ETHNIC VARIATIONS OF SELECTED CERVICAL SPINE RADIOGRAPHIC PARAMETERS OF MALES IN KWAZULU NATAL

By

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I, Ashveer Roopnarian, 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 divine holy trinity: Brahma, Vishnu and Maheshwar for guiding me, giving me strength and for blessing me with the beautiful people in my life.

My compassionate grandparents, Mrs V. Roopnarian and Mr and Mrs Rampersadh and the late Mr. H. Roopnarian for his ever positive advice. My dad Mr. A. Roopnarian and my mum Mrs. S. Roopnarian, thank you for being so loving and supportive in my life. I shall forever be greatful for the education that you have provided me with in all aspects of life and for the faith that you have instilled in me, I love you. My brothers Tashay and Shivek and my little sister Shreya, thank you for all the laughter, care and closeness during those arduous times, I love you. My true love Charlene, for all the devotion, love and time you have for me, I am very greatful. Thank you for being so special and assisting me in every way possible. My Aunt Venetia and Uncle Ashen for giving excellent advice and for your assistance, I thank you. Dr. J. Shaik for believing in me. I am truly blessed to have all these inspirational individuals in my life and I thank you all.

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ABSTRACT

Introduction: Radiographic parameters of the cervical spine are utilized by chiropractors and spinal surgeons for making diagnoses and determining management protocols. However several researchers have reported discrepancies in these parameters which need to be investigated across ethnic groups and gender.

Aim: To evaluate the normal selected cervical spine radiographic parameters i.e. the cervical lordosis (CL), sagittal canal diameter (SCD), interpedicular distance (IPD), and the cervical gravity line (CGL) in apparently healthy young to middle-aged males across four ethnic groups in Durban, KwaZulu Natal.

Participants: Eighty healthy male participants between 18 and 45 years of age of White, Black, Indian and Coloured ethnicity.

Methodology: A case history, physical examination and an orthopedic assessment of the cervical spine was conducted for each participant. Study-specific data such as age, ethnicity, weight and height were recorded. A lateral and an A-P radiograph of the cervical spine was taken of each participant. Selected radiographic parameters viz. SCD, IPD, CL, CGL were assessed and recorded. SPSS version 15.0 (SPSS Inc., Chicago, Illinois, USA) was used for data analysis.

Results: The mean (± SD) values of the CL, SCD and IPD are shown in the table below for the respective ethnic groups

Parameter	**Ethnic Group**			
	Black (Mean (± SD))	**White (Mean (± SD))**	**Indian (Mean (± SD))**	**Coloured (Mean (± SD))**
CL° (C1-C7 method)	42.6° (± 9.6°)	46.2° (± 11.0°)	46.5° (± 11.3°)	47.7° (± 9.1°)
CL° (C2-C7 method)	15.1° (± 6.4°)	17.4° (± 9.3°)	13.1° (± 10.2°)	18.1° (± 10.4°)
SCD (mm)				
C2	22.1mm (± 1.6)	24.1mm (± 1.4)	22.8mm (± 1.7)	22.9mm (± 1.5)
C3	19.5mm (± 1.6)	20.6mm (± 1.4)	19.7mm (± 1.6)	20.0mm (± 1.5)
C4	18.6mm (± 1.9)	19.9mm (± 1.3)	19.1mm (± 1.6)	19.5mm (± 1.3)
C5	18.9mm (± 1.8)	20.0mm (± 1.5)	19.3mm (± 1.7)	19.8mm (± 1.6)
C6	18.8mm (± 1.7)	20.4mm (± 1.5)	19.5mm (± 1.6)	20.0mm (± 1.8)

C7	18.5mm (± 1.7)	20.3mm (± 1.5)	19.4mm (± 1.6)	19.7mm (± 1.9)
IPD (mm)				
C3	28.2mm (± 1.2)	28.9mm (± 1.8)	27.8mm (± 1.1)	29.1mm (± 1.4)
C4	28.6mm (± 1.4)	29.6mm (± 1.8)	28.5mm (± 1.4)	29.5mm (± 1.6)
C5	29.4mm (± 1.2)	30.0mm (± 1.7)	28.8mm (± 1.2)	30.1mm (± 1.5)
C6	29.3mm (± 1.6)	30.7mm (± 1.6)	30.0mm (± 1.6)	30.1mm (± 1.5)
C7	29.3mm (± 1.2)	30.1mm (± 1.5)	29.6mm (± 1.6)	30.3mm (± 1.9)

There was anterior placement of the CGL in 60% of the Black ethnic group, 45% of the White ethnic group, 55.6% of the Indian ethnic group and 52.6% of the Coloured ethnic group. No significant differences in mean CL was observed across the four ethnic groups for both methods utilized (p > 0.05). The significant differences in SCD lay between the White and Black ethnic groups at C2, C6 and C7 (p = 0.002, 0.030 and 0.017, respectively, ANOVA). The C3 and C5 IPD varied significantly between the Coloured and Indian ethnic group (p = 0.048 and 0.027, respectively, ANOVA). The CGL was not influenced by the CL in all the ethnic groups.

Conclusion: Significant differences were observed between ethnic groups for the SCD and IPD. These will assist South African health care practitioners with patient management within these ethnic groups when diagnosing spinal stenosis and tumors. A larger South African based population should be evaluated to confirm the trends observed utilizing digitized diagnostic imaging modalities including radiographs, CT and MRI scans as errors may occur during manual assessment of conventional radiographs.

LIST OF SYMBOLS AND ABBREVIATIONS

=:	Results are equal to those of other studies
>:	Greater than
↑:	Increase /increased/results are more than the findings of other studies
↓:	Decrease/decreased/results are less than the findings of other studies
ABCS:	Alignment, Bone, Cartilage and Soft tissue
AF:	Annulus fibrosis
ALL:	Anterior longitudinal ligament
ANOVA:	Analysis of variance
A-P:	Anterior to posterior
BMI:	Body mass index
CDC:	Chiropractic Day Clinic
C:	Cervical
CL:	Cervical lordosis
CGL:	Cervical gravity line
CT:	Computed tomography
DUT:	Durban University of Technology
F:	Female
FFD:	Focal film distance
IVD:	Intervertebral disc
IVF:	Intervertebral foramina
IPD:	Interpedicular distance
Kv:	Killovoltage
L:	Lumbar
M:	Male
mAS:	Milliamperes per second
mm:	Millimeters
MRI:	Magnetic resonance imaging
***n*:**	Sample size/count
N/A:	Not applicable/Not available
NP:	Nucleus pulposis

PLL:	Posterior longitudinal ligament
RC:	Radiographic Clinic
SCD:	Sagittal canal diameter
SP:	Spinous process
SPSS:	Statistical Package for the Social Sciences
TVP:	Transverse process
USA:	United States of America
VB:	Vertebral body
yrs:	Years

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CHAPTER ONE

INTRODUCTION

1.1 INTRODUCTION TO THE STUDY

Conventional plain film radiography is the most extensively utilized imaging technique in clinical practice for skeletal abnormalities and musculoskeletal conditions (Yochum and Rowe, 2005). It is preferred first over other imaging modalities due to its affordability, availability and ability to demonstrate anatomic bony structure (Ory, 2003; Yochum and Rowe, 2005). The primary reasons for requesting cervical spine radiographs include assistance in confirming a diagnosis and shortening the list of other possible diagnoses (Yochum and Rowe, 2005; McAviney *et al*., 2005).

Cervical spine radiographs may be evaluated according to the ABCS (**A**lignment, **B**one, **C**artilage and **S**oft Tissue) method described by Yochum and Rowe (2005). Various radiographic parameters which include the cervical lordosis (CL), cervical gravity line (CGL), sagittal canal diameter (SCD) and if required, the interpedicular distance (IPD) can then be assessed for diagnostic and therapeutic interventions in the anterior-posterior (A-P) and lateral views accordingly for variation from the normal range and mean values, provided the radiograph quality is satisfactory (Lim and Wong, 2004; McAviney *et al*., 2005; Yochum and Rowe, 2005). Cervical spine stenosis, spondylosis, post-traumatic and post-surgical states can be evaluated on radiographs (Herzog *et al*., 1991; Tierney *et al*., 2002; Yochum and Rowe, 2005).

Discrepancies in standard values for selected radiographic parameters in the cervical spine when assessed across ethnic groups and gender are described by several authors (Lim and Wong, 2004; Tatarek, 2005; Tossel, 2007). Since standard radiographic measurements for evaluating the alignment and anatomical structure of the cervical spine appear to lack a broadly established guideline, there is a need for these parameters to be investigated across different ethnic groups and gender (McAviney *et al*., 2005; Christensen and Hartvigsen, 2008).

Numerous studies have reported results that are inconsistent for the selected cervical spine radiographic parameters (Hinck *et al*., 1962; Jochumsen, 1969; Cooke and Wei, 1988; Owens and Hoiriis, 1990; Lim and Wong, 2004; Tatarek, 2005; Tecco and Festa, 2007; Tossel, 2007). However these variations could be explained by differences in population samples and methods employed for evaluation and gender.

There are a limited number of studies which describe variation in the measurement of cervical spine radiographic parameters due to ethnicity (Murone, 1974; Solow *et al*., 1982; Lim and Wong, 2004; Tatarek, 2005) and even fewer in the South African population (Tossel, 2007).

McAviney *et al.* (2005) determined a clinically significant therapeutic range for the CL in a study which compared its relation to neck complaints and Gay (1993) reported that the CL is to a degree gender dependent. The CGL is used to determine the gravitational force acting at the cervicothoracic junction (Fox and Young, 1954; Yochum and Rowe, 2005), but there is paucity in the literature with regards to the effect that gender and ethnicity has on this parameter. These are useful parameters to evaluate with respect to cervical spine biomechanics. Christensen and Hartvigsen (2008) recommended that the CL be evaluated amongst different population groups due to discrepancies in the results of previous studies and to determine if differences in the values of the CL have any clinical significance.

Some researchers also recommended that the SCD be based on ethnicity and gender because the significant differences between ethnic groups may affect the diagnosis of cervical spine stenosis (Lee *et al.,* 1994; Lim and Wong, 2004; Tatarek, 2005; Tossel, 2007). However Taitz (1996) reported that there were no differences in SCD between gender while Yochum and Rowe (2005) recommended a common value for SCD in gender. Significant differences in SCD and IPD in the lumbar spine were observed between genders and in two South African ethnic groups (Eisenstein, 1976; Naidoo, 2008). It is, therefore, hypothesised that similar differences would be observed in the cervical spine.

The IPD assists practitioners in the diagnosis of cervical spine stenosis and intraspinal neoplasms (Tatarek, 2005; Yochum and Rowe, 2005) as well as post-operative assessment for trans-pedicular screw fixation (Ugur *et al.,* 2000).

It is essential that a chiropractor be familiar with normal radiographic ranges and values from which to draw comparisons (McAviney *et al*., 2005). However, these values will assist not only chiropractors but also spinal surgeons in making accurate diagnoses within the respective gender and ethnic group for spinal stenosis, tumors and post-traumatic, post-surgical and biomechanical assessment of the cervical spine.

If variations between ethnic groups and within the male gender were to be observed in this study then this will be an advantage to chiropractors and spinal surgeons in the South African setting with respect to patient assessment and management since the data obtained will provide more accurate ranges and values specific to these ethnic and gender groups. Therefore, the aim of this research study was to evaluate the normal selected cervical spine radiographic parameters in apparently healthy young to middle-aged males across four ethnic groups in South Africa.

1.2 AIMS AND OBJECTIVES OF THE STUDY

The aim of this study was:

To evaluate the normal selected cervical spine radiographic parameters (CL, SCD, IPD and CGL) in apparently healthy young to middle-aged males across four ethnic groups in Durban, KwaZulu Natal.

Specific objectives were identified and these included:

1.2.1 The recording of the radiographic measurements of the cervical spine of the selected participants with respect to the following:

1. CL
2. SCD
3. IPD
4. CGL

1.2.2 To determine if there was variation in the selected radiographic parameters within and between the Black, White, Indian and Coloured ethnic groups. For the purpose of this study the Coloured ethnic group was defined as those participants of mixed White and Black ethnic descent (Oxford Dictionaries, 2011).

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1.2.3 To determine if there was a significant association between CL and body mass index (BMI).

1.2.4 To determine if the CL had an influence on the CGL.

1.3 HYPOTHESES OF THE STUDY

The Alternate Hypothesis (Ha) was set which stated that there was a significant association between the CL and BMI. The Alternate Hypothesis (Ha) was set which stated that the CL will significantly influence the CGL.

1.4 SCOPE OF THE STUDY

The results of 80 apparently healthy young to middle-aged males of Black, White, Indian and Coloured ethnicity who met all the inclusion criteria are reported in this dissertation. The participants were informed of the nature of the study and written informed consent was obtained from each participant. All participants underwent a case history, physical examination and cervical spine orthopedic examination. Erect lateral and A-P cervical radiographs were taken for each participant and the selected cervical spine radiographic parameters were evaluated by the researcher.

1.5 LIMITATIONS OF THE STUDY

The sample size was limited to 80 individuals due to financial and human resource constraints. The four radiographic parameters were selected on the basis of their usefulness to clinicians and availability of literature. The assessments were done manually by the researcher on the plain film radiographs rather than on digitized images using computer aided programmes.

The participants had to be over the age of 18 as per the guidelines of the South African Medical Research Council (South African Medical Research Council Guidelines on Ethics for Medical Research, 2002) and under the age of 45 as the incidence of degenerative changes in the cervical spine and neck pain reportedly increased after the fourth decade of life (Grob *et al*., 2007). The degenerative changes that occur in the cervical spine are known to affect the CL due to spondylosis and the SCD due to osteophyte formation (Yochum and Rowe, 2005).

