellar dysfunction:

= Intention Tremor:
= Nystagmus:
= Truncal Ataxia:

Finger-nose test (Dysmetria):
Rapid alternating movements (Dysdiadochokinesia):
Heel-shin test:
Heel-toe gait:
Reflexes:
Signs of Parkinsons:

8. SPINAL EXAMINATION: (See Regional examination)

Obvious Abnormalities:
Spinous Percussion:
R.O.M:
Other:

9. BREAST EXAMINATION:

Summon female chaperon.

Inspection	- Hands rested in lap:
	- Hands pressed on hips:
	- Arms above head:
	- Leaning forward:
Palpation	- masses:
	- tenderness:
	- axillary tail:
	- nipple:
	- regional lymph nodes:

APPENDIX F

THORACIC SPINE REGIONAL EXAMINATION

Patient:______________________________________File:__________ Date:_________________________

Student:______________________________________Signature:____________________________________

Clinician: _____________________________________Signature:____________________________________

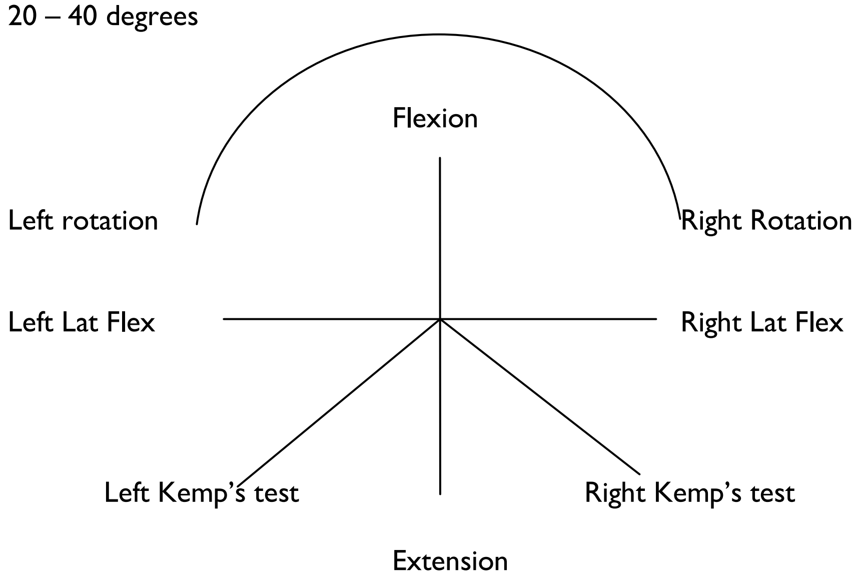
STANDING:

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): LOCAL PAIN (T/S) DISTAL PAIN (L/S) DISTAL PAIN (LEG)

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	T11	T12	L1	L2	L3	L4	L5	S1	S2	S3
Dermatomes	T11	T12	L1	L2	L3	L4	L5	S1	S2	S3
Reflexes	Patella – Left					Achilles – Left				
	Patella - Right					Achilles – Right				

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

Data Collection Sheet 1

Group	Race
A	White
B	Black
C	Indian
D	Coloured

Demographic data: Males

Group							Exercise		
No.	File No.	Code	Age	Occupation	Height	Weight	Type	Frequency	Duration
1									
2									
3									
4									
5									
6									
7									
8									
9									
10									
11									
12									
13									
14									
15									
16									
17									
18									
19									
20									
		Average							
		Range							

Radiographic Data: Males

Thoracic Kyphosis - Degrees

No.	Code	TK	No.	Code	TK
1			11		
2			12		
3			13		
4			14		
5			15		
6			16		
7			17		
8			18		
9			19		
10			20		
				Average	
				Range	

IVD Height- millimetres (mm)

No.	Code	T5	T6	T7	T8	T9	T10	T11	T12
1.									
2.									
3.									
4.									
5.									
6.									
7.									
8.									
9.									
10.									
11.									
12.									
13.									
14.									
15.									
16.									
17.									
18.									
19.									
20.									
	Range								
	Average								

Anterior Vertebral Body Height- millimetres (mm)

No.	Code	T5	T6	T7	T8	T9	T10	T11	T12
1.									
2.									
3.									
4.									
5.									
6.									
7.									
8.									
9.									
10.									
11.									
12.									
13.									
14.									
15.									
16.									
17.									
18.									
19.									
20.									
	Range								
	Average								

Posterior Vertebral Body Height- millimetres (mm)

No.	Code	T5	T6	T7	T8	T9	T10	T11	T12
1.									
2.									
3.									
4.									
5.									
6.									
7.									
8.									
9.									
10.									
11.									
12.									
13.									
14.									
15.									
16.									
17.									
18.									
19.									
20.									
	Range								
	Average								

Interpedicular Distance- millimetres (mm)

No.	Code	T1	T2	T3	T4	T5	T6	T7	T8	T9	T10	T11	T12
1.													
2.													
3.													
4.													
5.													
6.													
7.													
8.													
9.													
10.													
11.													
12.													
13.													
14.													
15.													
16.													
17.													
18.													
19.													
20.													
	Range												
	Ave.												