The three views that are normally requested for in a cervical spine radiograph series are the A-P, lateral and A-P open mouth views. The A-P open mouth view assesses the atlantoaxial alignment which is mainly altered by a dens fracture, alar ligament instability or atlantoaxial subluxation (Yochum and Rowe, 2005). The A-P open mouth view was excluded due to financial constraints, this view was also not necessary and in the interests of radiation protection. The A-P and lateral cervical spine radiographic views allow for the evaluation of the selected radiographic parameters.

CHAPTER TWO

LITERATURE REVIEW

2.1 INTRODUCTION

Conventional radiography is utilized in the evaluation of cervical spine disorders and biomechanics and is recognized as a primary diagnostic investigative tool for skeletal abnormalities (Bland, 1994; Yochum and Rowe, 2005). Studies have reported that ethnicity and gender may contribute to differences in the selected radiographic parameters of the cervical spine (Bland, 1994; Lim and Wong, 2004; McAviney *et al*., 2005; Tatarek, 2005; Tossel, 2007). Several researchers recommend that these parameters be investigated in different ethnic groups and gender to determine its possible variation and significance (Lim and Wong, 2004; Tossel, 2007; Christensen and Hartvigsen, 2008).

2.2 AN OVERVIEW OF THE RELEVANT BONY AND SOFT TISSUE ANATOMY OF THE CERVICAL SPINE

The cervical spine is situated in the neck between the skull and the thoracic spine and consists of seven vertebrae (C1-C7) and serves as a shock absorber for the head and brain (Bland, 1994; Moore and Dalley, 1999; Nordin and Frankel, 2001). It also assists with the weight transfer and bending movements caused by the head. Vital structures such as the spinal cord, brainstem and neurovascular components traverse the neck into and out of the skull (Nordin and Frankel, 2001).The cervical spine comprises of bony vertebrae that are either typical or atypical, soft tissue structures such as muscles, ligaments, the intervertebral discs (IVDs), blood vessels and neural structures such as the spinal cord.

2.2.1 Typical Cervical Vertebrae

The typical cervical vertebra consists of a small vertebral body (VB) that is greater in length from side to side rather than A-P. It is convexly-shaped inferiorly and concave superiorly. The spinous process (SP) is usually short, bifid and has two tubercles (Moore and Dalley, 1999). The transverse processes (TVPs) contain a lumen known as the foramen transversarium for the vertebral vessels to traverse and they terminate laterally as tubercles (Moore and Dalley, 1999; Standring, 2005).

Pedicles are attached in the centre between the distal surfaces of the VB, directed posterolaterally to link up with the laminae which are directed posteromedially to join and form a more or less triangular-shaped vertebral foramen (Standring, 2005). The articular processes possess superior and inferior articular facets that are directed superoposteriorly and inferoposteriorly respectively (Moore and Dalley, 1999; Standring, 2005).

2.2.2 Atypical Cervical Vertebrae

a) The Atlas (C1)

This vertebra which lacks a body and a SP, is made up of two lateral masses which attach via its posterior and anterior arches (Moore and Dalley, 1999; Standring, 2005). It provides support for the head by allowing the occipital condyles of the head to rest in its concave superior articular facets. Its inferior articular facets are directed inferomedially (Moore and Dalley, 1999). The vertebral canal contains the dens of the axis which rests securely against the posterior surface of the anterior arch due to the transverse ligament. The posterior arch allows for attachment of the highest pair of ligamenta flava at its inferior border and the posterior atlanto-occipital membrane at its inferior border (Standring, 2005). The TVPs of the atlas provide strong attachment points for muscles which assist the head to balance via subtle and precise movements of the upper neck (Standring, 2005).

b) The Axis (C2)

This vertebra is known to be the strongest of the cervical spine. It acts as a pivot for rotation of the atlas and the head around the superiorly projecting dens which has a groove posteriorly for the attachment of the transverse ligament (Moore and Dalley, 1999). The dens is approximately 15mm in length and tilts about 14° posteriorly and 10° laterally and contains facets on the anterior border for attachment to the anterior arch of C1. It also provides sites of attachment for the anterior longitudinal ligament (ALL) on the anterior VB border and for the posterior longitudinal ligament (PLL) on the posterior VB border (Standring, 2005).

The vertebral arch is located posterior to the VB and its formation is attributed to the fusion of the left and right pedicles and laminae of the respective vertebral segment. The pedicles are known to be short and stout processes which project posterior to join the vertebral arch to the VB. The vertebral arch and the posterior surface of the VB form the vertebral foramen which link up in succession to form the vertebral canal which contains and protects the spinal cord. The foramen of vertebral segments C3-C7 are significantly larger due to the enlargement of the cervical spinal cord segment which innervates the upper limbs (Moore and Dalley, 1999).

The boundary of the spinal canal consists of the anterior aspect of the laminae and the adjacent ligamenta flava, the pedicles laterally and the posterior aspect of the IVDs and vertebral bodies (Standring, 2005; Fast and Goldsher, 2007). The boundary of the cervical vertebral canal is triangular in shape (Standring, 2005). The space available in this canal and the size of its vital neural structures share a significant relationship.

2.2.3 Facet Joints

The synovial joints situated on the vertebral arches are located between the inferior and superior articular processes of adjacent vertebrae. The orientation of the facet joints in the cervical spine limits movement in lateral bending and rotation compared to the range of movement in flexion thereby playing a pivotal role in providing stability to the cervical spine (Moore and Dalley, 1999; Nordin and Frankel, 2001; Standring, 2005). They also assist the IVDs with weight bearing, being able to take up to 16% of compressive forces directed at the spine and allowing for gliding movements between vertebrae (Moore and Dalley,1999; Standring, 2005).

2.2.4 Intervertebral Discs

These highly specialized structures form a strong attachment between the cartilaginous endplates of the adjacent vertebral bodies creating a specialized joint (Moore and Dalley, 1999; Nordin and Frankel, 2001). They also constitute a third of the vertebral column height and contribute to the anterior border of the intervertebral foramen (IVF). The IVD consists of two important components: the annulus fibrosus (AF) and the nucleus pulposus (NP). The AF has an outer fibrous component made up of concentric lamellae of fibrocartilage and thus makes up the circumference of the IVD. The central core of the IVD is known as the nucleus pulposus (NP) which is highly elastic and is normally more cartilagenous than fibrous. The cervical IVD is slightly thicker anteriorly than posteriorly and this primarily assists in maintaining the CL (Nordin and Frankel, 2001).

2.2.5 Intervertebral Foramina

This short tunnel is also known as the lateral or nerve root canal and forms outlets from the spinal canal for the spinal nerves. The IVF is bounded anteriorly by the IVD and adjacent VBs, posteriorly by the facet joints and inferiorly by the pedicles (Middleditch and Oliver, 2005). The spinal nerve is more prone to injury due to compression from mechanical forces when compared to a peripheral nerve since the latter has a better lymphatic drainage system and thicker epineurium (White and Panjabi, 1990).

2.2.6 Related Ligamentous Anatomy

a) Anterior longitudinal ligament

The anterolateral aspects of the vertebral bodies and IVDs are covered and joined by these strong fibrous bands which tend to be thicker in the cervical and lumbar regions of the spine (Moore and Dalley, 1999; Standring, 2005). It attaches superiorly to the anterior tubercle of the atlas and the occipital bone anterior to the foramen magnum and to the sacrum inferiorly (Moore and Dalley, 1999). It assists with stability between the VB and IVD joint and also prevents hyperextension of the spine by being taut but it is relaxed in flexion (Middleditch and Oliver, 2005).

b) Posterior longitudinal ligament

The posterior longitudinal ligament (PLL) forms part of the anterior wall of the spinal canal as it is attached firmly to the IVD and loosely to the VB which allows for the spinal canal to be like a smooth-walled tube (Bland, 1994; Moore and Dalley, 1999; Middleditch and

Oliver, 2005). The PLL becomes clinically significant when it begins to ossify and thicken as this causes the spinal canal space to be compromised even without posterior disc herniation or ossification (Bland, 1994).

c) Ligamentum Flavum

These strong elastic yellow ligaments are long, thin and wide in the cervical spine and make up part of the posterior wall of the spinal canal. This is achieved by joining the anteroinferior surface of the laminae of the superior vertebra to the posterosuperior surface of the inferior vertebra respectively. It prevents injury to the IVDs and the vertebral column by inhibiting abrupt hyperflexion. This is achieved by braking the movement produced in neck hyperflexion and also by preventing the end range of motion to be reached suddenly. It helps to maintain the normal curves of the spine and to assist the muscles of the neck in extension from a flexed position (Bland, 1994; Moore and Dalley, 1999; Middleditch and Oliver, 2005).

2.2.7 Muscles of the neck

The principle muscles producing movement of the cervical intervertebral joints are shown in **Table 2.1** (the smaller muscles of the neck are not mentioned or described here).

Table 2.1 The major flexor and extensor muscles of the neck

Flexor muscles	Extensor muscles
Longus coli	Splenius capitis
Scalenes	Semispinalis capitis
Sternocleidomastoid	Semispinalis cervicis

Source: Moore and Dalley (1999)

The short muscles of the neck responsible for flexion and lateral flexion of the cervical region of the spine consist of the longus colli, anterior, posterior and middle scalenes and the sternocleidomastoid muscles (Moore and Dalley, 1999; Standring, 2005). The muscle group responsible for extension of the cervical region comprises of the semispinalis capitis and cervicis and the splenius capitis muscles (Moore and Dalley, 1999; Standring, 2005).

The longus colli muscle of the cervical flexor compartment plays a significant role in posture and support for the cervical curve (Giles and Singer, 1998). Traumatic conditions such as whiplash may reduce the curvature due to muscle spasm (White and Panjabi, 1990).

2.3 CURVATURE OF THE CERVICAL SPINE

The vertebral column has four sagittal curves viz. cervical, thoracic, lumbar and sacral. The cervical curve is primarily due to the biconvex shape of the IVD which is thicker anteriorly than posteriorly (Bland, 1994; Nordin and Frankel, 2001). The cervical and lumbar curvatures are convex anteriorly and are described as lordotic curves whereas the thoracic and sacral curvatures are convex posteriorly and are described as kyphotic curves (Moore and Dalley, 1999). The development of the thoracic and sacral curvatures occurs during the fetal stage. These are known as the primary curvatures. The cervical curve develops when the infant starts crawling from about six to nine months of age and the lumbar curvature when the infant starts to stand and walk (Moore and Dalley, 1999).

2.4 ROLE OF PLAIN FILM RADIOGRAPHY IN THE ASSESSMENT OF THE CERVICAL SPINE

In the discipline of chiropractic, spinal radiographic analysis is an essential tool for structure assessment and to determine a diagnosis (McAviney *et al*. 2005). The cervical spine radiograph can be evaluated by utilizing a useful approach described by Yochum and Rowe (2005) known as the ABCS (**A**lignment, **B**one, **C**artilage and **S**oft tissue) method. This system ensures a thorough inspection of the radiograph as it may be scanned for abnormalities in its respective projection for stenosis, tumors, spinal instability, congenital anomalies, post-traumatic and spondylitic conditions as well for placement of orthopedic devices (Yochum and Rowe, 2005; Fast and Goldsher, 2007).

The advantages of the conventional radiograph are that it is readily available, possesses rapid turn-around time and one is able to assess the spine dynamically during evaluation of the stress views in flexion and extension (Fast and Goldsher, 2007). The A-P view of the lower cervical spine radiograph can depict many conditions including traumatic, arthritic, neoplastic and congenital anomalies. The A-P open mouth view is useful for evaluating fractures and congenital anomalies of the upper two cervical vertebrae in particular the odontoid process (Yochum and Rowe, 2005). The lateral view is vital for assessing fractures, dislocations, IVD space integrity, anomalies and stenosis (Lim and Wong, 2004; Yochum and Rowe, 2005). Any narrowing or widening of the IVF may be assessed in the oblique views (Yochum and Rowe, 2005).

The use of radiography is required for preoperative evaluation for intralaminar screw fixation (Hong *et al*., 2010). Ugur *et al*. (2000) also recommends its use for preoperative evaluation of the cervical spine for transpedicular screw fixation as it may enhance the safety of the procedure since pedicle structure may vary in the spine. Suk *et al*. (2007) recommended the use of plain film radiography as a preoperative procedure as well as for post-operative screening in patients with cervical myelopathy who underwent laminoplasty. It is also recommended in patients who have undergone posterior cervical stabilization to assess the integrity of orthopedic screws and rods as well as to evaluate the cervical alignment (Deen *et al*., 2003). Deen *et al*. (2003) and Suk *et al*. (2009) agreed with Herzog *et al*. (1991) that other digital investigative procedures such as CT and MRI are better, but acknowledge that not every patient is able to afford these.

Radiograhs are often the first choice of investigation for the assessment of osteoarthritis in the spine (Wiegand *et al*., 2003; Pouletaut *et al*., 2010). The SCD is evaluated in the lateral radiograph of the cervical spine to assess central canal stenosis (Lee *et al*. 1994; Engle *et al*., 1995; Lim and Wong, 2004). In patients with rheumatoid arthritis, subaxial subluxation is the second most common type of subluxation that is likely to occur. This is caused by transverse ligament laxity, facet joint arthritis and IVD involvement leading to a step ladder deformity that can also affect the cervical spine SCD and CL. The radiographs of the cervical spine in these patients contain warning signs of the often clinically-silent and common cervical subluxations which could cause serious complications (Roche *et al*., 2002; Younes *et al*., 2009).

Most emergency departments utilize standard screening radiography of the cervical spine for acute trauma patients (El-Khoury *et al*., 1995). The main principle of screening radiography is to identify potential injury rather than to discover every injury, which will ultimately determine whether further radiographic investigation is required (Mower *et al*., 2001). This is further supported by the fear of commonly associated severe and possible permanent damage of the spinal cord due to these injuries (Vandemark, 1990).

2.5 RADIOGRAPHIC EVALUATION OF THE CERVICAL SPINE

The quickest investigation to survey the cervical spine is through plain film radiography. Assessment of cervical spine radiographs in an orderly manner is vital in patients with cervical spine disorders. The evaluation of cervical spine radiographs in the chiropractic discipline is normally done using the ABCS approach (**A**lignment, **B**one, **C**artilage, **S**oft Tissue) described by Yochum and Rowe (2005). The CL and CGL can then be evaluated in the category of alignment and the SCD and IPD in the category of bone assessment. The advantage of the ABCS method of assessment includes its simplicity and effectiveness in the sequential analysis of the radiograph for abnormalities.

2.5.1 Cervical Lordosis

One of the radiographic parameters evaluated during the reading of cervical spine x-rays (lateral view) is the CL. A summary of the reported cervical lordotic angles and methods for evaluation are presented in **Tables 2.2** and **2.3**.

Table 2.2 Alternative methods to the Cobb and posterior tangent methods to evaluate the CL

Reference	Sample	Method	CL value
Borden *et al*. (1960)	180 asymptomatic males and females (90 each) of white ethnicity. 180 FFD	Depth of the cervical curve	12mm (mean)
Drexler (1962)	N/A	Drexler's method	40° (mean)
Jochumsen (1970)	N/A	Jochumsen's method	3-8mm (range)
Gore *et al*. (1986)	200 asymptomatic males and females (100 each)	Lines were drawn parallel to the posterior VB of C2 and C7 and the angle formed was measured	23° (mean)

N/A = not available

Table 2.3 A summary of the investigations conducted to determine the CL

Reference	Sample	Method	CL value
Owens and Hoiriis (1990)	N/A	Posterior tangent method	22.3°
Hardacker *et al.* (1997)	100 asymptomatic adults in the erect posture	Cobb method (C0-C7)	mean ± SD: 40° ± 9.7°
Harrison *et al.* (2000)	30 lateral radiographs selected from clinical files were digitized twice by each of the three examiners to test their reliability	Cobb method (C1-C7) Cobb method (C2-C7) Posterior tangent method	53.6° * mean 17.2° * mean 25.8° * mean
McAviney *et al.* (2005)	277 lateral radiographs of symptomatic (neck complaints) and asymptomatic patients	Posterior tangent method	Symptomatic: 9.6° * mean Asymptomatic: 23.4° * mean
Yochum and Rowe (2005)	N/A	Angle of cervical curve Cobb method (C1-C7)	40° * mean

***SD not available, N/A = not available**

There are several techniques described in the literature to evaluate cervical curvature on the lateral radiograph (**Tables 2.2** and **2.3)**. Borden *et al*. (1960) utilized the depth of the cervical curve method which though useful is not commonly utilized. The study was conducted on Whites and an average measurement was determined (**Table 2.2**). The method of Drexler is accurate for use, but it is a laborious process which increases the possibility of human error (Yochum and Rowe, 2005). This is due to the need for each segment to be measured individually before the total CL is determined, which may be impractical for clinicians due to time constraints.

The best method to measure the CL intuitively is that of the Cobb method (Cote *et al*., 1997). This method is more widely utilized compared to the posterior tangent method for CL assessment (Harrison *et al*., 2000; **Table 2.3**). However it is not without its limitations and there are differences in opinion with regards to which landmarks to utilize (Hardacker *et al*., 1997; Harrison *et al*., 2000). The C1-C7 Cobb method overestimates the curve while the C2-C7 method underestimates the curve because it is reduced artificially due to the deviation of the inferior vertebral endplates from the perpendicular at the posterior VB and the hook-like shape of the C2 anterior-inferior VB. However it is reported that the results demonstrated good to excellent reliability for the C1-C7 and C2-C7 methods which also had good correlation values (Cote *et al*., 1997; Harrison *et al*., 2000). The C1-C7 method demonstrated an interexaminer error of measurement of 9.1° and the C2-C7 method an interexaminer error of 8.3°. The yielding agreement was excellent for reproducibility and high intraclass coefficients were also observed (Cote *et al*., 1997). With respect to interexaminer reliability the C2-C7 method was superior by one degree and should be utilized since the C1-C7 method lacked clinical accuracy due to the plane of angulation of the atlas (Cote *et al*.,1997).

The posterior tangent method has a smaller standard error of measurement (Harrison *et al*., 2000). The main limitations of this method are an increased risk of human error due to the increased number of points to mark, lines to draw and angles to add up if the radiograph is not digitized. Furthermore, it is also not a widely utilized method. Therefore, in this study both the C1-C7 and C2-C7 Cobb methods were utilized.

2.5.1.1 Ethnic and gender differences in the cervical lordosis

A number of studies have reported that gender influences the CL (Borden *et al*., 1960; Rechtman *et al*.,1961; Solow *et al*., 1982; Cooke and Wei, 1988; Gay, 1993). Hardacker (1997) reported that CL becomes more pronounced as age increases in males and females. On the other hand, Boyle *et al*. (2002) observed a progressive flattening of the CL with age in males and the case was the same for females until middle-age. Thereafter, an increase in the curve was observed in older females. This finding was also observed earlier by Rechtman *et al*. (1961) in females greater than 50 years, although males less than 50 years had a greater CL.

Differences in CL were observed between males and females that were 12 years of age in British Caucasian and Chinese population groups (Cooke and Wei, 1988). Australian Aboriginal males had a less pronounced CL when compared to Danish males (Solow *et al*., 1982). Since Christensen and Hartvigsen (2008) recommended that the CL be evaluated in different population groups due to the discrepancies in the results of previous studies, it would be useful to investigate whether these exist in a South African setting across its four main ethnic groups.

2.5.1.2 Factors that could influence the cervical lordosis

Chronic infections such as tuberculosis and metastatic disease may occur within vertebrae which may deform and eventually collapse (Standring, 2005). Scoliosis may eventually cause a loss of curvature in the spine since it causes lateral deviation and excessive rotation along the vertical axis (White and Panjabi, 1990). The longus colli muscle (**Table 2.1**) of the cervical flexor compartment plays a significant role in posture and support for the cervical curve (Giles and Singer, 1998). Traumatic conditions such as whiplash may reduce the curvature due to muscle spasm (White and Panjabi, 1990). The presence of congenital anomalies such as block vertebrae may also reduce the CL. Degenerative IVD disease is also known to reduce the curvature of the cervical spine, but is most noticeable in subjects over 50 years of age (Gore *et al*., 1986).

Instability and deformity may occur as a result of systemic inflammatory conditions such as rheumatoid arthritis and ankylosing spondylitis which causes a loss of the cervical curvature (Standring, 2005). The CL is accentuated in the presence of an increased thoracic kyphosis as it causes a forward gaze head posture (Boyle *et al*., 2002). The lordosis allows for the forces acting on the VB both anteriorly and posteriorly to be minimal. Anterior head carriage, which may occur as a result of altered CL causes an uneven distribution of forces on the anterior cervical VB (Harrison *et al*., 2001).

2.5.2 Sagittal Canal Diameter

A summary of the studies that have investigated the sagittal canal diameter in the cervical spine is shown in **Table 2.4**.

Table 2.4 A summary of the investigations on SCD

Reference	Sample	Method	SCD (mm)	
Oon (1974)	Lateral radiographs of 400 asymptomatic individuals: 200 males and 200 females aged 20-80. Mixed sample of 157 Chinese, 22 Indians, 16 Malaysians and 5 others. (180cm FFD)	Distance measured from the midpoint of the posterior border of the body to the nearest point on the lamina of the respective vertebra	Combined mean values for male and female as well as ethnic groups: C1: 20.3 C2: 18.5 C3: 15.5 C4: 14.9 C5: 15.2 C6: 15.5 C7: 15.4	
Gupta *et al.* (1982)	Lateral radiographs of 300 Indians: 207 males and 93 females. (180cm FFD)	SCD measured on lateral radiograph from the middle of the posterior surface of the vertebral body to the spinolaminar line of the respective vertebra	Indian Males: mean values C2: 19.66 C3: 17.07 C4: 16.59 C5: 16.64 C6: 16.73 C7: 16.42	 Females: mean values C2: 18.60 C3: 16.13 C4: 15.60 C5: 15.72 C6: 15.84 C7: 15.54

Lee *et al.* (1994)	90 dried Korean human spinal columns: 63 male and 27 female aged 19-70	Measured from the midpoint of the posterior aspect of the vertebral body to the near point on the corresponding spinolaminar line	Korean Males: mean ± SD C3: 13.3 ± 1.3 C4: 12.8 ± 1.4 C5: 13.0 ± 1.4 C6: 13.2 ± 1.3 C7: 13.4 ± 1.3	Females: mean ± SD C3: 13.3 ± 2.5 C4: 12.9 ± 2.7 C5: 13.0 ± 2.7 C6: 13.2 ± 2.6 C7: 13.4 ± 2.3
Lim and Wong (2004)	Lateral radiographs of 40 men and 40 women of Chinese ethnicity 21-46 years of age. (180cm FFD)	Distance between the cephalocaudal midpoint of the posterior aspect of the vertebral body to the nearest point on the corresponding spinal laminar line with a vernier caliper	Chinese Male: mean values C2: 19.1 C3: 16.8 C4: 16.2* C5: 16.8 C6: 17.2 C7: 17.1	Female: mean values C2: 18.5 C3: 16.1 C4: 15.7* C5: 16.0 C6: 16.1 C7: 16.0
Tatarek (2005)	321 skeletons specimens: 160 males and 161 females of African American and Caucasian ethnicity	A-P diameter of each vertebral canal were measured with a vernier caliper	African-American Male: mean ± SD C2: 16.40 ± 1.31 C3: 14.43 ± 1.20 C4: 13.98 ± 1.32* C5: 14.12 ± 1.22 C6: 14.25 ± 1.13 C7: 14.37 ± 0.97 Female: mean ± SD C2: 15.09 ± 1.57 C3: 13.33 ± 1.37 C4: 13.16 ± 1.44* C5: 13.28 ± 1.31 C6: 13.32 ± 1.29 C7: 13.57 ± 1.21	Caucasian Male: mean ± SD C2: 16.80 ± 1.54 C3: 15.02 ± 1.34 C4: 14.58 ± 1.33 C5: 14.50 ± 1.42 C6: 14.26 ± 1.37 * C7: 14.33 ± 1.41 Female: mean ± SD C2: 16.61 ± 1.14 C3: 14.44 ± 1.39 C4: 13.73 ± 1.34 C5: 13.61 ± 1.26 C6: 13.39 ± 1.08* C7: 13.42 ± 1.07
Yochum and Rowe (2005)	Ethnicity not stated	Measured from the posterior surface of the mid vertebral body to the nearest surface of the same segmental spinolaminar junction line	Combined mean values for male and female: C1: 22 C2: 20 C3: 18 C4: 17 C5: 17 C6: 17 C7: 17	
Tossel (2007)	179 skeletal remains of Blacks were measured: 90 males and 89 females 30 – 75 years of age	The A-P diameter of the vertebral canal was measured with a vernier digital caliper	Black Male: mean values C3: 13.89 C4: 13.60 C5: 13.94 C6: 14.07 C7: 14.32	Female: mean values C3: 14.01 C4: 13.80 C5: 13.81 C6: 13.82 C7: 13.77

***narrowest vertebral level, FFD = Focal film distance (FFD of 180cm was most commonly utilized), A-P = Anteroposterior**

The SCD is measured from the midpoint of the posterior VB to the closest border of its respective spinoloaminar junction line (Hinck *et al*., 1962). This is also known as the A-P diameter of the spinal canal. Stenosis occurs when the space available for the spinal cord is compromised leading to cord compression. The spinal canal should possess a minimum diameter of 13mm for it not to be considered stenotic (Wolf *et al*., 1956). The evaluation of this parameter is important in patients with cervical myelopathy (Roche *et al*., 2002). Although the use of CT is the ideal method for measuring the SCD when stenosis is suspected (Tossel, 2007), the lateral radiograph has been shown to depict the SCD accurately when compared to a sagittal CT image. It should also be noted that not all patients are able to afford expensive digital investigations (Herzog *et al*., 1991).

The assessment of this parameter is still more reliable than the Torg ratio method in the lateral cervical radiograph (Lim and Wong, 2004). The Torg ratio refers to the ratio of the SCD of the spinal canal to the sagittal diameter of the same vertebral body which should ideally be 0.80. Any value less than this would be considered stenotic (Pavlov *et al*., 1987). On the other hand, Lee *et al.* (1994) are of the view that the Torg ratio is more reliable than direct measurement of the SCD on the lateral radiograph since it is not affected by the radiographic magnification. The Torg ratio for evaluation of stenosis in the cervical canal was utilized by Lim and Wong (2004) in their study on a Chinese population and they state that this method is not a consistent indicator of the SCD and may not be used reliably to assess the presence of stenosis. This is because of the variation of the SCD across ethnicity and the inability of the VB to vary in proportion to the changes in SCD and hence the inconsistency of this ratio method.

Lee *et al.* (1994) reported that there are no differences in the SCD between gender at all cervical vertebral levels since they did not find any difference in the measurements on actual bony specimens. In their opinion the differences observed in gender, in previous studies, must have been due to the magnification error that is present in radiographs. Tatarek (2005), on the other hand, observed differences in SCD in gender in the African American and Caucasian skeletal specimens she evaluated.

One of the possible reasons why the results of several studies differ is that the investigators utilized different focal film distances (Lee *et al*., 1994). The most common FFD utilized was 180cm (Oon, 1974; Gupta *et al*., 1982; Lim and Wong, 2004) which was also utilized in this study. Skeletal specimens were utilized by Lee *et al*. (1974), Tatarek (2005) and Tossel (2007). Radiographs taken from a distance of 40 inches have a magnification error of 2-3mm. This is the reason why a focal film distance of 180cm was more commonly utilized (Oon, 1974; Gupta *et al*., 1982; Lim and Wong, 2004). The SCD measurements obtained from an anthropometric study were smaller than of those obtained from radiographic studies. Tatarek (2005) also recommended that standard values for stenosis should not be utilized across the different ethnic groups and gender since the normal SCD measurements vary across ethnicity and gender.

Wolf *et al*. (1956) stated that a SCD of 17mm was considered normal and 13mm was considered congenital stenosis in the cervical spine. The smallest SCD observed in vertebral segments C3-C7 in an Indian population was 13mm (Gupta *et al*., 1982). Roche *et al*. (2002) suggested that the SCD should not be less than 14mm in patients with rheumatoid arthritis. These results differ when compared to studies that have observed this parameter in the Japanese and Caucasian ethnic groups (Lim and Wong, 2004).

2.5.2.1 Ethnic and gender differences in the SCD

The SCD in males was observed to be significantly larger than in females (Lee *et al*., 1994; Lim and Wong, 2004; Tatarek, 2005; Tossel, 2007). Tatarek (2005) recommended that a minimum definition for stenosis should be determined for each gender since sexual dimorphism has a more significant effect than ethnicity in relation to the SCD.

The cervical spine SCD in the Chinese population was narrower when compared to the Indian, White and Black population groups (Lim and Wong, 2004). However Tatarek (2005) reported that the SCD in African-American and Caucasian populations did not have much variation but still recommended that it be evaluated in other populations. Tossel (2007) also conducted research on the dimensions of the cervical spinal canal of the Black population in South Africa and reported that their SCD was consistently smaller than the Japanese population but similar in size to the Korean population. She also stated that it is essential to have normal guidelines for each population group when diagnosing stenosis.

2.5.2.2 Factors that influence the SCD from an anatomical perspective

The presence of a spinal tumor may cause abnormal widening of the SCD (Yochum and Rowe, 2005). Thickening of the PLL due to ossification, degenerative IVD disease, osteophytes and osteoarthritis of the facet joints can decrease the A-P diameter of the spinal canal (White and Panjabi, 1990; Giles and Singer, 1998). When these factors are present in a patient it, predisposes them to spinal cord injury more easily compared to a normal patient.

2.5.3 Interpedicular Distance

The shortest distance measured between the medial surfaces of the pedicles of a vertebra is referred to as the IPD (Hinck *et al*., 1966). A summary of the studies that have investigated the interpedicular distance is shown in **Table 2.5**.

Table 2.5 A summary of investigations on IPD

Reference	Sample	Method	IPD (mm)	
Hinck *et al.* (1966)	373 children and 121 adults (male and female combined)	Shortest distance between the medial surfaces of a pedicle of a given vertebrae	Caucasian Adults: male and female combined C3: 28.0 C4: 28.8 C5: 29.4 C6: 29.3 C7: 28.0	
Ugur *et al.* (2000)	20 cadavers: 14 males and 6 females 24 to 72 years of age	Goniometer used by neurosurgeons. No measurement sites given	Male: mean ± SD C3: 21.6 ± 1.1 C4: 20.8 ± 1.0 C5: 20.7 ± 1.6 C6: 21.6 ± 2.0 C7: 22.9 ± 2.4	Female: mean ± SD C3: 22.4 ± 0.7 C4: 22.5 ± 1.6 C5: 23.2 ± 0.0 C6: 25.1 ± 0.1 C7: 24.5 ± 1.1
Tatarek (2005)	321 skeletons: 160 males and 161 females	Skeletal samples: measured using vernier calipers accurate to 1mm	African-American Male: mean ± SD C2: 23.39 ± 1.23 C3: 23.32 ± 1.22 C4: 24.31 ± 1.23 C5: 25.02 ± 1.36 C6: 25.46 ± 1.44 C7: 24.48 ± 1.31 Female: mean ± SD C2: 22.52 ± 1.39 C3: 22.68 ± 1.22 C4: 23.47 ± 1.48 C5: 23.98 ± 1.46 C6: 24.49 ± 1.60 C7: 23.53 ± 1.35	Caucasian Male: mean ± SD C2: 23.79 ± 1.47 C3: 23.43 ± 1.35 C4: 24.13 ± 1.46 C5: 24.86 ± 1.60 C6: 25.21 ± 1.65 C7: 24.33 ± 1.61 Female: mean ± SD C2: 22.90 ± 1.51 C3: 22.48 ± 1.31 C4: 23.47 ± 1.29 C5: 24.42 ± 1.28 C6: 24.32 ± 1.41 C7: 23.41 ± 1.33
Yochum and Rowe (2005)	Data was utilized from the study conducted by Hinck *et al.* (1966)	The IPD was considered the shortest distance between the inner convex cortical surfaces of the opposing segmental pedicles	C3: 28 C4: 29 C5: 29 C6: 29 C7: 28 The measurements from Hinck *et al.* (1966) study were rounded-off to 0 decimal place	

In the study by Hinck *et al*. (1966) 474 A-P radiographs of the cervical spine of Whites were evaluated. They reported that the average female IPD measurement was one millimeter less than that of the males. A single vertebra or adjacent segment that is larger than their mean values for each region should be treated with suspicion in the event of the presence of a spinal tumor or stenosis.

The C7 IPD was the largest and there was no significant difference in gender (Ugur *et al*., 2000). Tatarek (2005) also observed differences in IPD at specific vertebral levels which was mainly due to the influence of gender (contrary to the conclusions of Ugur *et al*., 2000) and to a slight degree, ethnicity. The IPD measurements reported by Tatarek (2005) were smaller than those reported in other studies. This could be due to the measurements being taken from skeletal samples and radiographs which were not adjusted for radiographic magnification error. Furthermore the IPD in the skeletal specimens were measured using a vernier caliper which is accurate to one millimeter.

Ugur *et al*. (2000) observed a smaller pedicle width and height in females. Since the IPD is measured from the medial surface of one pedicle to the other in the respective vertebral segments, this could possibly affect the measurement in gender. Their reported values for the cervical spine IPD did not take factor the possible effects that ethnicity may have had. Since this was a cadaver sample, it would be difficult to determine if the individuals were asymptomatic or had a history of trauma or arthritic disease or not when they were alive. The use of preoperative conventional radiography in conjunction with CT to assess the integrity of the pedicles is also recommended (Ugur *et al*., 2000).

2.5.3.1 Ethnic and gender differences in the IPD

The male vertebral canal is reported to be larger than in females (Bland, 1994). The average measurements of the male IPD were consistently larger than the female by approximately one millimeter (Hinck *et al*. 1966). There were significant differences in pedicle width observed in male and female cadavers (Rongming *et al*., 1999; Ugur *et al*., 2000).

Significant differences in the IPD were observed in the lumbar spine between gender as well as in two South African ethnic groups (Eisenstein, 1976; Naidoo, 2008). Nirvan *et al*. (2005) reported significant differences in the lumbar spine IPD between north and south Indian ethnic groups and emphasized the importance of obtaining the normal ranges for IPD in different populations. In light of these observations, it is therefore hypothesized that similar differences would be observed in the cervical spine in the four main South African ethnic groups.

2.5.3.2 Factors that influence the IPD

The presence of intraspinal tumors may erode the pedicles which could cause widening of the IPD. Paget's disease and congenital malformations such as achondroplasia which cause thickening of the pedicles may decrease this radiographic parameter by causing stenosis (Yochum and Rowe, 2005).

2.5.4 Cervical Gravity Line

The CGL is a vertical line which passes from the apex of the odontoid process through the C7 VB. It allows for assessment of the gravitational forces acting at the cervico-thoracic junction (Yochum and Rowe, 2005). The lordosis allows for the forces acting on the VB both anteriorly and posteriorly to be minimal. Anterior head carriage which may occur as a result of altered CL causes an uneven distribution of forces on the anterior cervical VB (Harrison *et al*., 2001). Hardacker *et al*. (1997) investigated the standing cervical segmental alignment in 100 asymptomatic adult males and females. They observed the sagittal plumb line in the erect lateral radiographic view of the spine passed from the tip of the odontoid through the centre of the C7 VB before connecting to the posterior superior corner of the sacrum. They named this section that passed from the tip of the odontoid process to the C7 VB the cervical plumb line which is referred to as the CGL by Yochum and Rowe (2005). The mean ± SD measurement from the centre of the C7 VB anterior to this line was 16.8 ± 11.2mm, but whether there were any differences in CGL between gender or ethnic groups was not reported.

2.6 CONCLUSION

There are various methods that are available to evaluate the selected radiographic cervical spine parameters. However, the results were not consistent for the SCD and CL, possibly due to variation in sample size, population or sample profile and methods employed. There are a limited number of studies that have investigated the cervical IPD and CGL (Hinck *et al*., 1966; Hardacker *et al*., 1997). There are no studies that have investigated these parameters in the cervical spine for a South African population. It would be of benefit to surgeons, chiropractors and clinicians in a South African clinical setting to know these normal values for assessment of various conditions such as stenosis, spondylosis, tumors and post-surgical and post-traumatic states. Several researchers also recommended that normal values for these radiographic parameters be determined and evaluated across ethnic groups and gender (Lim and Wong, 2004; Tossel, 2007; Christensen and Hartvigsen, 2008)

Researchers have observed differences in the selected parameters in the cervical spine across gender and ethnicity e.g. in the African American, Caucasian, Korean, Chinese, Black and Indian population groups (Gupta *et al*., 1982; Lee *et al*., 1994; Lim and Wong, 2004; Tatarek, 2005; Tossel, 2007). This study will address the possibility of variation of the SCD, IPD, CL and CGL within the respective ethnic groups in a South African population since no investigations have been conducted for these parameters on the Coloured, Indian and White ethnic groups.

There are currently no studies that have investigated these radiographic parameters in young to middle-aged adults across the four main ethnic groups in a South African population. In keeping with the aim of this study this would provide more accurate values for clinicians to work with when treating patients of a specific ethnic group and for gender.

CHAPTER THREE

MATERIALS AND METHODS

3.1 STUDY DESIGN

This research was designed in the form of a quantitative, descriptive, cross-sectional study. Approval to conduct this study was obtained from the Durban University of Technology's Faculty of Health Sciences Research Committee **(Ethics Clearance Certificate No.: 024/10 [Appendix G])**.

3.2 RECRUITMENT

Prospective participants were recruited via advertisements and pamphlets **(Appendix A)**. The adverts were placed in local newspapers of the surrounding communities and pamphlets were distributed in the Chiropractic Day Clinic (CDC), the Homeopathic Clinic, Student Wellness Clinic (DUT), a local university, stores and libraries in the greater Durban area.

3.3 SAMPLE SIZE AND SAMPLING METHOD

Convenience sampling was utilized in this study (Brink, 2007). Twenty participants from each of the four ethnic groups were recruited for this study. Therefore the sample size was *n* = 80 participants which was determined after discussions with an experienced biostatistician (Esterhuizen, 2010). Financial constraints also played a roll in the determination of the sample size.

3.4 INCLUSION AND EXCLUSION CRITERIA

3.4.1 Inclusion Criteria

- All participants had to be between the ages of 18-45 years. The incidence of degenerative changes in the cervical spine and neck pain reportedly increased after the fourth decade of life (Grob *et al*., 2007) and those under the age of 18 are not recommended to be used as participants in these types of studies as per the guidelines of the South African Medical Research Council (South African Medical Research Council Guidelines on Ethics for Medical Research, 2002).

- All participants were of male gender. This was done to maintain sample homogeneity with respect to gender. Several researchers have reported differences in radiographic parameters of the cervical spine in gender (Eisenstein, 1972; McAviney *et al*. 2005; Tossel, 2007). A study conducted concurrently with this one examined these parameters in females.

- Participants were to be free of neck pain for the last three months prior to and during their participation in this research. Furthermore, the participants were not to have had any significant complaints in the medical history and physical examination.

- Participants were South Africans of Black, White, Coloured and Indian ethnicity.

3.4.2 Exclusion Criteria

- Participants who had any radiographs done within a month prior to commencement of the study in order to minimize their radiation dose.

- The development of any neck pain or injuries sustained by the participant between the initial consultation and their Radiographic Clinic (RC) appointment.

3.5 RESEARCH PROCEDURE

3.5.1 Telephonic screening of participants

The following screening questions were asked of any prospective participant who responded telephonically to the advertisements:

1. “Are you free of neck pain?”
2. “Are you between the ages 18-45 years?”

3. "Have you had any surgery in the past year or injury to your neck in the past three months?"
4. "Have you had any x-rays done within the last month of any region of your body?"

If the prospective participant answered "Yes" to Questions 1 and 2 and "No" to Questions 3 and 4 then an appointment was made for him at the CDC.

3.5.2 Phase One

When the prospective participants arrived at the CDC for their appointment, they were given a letter of information **(Appendix B)** to read. The nature of the study was also fully verbally explained by the researcher. The prospective participants were also given an opportunity to ask any questions pertaining to the study and the researcher responded accordingly. Anyone who then expressed a willingness to participate in the study was then required to sign an informed consent form **(Appendix B)**. Thereafter, a case history **(Appendix C)**, physical examination **(Appendix D)** and cervical orthopedic examination **(Appendix E)** was performed by the researcher. The participants were only allowed to proceed to Phase Two of the research if they had met all the inclusion criteria. Thereafter, an appointment was scheduled for these participants to present at the RC to obtain their cervical spine x-rays.

3.5.3 Phase Two

The participant proceeded to the RC at his scheduled appointment time provided he did not sustain any injuries to the neck since the initial consultation at the CDC. The researcher then asked the participant to change into a gown and used gonad protection to limit radiation exposure to the participant as per the RC protocols. Thereafter, the A-P and lateral views of the cervical spine were radiographed by the researcher with the participant in the erect position according to the techniques described by Yochum and Rowe (2005) with the arms at the side, shoulders relaxed and standing barefoot on a flat surface. The generator of the x-ray unit was set at 63Kv and 10mAS for the A-P view and 70Kv and 20mAS for the lateral view. Participant's identity were protected on the radiographs as each of them had an identification code. The participants were then allowed to change back into their clothing while the researcher processed the radiographs. This concluded their participation in this study.

3.5.4 Phase Three

The ABCS (**A**lignment, **B**one, **C**artilage and **S**oft tissue) method for radiograph assessment was utilized in this study (Yochum and Rowe, 2005). The following parameters of the cervical spine radiographs were then evaluated by the researcher according to the methods described in **Table 3.1** and recorded on Data Sheet 1 (**Appendix F**).

The references for the methods utilized for assessing the selected radiographic parameters is presented in **Table 3.1**.

Table 3.1 A description of the selected radiographic parameters

Parameter	**Reference**	**Description**
Cervical lordosis (CL)	Jochumsen (1969); Hardacker *et al.* (1997)	"Anterior convex sagittal curve of the cervical spine. Evaluated via drawing two lines, one through and parallel to the inferior endplate of the C7 body and the other through the midpoints of the anterior and posterior tubercles of the atlas. Perpendiculars are then constructed to the point of intersection; the resultant angle is measured." Yochum and Rowe (2005)
Sagittal canal diameter (SCD)	Wolf *et al*. (1956); Hinck *et al*. (1962)	"The distance from the posterior surface of the mid-vertebral body to the same segmental spinolaminar junction line at its most convex point." Yochum and Rowe (2005).
Interpedicular distance (IPD)	Hinck *et al*. (1966)	"Shortest distance between the inner cortical most medial surfaces of the opposing segmental pedicles." Yochum and Rowe (2005)
Cervical gravity line (CGL)	Fox and Young (1954)	"Vertical line drawn through the apex of the odontoid process which should pass through the C7 vertebral body." Yochum and Rowe (2005)

The following instruments and measuring tools were utilized in this study:

- X-ray viewing box with good lighting (The same viewing box was utilized throughout the study to reduce variation in lighting)
- Divider (for accurate measurement between two points)
- A 30cm ruler
- Protractor (for measurement of angles)

- Dermatography liberty marking pen (this was used to mark the angles and lines on the radiographs)

3.6 STATISTICAL ANALYSIS

SPSS version 15.0 was used to anlayse the data. A *p* value ≤ 0.05 was used to indicate statistical significance. Coefficients of variation were calculated within ethnic groups to assess intra-group variation. Inter-group variation was assessed using ANOVA testing with Bonferroni-adjusted *post-hoc* tests in the case of a significant ANOVA test. Pearson's chi square test was used to assess the association between ethnic groups and placing of the CGL. T-tests were used to compare mean CL between those with anterior and normally placed CGL within each ethnic group (Esterhuizen, 2010).

CHAPTER FOUR

RESULTS

4.1 AGE AND ANTHROPOMETRIC CHARACTERISTICS OF THE PARTICIPANTS

The mean and standard deviations of the ages, heights and weights of the 80 participants by ethnic group and in total who met all the inclusion criteria are shown in **Table 4.1**. The overall ages of the participants ranged from 18 to 44 years. The body mass index (BMI) of the respective ethnic groups is represented graphically in **Figure 4.1**.

Table 4.1 Age and Anthropometric parameters of participants by ethnic group

Group		Age (yrs)	Height (m)	Weight (kg)
Black	Mean	25.4	1.7	66.1
	n	20	20	20
	Std. deviation	6.6	0.1	7.6
White	Mean	26.9	1.7	77.2
	n	20	20	20
	Std. deviation	5.8	0.1	10.9
Indian	Mean	25.7	1.7	75.3
	n	20	20	20
	Std. deviation	5.4	0.0	13.7
Coloured	Mean	27.2	1.7	73.5
	n	20	20	20
	Std. deviation	6.4	0.1	11.8
Total	Mean	26.3	1.7	73.0
	n	80	80	80
	Std. deviation	6.0	0.1	11.8

yrs = years

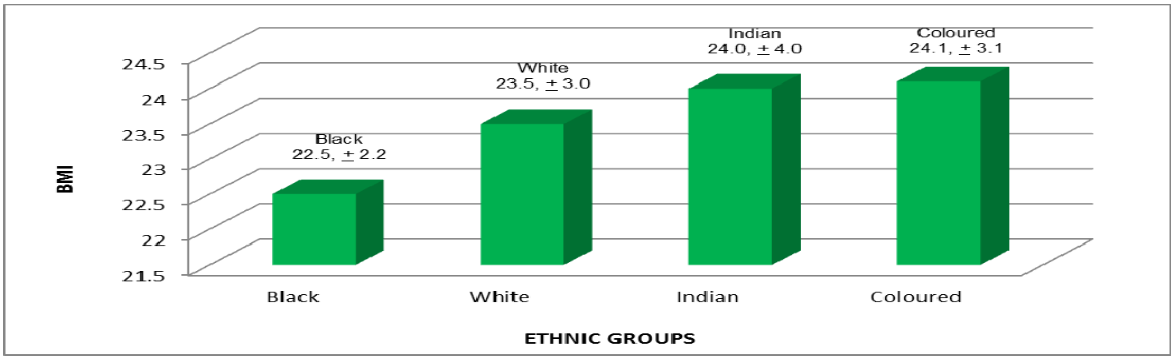

Figure 4.1 The BMI (kg.m^{-2}) of the respective ethnic groups

(Mean ± SD is shown above each bar)

4.2 THE SELECTED RADIOGRAPHIC PARAMETERS

4.2.1 Cervical Lordosis

A total of nine participants were excluded for this parameter since the C7 VB was obstructed on their lateral radiograph by the trapezius muscle. The mean and standard deviation of the CL for the selected ethnic groups, evaluated using the C1-C7 and C2-C7 Cobb method is shown in **Tables 4.2** and **4.3** respectively. A smaller mean, minimum and maximum value for the CL using the C2-C7 Cobb method was observed in all the ethnic groups when compared to the C1-C7 method for CL. There were no significant differences in the mean CL values noted between the ethnic groups for CL ($p > 0.05$, ANOVA; **Table 4.4)**. There was a highly significant difference between the mean of the C1-C7 method and the mean of the C2-C7 method ($p < 0.001$, paired samples test; **Table 4.5**). The mean difference was 29.77 (**Table 4.5**). There were no significant correlations observed between BMI and the CL (obtained using both the C1–C7 and C2–C7 Cobb methods) ($p > 0.05$, Pearson’s Correlation; **Table 4.6)**. No significant correlations were observed between BMI and total CL for both the methods ($p > 0.05$, Pearsons Correlation; **Table 4.7**).

Table 4.2 The mean, standard deviation and range of the CL by ethnic group using the C1–C7 Cobb method

Ethnicity	Mean (°)	*n*	Std. deviation	Minimum (°)	Maximum (°)
Black	42.6	19	9.6	25.0	61.0
White	46.2	18	11.0	18.0	63.5
Indian	46.5	17	11.3	25.0	67.0
Coloured	47.7	17	9.1	31.0	63.2
Total	45.7	71	10.2	18.0	67.0

Table 4.3 The mean, standard deviation and range of the CL by ethnic group using the C2-C7 Cobb method

Ethnicity	Mean (°)	*n*	Std. deviation	Minimum (°)	Maximum (°)
Black	15.1	19	6.4	7.0	30.0
White	17.4	18	9.3	6.0	33.0
Indian	13.1	17	10.2	3.0	34.0
Coloured	18.1	17	10.4	3.0	37.0
Total	15.9	71	9.1	4.8	33.5

Table 4.4 ANOVA test to compare the mean CL between ethnic groups

	Sum of Squares	Df	Mean Square	F	*p-value*
Between groups	258.605	3	86.202	0.810	0.493
Within groups	7133.150	67	106.465		
Total	7391.755	70			

Table 4.5 Paired sample tests to compare the significance between the results of the C1 - C7 and C2 – C7 Cobb methods for CL evaluation

Paired Samples Test

		Paired Differences				
		Mean	Std. deviation	Std. error mean	95% Confidence Interval of the Difference	
					Lower	Upper
Pair 1	C1-C7 - C2-C7	29.7718	5.5797	.6622	28.4511	31.0925

Paired Samples Test

		T	df	Sig. (2-tailed)
Pair 1	C1-C7 - C2-C7	44.959	70	<0.001

Table 4.6 The correlation between BMI and CL by ethnic group

Correlations

Ethnic Group			BMI
Black	BMI	Pearson’s correlation	1
		Sig. (2-tailed)	
		n	20
	C1-C7	Pearson’s correlation	-0.239
		Sig. (2-tailed)	0.324
		n	19
	C2-C7	Pearson’s correlation	-0.191
		Sig. (2-tailed)	0.434
		n	19
White	BMI	Pearson’s correlation	1
		Sig. (2-tailed)	
		n	20
	C1-C7	Pearson’s correlation	-0.063
		Sig. (2-tailed)	0.802
		n	18
	C2-C7	Pearson’s correlation	-0.097
		Sig. (2-tailed)	0.703
		n	18
Indian	BMI	Pearson’s correlation	1
		Sig. (2-tailed)	
		n	20
	C1-C7	Pearson’s correlation	-0.314
		Sig. (2-tailed)	0.220
		n	17
	C2-C7	Pearson’s correlation	-0.451
		Sig. (2-tailed)	0.069
		n	17
Coloured	BMI	Pearson’s correlation	1
		Sig. (2-tailed)	
		n	20
	C1-C7	Pearson’s correlation	-0.107
		Sig. (2-tailed)	0.683
		n	17
	C2-C7	Pearson’s correlation	-0.050
		Sig. (2-tailed)	0.848
		n	17

BMI = Body mass index

Table 4.7 Correlation between BMI and CL for the total sample

		BMI
C1-C7	Pearson's correlation	-0.145
	Sig. (2-tailed)	0.228
	n	71
C2-C7	Pearson's correlation	-0.193
	Sig. (2-tailed)	0.107
	n	71

BMI = Body mass index

4.2.2 Sagittal Canal Diameter

The mean, standard deviation and range for the SCD at the respective vertebral levels for each ethnic group is presented in **Table 4.8**. A decrease in the mean SCD was observed at C3 and C4 before increasing at C5, thereafter decreasing at C6 and C7 respectively in the Black ethnic group. The mean SCD observed in the White ethnic group decreased at C3 and C4, increased at C5 and C6 before a decreasing at C7. In the Indian ethnic group the mean SCD decreased at C3 and C4, increased at C5 and C6 before decreasing at C7. The mean SCD decreased at C3 and C4, increased at C5 and C6 respectively and decreased at C7 in the Coloured ethnic group.

Overall, there was a significant difference noted between the ethnic groups at vertebral levels C2, C6 and C7 (p = 0.002, 0.030 and 0.017 respectively, ANOVA; **Table 4.9**). For these three vertebral levels, the difference in the measurement was between Blacks and Whites only as shown in **Table 4.10** (p = 0.001, 0.028 and 0.011 respectively, Bonferroni *post-hoc* test).

Table 4.8 SCD (in millimeters) at the respective cervical vertebral levels by ethnic group

Ethnicity		SCDC2	SCDC3	SCDC4	SCDC5	SCDC6	SCDC7
Black	Mean	22.1	19.5	18.6	18.9	18.8	18.5
	n	20	20	20	20	20	19
	Std. deviation	1.6	1.6	1.9	1.8	1.7	1.7
	Minimum	19.2	17.1	15.1	16.0	16.0	16.0
	Maximum	25.5	22.5	21.7	22.0	22.0	22.1
White	Mean	24.1	20.6	19.9	20.0	20.4	20.3
	n	20	20	20	20	20	19
	Std. deviation	1.4	1.4	1.3	1.5	1.5	1.5
	Minimum	21.8	17.1	17.1	16.0	16.0	16.1
	Maximum	27.0	23.5	22.8	23.0	23.0	22.2
Indian	Mean	22.8	19.7	19.1	19.3	19.5	19.4
	n	20	20	20	20	20	18
	Std. deviation	1.7	1.6	1.6	1.7	1.6	1.6
	Minimum	20.1	16.1	16.0	16.0	17.0	17.0
	Maximum	26.5	23.1	22.5	22.0	22.0	21.9
Coloured	Mean	22.9	20.0	19.5	19.8	20.0	19.7
	n	20	20	20	20	20	18
	Std. deviation	1.5	1.5	1.3	1.6	1.8	1.9
	Minimum	20.1	17.0	17.5	18.0	17.0	17.4
	Maximum	25.8	22.9	22.1	23.0	24.0	23.6
Total	Mean	23.0	19.9	19.3	19.5	19.7	19.4
	n	80	80	80	80	80	74
	Std. deviation	1.7	1.6	1.6	1.7	1.7	1.8
	Minimum	19.2	16.1	15.1	16.0	16.0	16.0
	Maximum	27.0	23.5	22.8	23.0	24.0	23.6

Table 4.9 ANOVA tests to compare the mean SCD parameters between ethnic groups

		Sum of Squares	Df	Mean Square	F	*p* - value
SCDC2	Between groups	41.769	3	13.923	5.270	0.002
	Within groups	200.791	76	2.642		
	Total	242.560	79			
SCDC3	Between groups	15.450	3	5.150	2.054	0.113
	Within groups	190.513	76	2.507		
	Total	205.964	79			
SCDC4	Between groups	17.991	3	5.997	2.313	0.083
	Within groups	197.009	76	2.592		
	Total	215.000	79			
SCDC5	Between groups	14.976	3	4.992	1.770	0.160
	Within groups	214.402	76	2.821		
	Total	229.378	79			
SCDC6	Between groups	27.805	3	9.268	3.148	0.030
	Within groups	223.763	76	2.944		
	Total	251.568	79			
SCDC7	Between groups	32.772	3	10.924	3.647	0.017
	Within groups	209.695	70	2.996		
	Total	242.466	73			

Table 4.10 Bonferonni *post-hoc* test to determine the difference in the means of the SCD for C2, C6 and C7

Dependent Variable	(I) group	(J) group	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
SCDC2	Black	White	-2.0000(*)	0.5140	0.001	-3.392	-0.608
		Indian	-0.6550	0.5140	1.000	-2.047	0.737
		Coloured	-0.7750	0.5140	0.815	-2.167	0.617
	White	Black	2.0000(*)	0.5140	0.001	0.608	3.392
		Indian	1.3450	0.5140	0.064	-0.047	2.737
		Coloured	1.2250	0.5140	0.118	-0.167	2.617
	Indian	Black	0.6550	0.5140	1.000	-0.737	2.047
		White	-1.3450	0.5140	0.064	-2.737	0.047
		Coloured	-0.1200	0.5140	1.000	-1.512	1.272
	Coloured	Black	0.7750	0.5140	0.815	-0.617	2.167
		White	-1.2250	0.5140	0.118	-2.617	0.167
		Indian	0.1200	0.5140	1.000	-1.272	1.512
SCDC6	Black	White	-1.585(*)	0.543	0.028	-3.05	-0.12
		Indian	-0.740	0.543	1.000	-2.21	0.73
		Coloured	-1.195	0.543	0.184	-2.66	0.27
	White	Black	1.585(*)	0.543	0.028	0.12	3.05
		Indian	0.845	0.543	0.741	-0.62	2.31
		Coloured	0.390	0.543	1.000	-1.08	1.86
	Indian	Black	0.740	0.543	1.000	-0.73	2.21
		White	-0.845	0.543	0.741	-2.31	0.62
		Coloured	-0.455	0.543	1.000	-1.92	1.01
	Coloured	Black	1.195	0.543	0.184	-0.27	2.66
		White	-0.390	0.543	1.000	-1.86	1.08
		Indian	0.455	0.543	1.000	-1.01	1.92
SCDC7	Black	White	-1.8158(*)	0.5615	0.011	-3.341	-0.291
		Indian	-0.9056	0.5693	0.697	-2.451	0.640
		Coloured	-1.2333	0.5693	0.202	-2.779	0.312
	White	Black	1.8158(*)	0.5615	0.011	0.291	3.341
		Indian	0.9102	0.5693	0.686	-0.636	2.456
		Coloured	0.5825	0.5693	1.000	-0.963	2.128
	Indian	Black	0.9056	0.5693	0.697	-0.640	2.451
		White	-0.9102	0.5693	0.686	-2.456	0.636
		Coloured	-0.3278	0.5769	1.000	-1.894	1.239
	Coloured	Black	1.2333	0.5693	0.202	-0.312	2.779
		White	-0.5825	0.5693	1.000	-2.128	0.963
		Indian	0.3278	0.5769	1.000	-1.239	1.894

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

4.2.3 Interpedicular Distance

A number of participants were excluded for the measurement at the C3 vertebral level. Therefore, there are 19, 17 and 19 IPD measurements for the White, Indian and Coloured ethnic groups respectively. This was due to the inability to locate the medial border of the respective pedicle as a result of the occipit overlapping the vertebra during the radiographic procedure. The IPD mean, standard deviation and range for the respective vertebral levels (C3–C7) for each ethnic group is shown in **Table 4.11**. An increase in the mean IPD at C4 and C5, decrease at C6 and no change at C7 was observed in the Black ethnic group. There was an increase in the mean IPD at C4, C5 and C6 respectively, and a decrease at C7 observed in the White ethnic group. In the Indian ethnic group, an increase in the mean IPD at C4, C5 and C6 respectively and a decrease at C7 was observed. An increase in the mean IPD was observed at C4 and C5 and remained unchanged at C6 and increased at C7 for the Coloured ethnic group. There was a significant difference between the ethnic groups for the mean IPD at C3, C4, and C5 levels (p = 0.020, 0.048 and 0.016, ANOVA; **Table 4.12**). For the mean IPD at C3 and C5 the difference was between the Indian and Coloured ethnic groups (p = 0.048 and 0.027 respectively, Bonferroni *post–hoc* test; **Table 4.13**).

Table 4.11 IPD (in millimeters) at the respective cervical vertebral levels by ethnic group

Group		IPDC3	IPDC4	IPDC5	IPDC6	IPDC7
Black	Mean	28.2	28.6	29.4	29.3	29.3
	n	20	20	20	20	20
	Std. deviation	1.2	1.4	1.2	1.6	1.2
	Minimum	26.0	26.3	27.4	26.5	27.9
	Maximum	30.6	31.0	31.1	32.1	31.5
White	Mean	28.9	29.6	30.0	30.7	30.1
	n	19	20	20	20	20
	Std. deviation	1.8	1.8	1.7	1.6	1.5
	Minimum	24.2	25.0	26.2	28.2	27.3
	Maximum	32.0	33.2	33.0	34.0	33.5
Indian	Mean	27.8	28.5	28.8	30.0	29.6
	n	17	20	20	20	20
	Std. deviation	1.1	1.4	1.2	1.6	1.6
	Minimum	26.5	26.7	26.0	26.9	27.4
	Maximum	30.4	31.0	30.9	32.1	32.7
Coloured	Mean	29.1	29.5	30.1	30.1	30.3

	n	19	20	20	20	20
	Std. deviation	1.4	1.6	1.5	1.5	1.9
	Minimum	26.5	26.0	27.1	26.9	26.2
	Maximum	32.7	32.9	32.8	34.0	34.2
Total	Mean	28.5	29.1	29.6	30.0	29.8
	n	75	80	80	80	80
	Std. deviation	1.5	1.6	1.5	1.6	1.6
	Minimum	24.2	25.0	26.0	26.5	26.2
	Maximum	32.7	33.2	33.0	34.0	34.2

Table 4.12 ANOVA tests to compare the mean IPD between ethnic groups

		Sum of Squares	**Df**	**Mean Square**	**F**	***p* - value**
IPDC3	Between groups	20.145	3	6.715	3.482	0.020
	Within groups	136.922	71	1.928		
	Total	157.067	74			
IPDC4	Between groups	19.451	3	6.484	2.762	0.048
	Within groups	178.437	76	2.348		
	Total	197.888	79			
IPDC5	Between groups	21.786	3	7.262	3.641	0.016
	Within groups	151.569	76	1.994		
	Total	173.355	79			
IPDC6	Between groups	20.197	3	6.732	2.655	0.054
	Within groups	192.715	76	2.536		
	Total	212.912	79			
IPDC7	Between groups	11.417	3	3.806	1.522	0.216
	Within groups	190.020	76	2.500		
	Total	201.437	79			

Table 4.13 Bonferroni *post-hoc* test to determine the difference in the means of the IPD for C3, C4 and C5

Dependent Variable	(I) group	(J) group	Mean Difference (I-J)	Std. Error	*p* - value	95% Confidence Interval	
IPDC3	Black	White	-0.7579	0.4449	0.557	-1.965	0.450
		Indian	0.4059	0.4581	1.000	-0.838	1.649
		Coloured	-0.8579	0.4449	0.347	-2.065	0.350
	White	Black	0.7579	0.4449	0.557	-0.450	1.965
		Indian	1.1638	0.4636	0.086	-0.095	2.422
		Coloured	-0.1000	0.4506	1.000	-1.323	1.123
	Indian	Black	-0.4059	0.4581	1.000	-1.649	0.838
		White	-1.1638	0.4636	0.086	-2.422	0.095
		Coloured	-1.2638(*)	0.4636	0.048	-2.522	-0.005
	Coloured	Black	0.8579	0.4449	0.347	-0.350	2.065
		White	0.1000	0.4506	1.000	-1.123	1.323
		Indian	1.2638(*)	0.4636	0.048	0.005	2.522
IPDC4	Black	White	-0.9450	0.4845	0.329	-2.258	0.368
		Indian	0.1750	0.4845	1.000	-1.138	1.488
		Coloured	-0.8300	0.4845	0.545	-2.143	0.483
	White	Black	0.9450	0.4845	0.329	-0.368	2.258
		Indian	1.1200	0.4845	.141	-0.193	2.433
		Coloured	0.1150	0.4845	1.000	-1.198	1.428
	Indian	Black	-.1750	0.4845	1.000	-1.488	1.138
		White	-1.1200	0.4845	0.141	-2.433	0.193
		Coloured	-1.0050	0.4845	0.249	-2.318	0.308
	Coloured	Black	0.8300	0.4845	0.545	-0.483	2.143
		White	-0.1150	0.4845	1.000	-1.428	1.198
		Indian	1.0050	0.4845	0.249	-0.308	2.318
IPDC5	Black	White	-0.5900	0.4466	1.000	-1.800	0.620
		Indian	0.6100	0.4466	1.000	-0.600	1.820
		Coloured	-0.6950	0.4466	0.743	-1.905	0.515
	White	Black	0.5900	0.4466	1.000	-0.620	1.800
		Indian	1.2000	0.4466	0.053	-0.010	2.410
		Coloured	-0.1050	0.4466	1.000	-1.315	1.105
	Indian	Black	-0.6100	0.4466	1.000	-1.820	0.600

	White	-1.2000	0.4466	0.053	-2.410	0.010
	Coloured	-1.3050(*)	0.4466	0.027	-2.515	-.095
Coloured	Black	0.6950	0.4466	0.743	-0.515	1.905
	White	0.1050	0.4466	1.000	-1.105	1.315
	Indian	1.3050(*)	0.4466	0.027	0.095	2.515

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

4.2.4 Cervical Gravity Line

Overall 53% of the participants had an anterior position of the CGL. This varied from 45% in Whites to 60% in Blacks (**Table 4.14**). Only two individuals had a posterior placing (one Black and one Indian). There was no significant difference between the ethnic groups and position of CGL (p = 0.733). The percentage of each ethnic group with anterior, normal and posterior position was relatively similar (**Table 4.14**). There were no significant differences in the mean CL (C1 – C7 method) between those with anterior and normal CGL in any of the ethnic groups (p > 0.05, t-tests; **Table 4.15**). This data suggests that CL (C1 – C7 method) does not influence the position of the CGL in any of the ethnic groups. In this study, it was observed that CL does not influence CGL (**Table 4.16**). There were no significant differences noted between or within the ethnic groups for the CL (C2 – C7 Cobb method) and the CGL (p = 0.310, ANOVA; **Table 4.17**).

Table 4.14 Cross tabulation of ethnic group and position of the CGL

			CGL			Total
			Anterior	**Normal**	**Posterior**	
Group	Black	Count	12	7	1	20
		% within group	60.0%	35.0%	5.0%	100.0%
	White	Count	9	11	0	20
		% within group	45.0%	55.0%	.0%	100.0%
	Indian	Count	10	7	1	18
		% within group	55.6%	38.9%	5.6%	100.0%
	Coloured	Count	10	9	0	19
		% within group	52.6%	47.4%	.0%	100.0%
Total		Count	41	34	2	77
		% within group	53.2%	44.2%	2.6%	100.0%

CGL = Cervical gravity line

Table 4.15 T-tests to compare the mean CL (C1 – C7 Cobb method) between those with anterior and normal CGL by ethnic group

Group	CGL	*n*	Mean CL	Std. deviation CL	Std. Error Mean CL	*p* - value
Black	Anterior	12	42.733	9.2221	2.6622	0.548
	Normal	6	45.533	8.8908	3.6297	
White	Anterior	8	46.450	5.2492	1.8559	0.939
	Normal	10	46.030	14.3915	4.5510	
Indian	Anterior	10	46.870	10.6347	3.3630	0.893
	Normal	7	46.086	13.0857	4.9459	
Coloured	Anterior	10	47.720	7.4923	2.3693	0.997
	Normal	7	47.700	11.7628	4.4459	

CGL = Cervical gravity line, CL = Cervical lordosis

Table 4.16 To determine if the CL (C2 –C7 method) influences the CGL

Report

C2-C7

CGL	Mean	*n*	Std. deviation
Anterior	14.850	40	7.8815
Normal	17.650	30	10.5562
Posterior	8.000	1	
Total	15.937	71	9.1437

Table 4.17 ANOVA tests between CL (C2-C7 method) and CGL

ANOVA

C2-C7

	Sum of Squares	df	Mean Square	F	*p*-value
Between Groups	198.290	2	99.145	1.192	0.310
Within Groups	5654.175	68	83.150		
Total	5852.465	70			

4.3 VARIATION IN THE SELECTED RADIOGRAPHIC PARAMETERS WITHIN THE ETHNIC GROUPS

4.3.1 Variation within groups

The coefficients of variation (%) are all relatively small within the ethnic groups (**Table 4.18**). For CL they tended to be larger than for the other measures since the standard deviations for this measure were relatively high (**Table 4.18**).

Table 4.18 Coefficient of variation (%) within ethnic groups

Ethnic group	SCDC2	SCDC3	SCDC4	SCDC5	SCDC6	SCDC7	CL	IPDC3	IPDC4	IPDC5	IPDC6	IPDC7
Black	7.6	8.3	10.5	9.6	9.4	9.5	22.7	4.2	4.9	4.1	5.5	4.1
White	6.0	7.0	7.0	7.6	7.8	7.7	23.8	6.1	6.0	5.6	5.4	5.0
Indian	7.7	8.5	8.6	9.0	8.4	8.4	24.3	3.9	4.7	4.3	5.4	5.5
Coloured	6.8	7.9	7.0	8.2	9.2	9.9	19.2	4.9	5.3	4.9	5.0	6.3

CHAPTER FIVE

DISCUSSION

5.1 AGE AND ANTHROPOMETRIC CHARACTERISTICS OF THE PARTICIPANTS

The age range and ethnicity of the participants were determined by the inclusion criteria of the study. The participants were young to middle-aged adults whose age ranged from 18 to 44 years. With respect to the anthropometric factors of the study, the mean heights of the participants were similar to that reported by Hardacker *et al*. (1997). The mean age (**Table 4.1)** was lower than those reported by Hardacker *et al.* (1997) and McAviney *et al*. (2005). The mean BMI for each ethnic group **(Figure 4.1)** fell into the normal range for adults as per the guidelines of the World Health Organisation (World Health Organization Global Data Base on Body Mass Index, 2011). When compared to other studies which investigated the radiographic parameters that were evaluated in this study, none had recorded BMI of their participants (Hardacker *et al.,* 1997; Lim and Wong, 2004; McAviney *et al*., 2005).

5.2 SELECTED RADIOGRAPHIC PARAMETERS OF THE CERVICAL SPINE

5.2.1 Cervical Lordosis

The mean CL (C1-C7 method) reported by Yochum and Rowe (2005) was 40°. The findings of the overall mean values of the CL (C1-C7 method) in this study (**Table 4.2)** were greater by 2.7°, 6.2°, 6.5° and 7.7° in the Black, White, Indian and Coloured ethnic groups respectively. The mean CL values (C1-C7 method) of the four ethnic groups in this study were similar to the mean CL (C0-C7 method) of the asymptomatic male group in the study by Hardacker *et al*. (1997). The mean CL (C1-C7 method) observed in this study was similar to that reported by Harrison *et al*. (2000) who also utilized the same method (**Table 2.3**). The mean CL (C1-C7 method) observed in this study was similar to that reported by Drexler (1962) although he utilized a different method (**Table 2.2**).

When the mean CL (C2-C7 method) of the four ethnic groups in this study (**Table 4.3**) was compared to that of Harrison *et al*. (2000) (**Table 2.3**) who also utilized the same method, a similar trend was observed. The difference in the mean CL (C2-C7 method) value was 2.1° less for the Black ethnic group, 0.2° more in the White ethnic group, 4.1° more in the Indian ethnic group and 0.9° more in the Coloured ethnic group when compared to Harrison *et al*. (2000). The mean CL of 40° reported by Drexler (1962) and Yochum and Rowe (2005) was a larger mean CL value when compared to the mean CL value (C2-C7 method) of the four ethnic groups of this study (**Table 4.3**). This finding emphasizes the importance of stating which method was utilized for evaluating the CL to assist the clinician in determining its significance.

When compared to the mean CL values of studies that utilized the posterior tangent method (Harrison *et al*., 2000; McAviney *et al*., 2005) **(Table 2.2)**, the mean CL values of this study (C1-C7 Cobb method) was greater in total for all four ethnic groups **(Table 4.2)**. This could possibly be due to the tendency of the C1-C7 Cobb method to overestimate the cervical lordosis, since most of the lordosis in the cervical spine occurs at the atlas (Harrison *et al*., 2000). When the mean CL value of the posterior tangent method (Harrison *et al*., 2000; McAviney *et al*., 2005) **(Table 2.2)**, is compared to the mean CL (C2-C7 method) values (**Table 4.3**) of the four ethnic groups in this study, smaller mean CL values are observed in this study. This is due to the tendency of C2-C7 method to underestimate the CL (Harrison *et al*., 2000). However, according to the literature, the more intuitively and commonly utilized method for CL evaluation is the Cobb method and the most accurate Cobb method is the C2-C7 method (Cote *et al*., 1997; Harrison *et al*., 2000). The interexaminer reliability for the C2-C7 method was superior than the C1-C7 method and it also demonstrated excellent reproducibility and intraclass coefficients (Cote *et al*., 1997).

The total mean CL value of the C2–C7 method in this study (**Table 4.3**) was similar to the mean CL value (C2-C7 method) of Harrison *et al*. (2000) shown in **Table 2.2**. There was a highly significant difference observed between the mean values of two Cobb methods utilized (**Table 4.5**). In light of these observations, the researcher of the present study recommends that the C2-C7 Cobb method be utilized by clinicians evaluating the CL. Since there were no significant differences in the mean CL between the four main ethnic groups, it is recommended that a future study with a larger sample size across the four ethnic groups in South Africa be conducted to establish whether a mean of 45.7° (C1-C7 method) or 15.9° (C2-C7 method) can be utilized as a norm reference for CL in the South African context.

There were no significant correlations observed between BMI and CL for the C1-C7 and C2-C7 Cobb methods as shown in **Table 4.6**. Hardacker *et al*. (1997) did not observe any significant association between the height and CL and none of the other studies that evaluated the CL investigated if there was any association between weight and CL. The studies that evaluated the CL did not investigate the possible relation or effect of this anthropometric factor. Although the results of this study show that the CL is not affected by the stature of an individual, this finding needs to be verified in a study with a larger sample size and with a broader range of BMI.

5.2.2 Sagittal Canal Diameter

Bland (1994) described the cervical spinal canal as funnel-shaped due to the canal being the widest at the C1 and C2 level before narrowing down to the smallest level at C5 and C6. The widest SCD in all ethnic groups was also observed at C2 in this study which was similar to the findings of Bland (1994). A decrease in the mean SCD of C3 was observed in all ethnic groups which is similar to the observations of Bland (1994).

Table 5.1 The mean SCD observed in this study compared to the reported mean SCD in combined male and female cohorts

Cervical vertebral level	Current study mean SCD (mm)	Oon (1974)	Yochum and Rowe (2005)
C2	**B**: 22.1	↑3.6	↑2.1
	W: 24.1	↑5.6	↑4.1
	I: 22.8	↑4.3	↑2.8
	C: 22.9	↑4.4	↑2.9
C3	**B**: 19.5	↑4.0	↑1.5
	W: 20.6	↑5.1	↑2.6
	I: 19.7	↑4.2	↑1.7
	C: 20.0	↑4.5	↑2.0
C4	**B**: 18.6	↑3.7	↑1.6
	W: 19.9	↑5.0	↑2.9
	I: 19.1	↑4.2	↑2.1
	C: 19.5	↑4.6	↑2.5
C5	**B**: 18.9	↑3.7	↑1.9
	W: 20.0	↑4.8	↑3.0
	I: 19.3	↑4.1	↑2.3
	C: 19.8	↑4.6	↑2.8
C6	**B**: 18.8	↑3.3	↑1.8
	W: 20.4	↑4.9	↑3.4
	I: 19.5	↑4.0	↑2.5
	C: 20.0	↑4.5	↑3.0
C7	**B**: 18.5	↑3.1	↑1.5
	W: 20.3	↑4.9	↑3.3
	I: 19.4	↑4.0	↑2.4
	C: 19.7	↑4.3	↑2.7

B = Black, W = White, I = Indian, C = Coloured, ↑ = larger, ↓ = smaller

When compared to the combined male and female mean SCD values of Oon (1974) and Yochum and Rowe (2005), the four ethnic groups of this study had larger mean SCD values at all cervical vertebral levels (**Table 5.1**). The greater differences in values were observed when compared to Oon (1974) who included a mixed sample although the majority of the cohorts were of Chinese ethnicity (**Table 2.4**). Furthermore, these participants had also experienced trauma to the cervical spine. The ethnicity of the participants whose SCD values are described by Yochum and Rowe (2005) is unknown.

Table 5.2 A comparison of the mean SCD of the current study to those of other studies

Cervical vertebral level	Current study mean SCD (mm)	Gupta *et al.* (1982)	Lee *et al.* (1994)	Lim and Wong (2004)	Tatarek (2005) African American	Tatarek (2005) Caucasian	Tossel (2007)
		M: (F)	M: (F)	M: (F)	M: (F)	M: (F)	M: (F)
C2	**B**: 22.1	↑ 2.4: ↑(3.5)	*	↑ 3.0: ↑(3.6)	↑ 5.7: ↑(7.0)	↑ 5.3: ↑(5.5)	*
	W: 24.1	↑ 4.4: ↑ (5.5)	*	↑ 5.0: ↑(5.6)	↑ 7.7: ↑(9.0)	↑ 7.3: ↑(7.5)	*
	I: 22.8	↑ 3.1: ↑ (4.2)	*	↑ 3.7: ↑(4.3)	↑ 6.4: ↑(7.7)	↑6.0: ↑(11.2)	*
	C: 22.9	↑ 3.2: ↑ (3.1)	*	↑ 3.8: ↑(4.4)	↑ 6.5: ↑(7.8)	↑ 6.1: ↑(6.3)	*
C3	**B**: 19.5	↑ 2.4: ↑ (3.4)	↑ 6.2: ↑(6.2)	↑ 2.7: ↑(3.4)	↑ 5.1: ↑(6.2)	↑ 4.5: ↑(5.1)	↑ 5.6: ↑(5.5)
	W: 20.6	↑ 3.5: ↑ (4.5)	↑ 7.3: ↑(7.3)	↑ 3.8: ↑(4.5)	↑ 6.2: ↑(7.3)	↑ 5.6: ↑(6.2)	↑ 6.7: ↑(6.6)
	I: 19.7	↑ 2.6: ↑ (3.6)	↑ 6.4: ↑(6.4)	↑ 2.9: ↑(3.6)	↑ 5.3: ↑(6.4)	↑ 4.7: ↑(5.3)	↑ 5.8: ↑(5.7)
	C: 20.0	↑ 2.9: ↑ (3.9)	↑ 6.7: ↑(6.7)	↑ 3.2: ↑(3.9)	↑ 5.6: ↑(6.3)	↑ 5.0: ↑(5.6)	↑ 6.1: ↑(6.0)
C4	**B**: 18.6	↑ 2.0: ↑ (3.0)	↑ 5.8: ↑(5.7)	↑ 2.4: ↑(2.9)	↑ 4.6: ↑(5.4)	↑ 4.0: ↑(4.9)	↑ 5.0: ↑(4.8)
	W: 19.9	↑ 3.3: ↑ (4.3)	↑ 7.1: ↑(7.1)	↑ 3.7: ↑(4.2)	↑ 5.9: ↑(6.7)	↑ 5.3: ↑(6.2)	↑ 6.3: ↑(6.1)
	I: 19.1	↑ 2.5: ↑ (3.5)	↑ 6.3: ↑(6.2)	↑ 2.9: ↑(3.4)	↑ 5.1: ↑(5.9)	↑ 4.5: ↑(5.4)	↑ 5.5: ↑(5.3)
	C: 19.5	↑ 2.9: ↑ (3.9)	↑ 6.7: ↑(6.6)	↑ 3.3: ↑(3.8)	↑ 5.5: ↑(6.3)	↑ 4.9: ↑(5.8)	↑ 5.9: ↑(5.7)
C5	**B**: 18.9	↑ 2.3: ↑ (3.2)	↑ 5.9: ↑(5.9)	↑ 2.1: ↑(2.9)	↑ 4.8: ↑(5.6)	↑ 4.4: ↑(5.3)	↑ 5.0: ↑(5.1)
	W: 20.0	↑ 3.4: ↑ (4.3)	↑ 7.0: ↑(7.0)	↑ 3.2: ↑(4.0)	↑ 5.9: ↑(6.7)	↑ 5.5: ↑(6.4)	↑ 6.1: ↑(6.2)
	I: 19.3	↑ 2.7: ↑ (3.6)	↑ 6.3: ↑(6.3)	↑ 2.5: ↑(3.3)	↑ 5.2: ↑(6.0)	↑ 4.8: ↑(5.7)	↑ 5.4: ↑(5.5)
	C: 19.8	↑ 3.2: ↑ (4.1)	↑ 6.8: ↑(6.8)	↑ 3.0: ↑(3.8)	↑ 5.7: ↑(6.5)	↑ 5.3: ↑(6.2)	↑ 5.9: ↑(6.0)
C6	**B**: 18.8	↑ 2.1: ↑ (3.0)	↑ 5.6: ↑(5.6)	↑ 1.6: ↑(2.7)	↑ 4.5: ↑(5.5)	↑ 4.3: ↑(5.4)	↑ 4.7: ↑(5.0)
	W: 20.4	↑ 3.7: ↑ (4.6)	↑ 7.2: ↑(7.2)	↑ 3.2: ↑(4.3)	↑ 6.1: ↑(7.1)	↑ 6.1: ↑(7.0)	↑ 6.3: ↑(6.6)
	I: 19.5	↑ 2.8: ↑ (3.7)	↑ 6.3: ↑(6.3)	↑ 2.3: ↑(3.4)	↑ 5.2: ↑(6.2)	↑ 5.2: ↑(6.1)	↑ 5.4: ↑(5.7)
	C: 20.0	↑ 3.3: ↑ (4.2)	↑ 6.8: ↑(6.8)	↑ 2.8: ↑(3.9)	↑ 5.7: ↑(6.7)	↑ 5.7: ↑(6.6)	↑ 5.9: ↑(6.2)
C7	**B**: 18.5	↑ 2.1: ↑ (3.0)	↑ 5.1: ↑(5.1)	↑ 1.4: ↑(2.5)	↑ 4.1: ↑(4.9)	↑ 4.2: ↑(5.1)	↑ 4.2: ↑(4.7)
	W: 20.3	↑ 3.9: ↑ (4.8)	↑ 6.9: ↑(6.9)	↑ 3.2: ↑(4.3)	↑ 5.9: ↑(6.7)	↑ 6.0: ↑(6.9)	↑ 6.0: ↑(6.5)
	I: 19.4	↑ 3.0: ↑ (3.9)	↑ 6.0: ↑(6.0)	↑ 2.3: ↑(3.4)	↑ 5.0: ↑(5.8)	↑ 5.1: ↑(6.0)	↑ 5.1: ↑(5.6)
	C: 19.7	↑ 3.3: ↑ (4.2)	↑ 6.3: ↑(6.3)	↑ 2.6: ↑(3.7)	↑ 5.3: ↑(6.1)	↑ 5.4: ↑(6.3)	↑ 5.4: ↑(5.9)

*** = did not measure, ↑ = larger, ↓ = smaller, M = male, F = female, ( ) = female value**

The mean SCD values of the males of the four ethnic groups of this study had larger values than those reported in previous studies at all cervical vertebral levels (**Table 5.2**). The mean SCD values of males of this study were greater than those of females reported in previous studies (**Table 5.2**). This is likely due to the anatomic differences in the size of the vertebral canal between gender as Bland (1994) reported that the female vertebral canal is smaller than the male vertebral canal.

The difference in the mean SCD observed in this study compared to Tatarek (2005) and Tossel (2007) may be due to the effect of radiographic magnification since they obtained their values from skeletal specimens and CT scans respectively. The FFD used in this study was the same as that utilized by Oon (1974), Gupta *et al*. (1982) and Lim and Wong (2004) (**Table 2.4**). The Caucasian American male population had larger mean SCD values at the C2, C3, C4, C5 and C6 vertebral levels and a smaller mean SCD value at the C7 vertebral levels when compared to the African American male population (Tatarek, 2005). A similar trend was observed between the White ethnic group and Black ethnic group of this study although the mean SCD at C7 of Whites was larger than that of the Black ethnic group (**Table 4.8**).

The widest SCD observed in all four ethnic groups was at the C2 vertebral level and this trend was also reported by Tatarek (2005) and Lim and Wong (2004) for the males and females in their studies. On the other hand, the widest SCD vertebral level for the Korean ethnic group was at C7 for the male and female gender (Lee *et al*., 1994). The widest SCD vertebral level was observed at C7 for South African Black males by Tossel (2007) but it should be noted that the C2 vertebral level was not evaluated in her study (**Table 2.4)** and could possibly account for the widest SCD being at C7 rather than at C2 as seen in the Black ethnic group of the current study.

The narrowest SCD level for the Black ethnic group of this study was at C4 and this was also the narrowest level for the Korean (Lee *et al*., 1994), Chinese (Lim and Wong, 2004), African American (Tatarek, 2005) and South African Black ethnic groups (Tossel, 2007) for both the male and female gender (**Table 2.4**). Tatarek (2005) reported that the narrowest SCD in the Caucasian American population was at the C6 vertebral level for both the male and female gender which was also in agreement with views of Bland (1994). These findings were similar to the White ethnic group of this study as the narrowest SCD vertebral level was observed at C5 and C6. The narrowest SCD in the Indian ethnic group of this study was observed at the C4 and C5 vertebral levels. These findings were similar to the Korean, Chinese, African American and South African Black ethnic groups for both the male and female gender (**Table 2.4**), but different to the Indian population reported by Gupta *et al*. (1982). The narrowest SCD vertebral levels were observed at C3 and C6 in the Coloured ethnic group of this study, the C6 level was similar to that of the American Caucasian population, but no other studies observed C3 to be the narrowest SCD vertebral level.

The Indian ethnic group of this study had larger mean SCD values at all vertebral levels than that of the Indian male and female cohorts of Gupta *et al*. (1982). The mean SCD values of the Indian population in this study decreased at C3 and C4, increased at C5 and C6, and decreased at C7 **(Table 4.4)** which was the similar pattern observed by Gupta *et al*. (1982). Lim and Wong (2004) observed the narrowest SCD in the Chinese population at the C4 vertebral level, which was different to that reported by Bland (1994) who found the narrowest vertebral level to be at C5 and C6. The mean SCD of the Chinese ethnic group decreased at C3 and C4, increased at C5 and C6 and then decreased at the C7 vertebral level, a trend observed in all four ethnic groups of this study. Lim and Wong (2004) reported that the mean SCD values of the White population was larger than that of the Indian population and this trend was also observed between the White and Indian ethnic groups of this study. Narrower mean SCD values were found in females when compared to the males in the Chinese ethnic group (Lim and Wong, 2004).

The results of the study indicate that normative reference values for the SCD should be based on ethnicity and gender. This is in keeping with the recommendation of Lee *et al*. (1994), Lim and Wong (2004), Tatarek (2005) and Tossel (2007). However, a study with a larger sample size needs to be conducted across South Africa to confirm the findings of this study.

5.2.3 Interpedicular Distance

The cervical cord enlargement begins at vertebral segment C3 and ends at T2. This part of the spinal cord is also known to be thicker than that of the lumbar spinal cord area (Bland, 1994). The results of this study show an increase in total IPD mean values at levels C4, C5, and C6 which could be due the cervical cord enlargement at these levels (Bland, 1994). The decrease in the total IPD mean value at C7 could possibly be due to the tapering of the cervical cord towards level T2 or the fact that the cervical cord has the greatest thickness at the level of C6, which is actually the midpoint of the cervical cord enlargement (Bland, 1994). Anatomical variation of any of the structures contributing to the boundary of the spinal canal (**Section 2.2.2**) of the cervical vertebrae could also have influenced the measurement of C7.

Table 5.3 The mean IPD observed in this study compared to the reported mean IPD in combined male and female cohorts

Cerviacl vertebral level	Current study mean IPD (mm)	Hinck *et al*. (1966)
C3	**B**: 28.2	↑ 0.2
	W: 28.9	↑ 0.9
	I: 27.8	↓ 0.2
	C: 29.1	↑ 1.1
C4	**B**: 28.6	↓ 0.2
	W: 29.6	↑ 0.8
	I: 28.5	↓ 0.3
	C: 29.5	↑ 0.7
C5	**B**: 29.4	=
	W: 30.0	↑ 0.6
	I: 28.8	↓ 0.6
	C: 30.1	↑ 0.7
C6	**B**: 29.3	=
	W: 30.7	↑ 1.4
	I: 30.0	↑ 0.7
	C: 30.1	↑ 0.8
C7	**B**: 29.3	↑ 1.3
	W: 30.1	↑ 2.1
	I: 29.6	↑ 1.6
	C: 30.3	↑ 2.3

B = Black, W = White, I = Indian, C = Coloured, ↑ = larger, ↓ = smaller, same value (=)

When compared to the combined male and female cervical vertebral level values of Hinck *et al*. (1966), the mean IPD of the Black ethnic group showed larger mean IPD values at C3 and C7, equal values at C5 and C6 and a smaller value at the C4 vertebral levels. The White ethnic group had mean IPD values that were larger at all the vertebral levels. Smaller mean IPD values were observed at C3, C4 and C5 and larger values were shown at C6 and C7 vertebral levels for the Indian ethnic group. The Coloured ethnic group had larger mean IPD values at all vertebral levels (**Table 5.3**). This suggests that mean IPD values vary between ethnic groups and gender.

Table 5.4 A comparison of the mean IPD of the current study to those of other studies

			Tatarek (2005)	
Cervical vertebral level	**Current study mean IPD**	**Ugur *et al*. (2000)**	**African American**	**Caucasian American**
	M: (mm)	**M: (F)**	**M: (F)**	**M: (F)**
C3	**B**: 28.2	↑ 6.6: ↑(5.8)	↑ 4.9: ↑(5.7)	↑ 4.8: ↑(5.7)
	W: 28.9	↑ 7.3: ↑(6.5)	↑ 5.6: ↑(6.2)	↑ 5.6: ↑(6.4)
	I: 27.8	↑ 6.2: ↑(5.4)	↑ 4.5: ↑(5.1)	↑ 4.4: ↑(5.3)
	C: 29.1	↑ 7.5: ↑(6.7)	↑ 5.8: ↑(6.4)	↑ 5.7: ↑(6.6)
C4	**B**: 28.6	↑ 7.8: ↑(6.1)	↑ 4.3: ↑(5.1)	↑ 4.5: ↑(5.1)
	W: 29.6	↑ 8.8: ↑(7.1)	↑ 5.3: ↑(6.1)	↑ 5.3: ↑(6.1)
	I: 28.5	↑ 7.7: ↑(6.0)	↑ 4.2: ↑(5.0)	↑ 4.4: ↑(5.0)
	C: 29.5	↑ 8.7: ↑(7.0)	↑ 5.2: ↑(6.0)	↑ 5.4: ↑(6.0)
C5	**B**: 29.4	↑ 8.7: ↑(6.2)	↑ 4.4: ↑(5.4)	↑ 4.5: ↑(5.0)
	W: 30.0	↑ 9.3: ↑(6.8)	↑ 5.0: ↑(6.0)	↑ 5.0: ↑(6.6)
	I: 28.8	↑ 8.1: ↑(5.6)	↑ 3.8: ↑(4.8)	↑ 3.9: ↑(4.4)
	C: 30.1	↑ 9.4: ↑(6.9)	↑ 5.1: ↑(6.1)	↑ 5.2: ↑(5.7)
C6	**B**: 29.3	↑ 7.7: ↑(4.2)	↑ 3.8: ↑(4.8)	↑ 4.1: ↑(5.0)
	W: 30.7	↑ 9.1: ↑(5.6)	↑ 5.2: ↑(6.2)	↑ 5.2: ↑(6.4)
	I: 30.0	↑ 8.4: ↑(4.9)	↑ 4.5: ↑(5.5)	↑ 4.8: ↑(5.7)
	C: 30.1	↑ 8.5: ↑(5.0)	↑ 4.6: ↑(5.6)	↑ 4.9: ↑(5.8)
C7	**B**: 29.3	↑ 6.4: ↑(4.8)	↑ 4.8: ↑(5.8)	↑ 5.0: ↑(5.9)
	W: 30.1	↑ 7.2: ↑(5.6)	↑ 5.6: ↑(6.6)	↑ 5.6: ↑(6.7)
	I: 29.6	↑ 6.7: ↑(5.1)	↑ 5.1: ↑(6.1)	↑ 5.3: ↑(6.2)
	C: 30.3	↑ 7.4: ↑(5.8)	↑ 5.8: ↑(6.8)	↑ 6.0: ↑(6.9)

B = Black, W = White, I = Indian, C = Coloured, ↑ = larger, ↓ = smaller, same value (=)

When the mean IPD values of the four ethnic groups of this study were compared to those of Ugur *et al*. (2000) and Tatarek (2005) the mean IPD values at all the cervical vertebral levels were larger than those of males and females (**Table 5.4**). The greater differences were observed when compared to the mean female IPD values of both these studies. These studies obtained their mean IPD values from cadavers and skeletal specimens, which could be the reason for larger mean IPD values at all cervical vertebral levels of this study. Tatarek (2005) observed larger mean IPD values in the African American population at vertebral levels C4, C5, C6 and C7 when compared to that of the Caucasian American population (**Table 2.5**). This pattern was not observed in this study when the Black and White ethnic groups were compared as larger mean IPD values were observed in the White ethnic group at vertebral levels C3, C4, C5, C6 and C7 (**Table 4.11**).

The IPD values of the Coloured and Indian ethnic groups were not available in the literature reviewed. The IPD values for these two ethnic groups are presented for the first time in this study. Greater mean IPD values were observed for the Coloured ethnic group compared to the Indian and Black ethnic group at all vertebral levels and at levels C3, C5 and C7 when compared to the White ethnic group of this study **(Table 4.11)**. The Indian ethnic group had IPD values that were smaller than the White and Coloured ethnic groups at all the vertebral levels and at levels C6 and C7 when compared to the Black ethnic group of this study **(Table 4.11)**.

As with the SCD, the results of this study indicate that normative reference values for IPD should be based on ethnicity and gender. This is in keeping with the recommendation of Tatarek (2005) and the observations of Bland (1994) and Ugur *et al*. (2000). However, a study with a larger sample size needs to be conducted across South Africa to confirm the findings of this study.

5.2.4 Cervical Gravity Line

An anterior placement of the CGL was observed by Hardacker *et al*. (1997) in all 100 volunteers, which was considered as normal. The results of this study were similar to that of Hardacker *et al*. (1997) since the majority of the participants had the CGL anterior to the anterior-inferior border of the C7 VB **(Table 4.15)**. The lateral cervical plumb line utilized by Hardacker *et al*. (1997) was assessed according to its distance from the centre of the C7 VB and the method utilized in the current study is different since the anterior-inferior border of C7 was the reference point rather than the centre of the C7 VB. There was no mention of the ethnic or population groups of the cohorts of Hardacker *et al*. (1997).

Both the methods utilized for CL evaluation did not influence the CGL significantly (**Tables 4.15** and **Table 4.16**). This could possibly be due to the small sample size or selection of normal participants who were free of neck pain, history of trauma to the neck or arthritic diseases. The effect of the CL on the CGL should be investigated on both asymptomatic and symptomatic cohorts to determine any significant differences between these two groups. All four ethnic groups had similar results for anterior, normal and posterior placement of the CGL. The significance of the potential influence that the CL might have had on the CGL had not been investigated prior to the current study. The importance of assessing this radiographic parameter lies in the evaluation of the gravitational forces acting at the cervicothoracic junction (Yochum and Rowe, 2005) and for radiographic assessment of the cervical spine in the sagittal plane (Hardacker *et al*., 1997). Although the CL may not have had an influence on the CGL of the participants in this study, the lordosis allows for the forces acting on the VB both anteriorly and posteriorly to be minimal. Anterior head carriage which may occur as a result of altered CL causes an uneven distribution of forces on the anterior cervical VB (Harrison *et al*., 2001).

The influence of the CL on the CGL has been investigated for the first time in this study. The results indicate that the CL does not significantly influence the CGL across the four ethnic groups and the CGL does not vary significantly between the four ethnic groups. This suggests that the curve of the cervical spine does not influence anterior head carriage irrespective of ethnicity. However, the relationship of the CL and CGL requires further investigating in future studies with larger cohorts stratified according to asymptomatic and symptomatic subjects before firm conclusions can be made.

CHAPTER SIX

CONCLUSION AND RECOMMENDATIONS

6.1 CONCLUSION

Based on the results of this study, the CL did not vary significantly for both the Cobb methods (C1-C7 and C2-C7) utilized across the four ethnic groups in a South African population. This indicates that they may be evaluated for post-traumatic, post surgical, degenerative spondylytic states as well as for biomechanical assessment of the cervical spine irrespective of ethnicity. It is imperative that clinicians state which method for CL evaluation is utilized and a mean of 45.7° (C1-C7 method) and 15.7° (C2-C7 method) is recommended to be the norm reference value for CL in a South African context but requires verification in a study with a larger sample size. Since the CL did not influence the CGL in this study, this implies that the cervical curve does not influence anterior head carriage. Therefore, the CGL can be assessed irrespective of ethnicity.

The evaluation of the spinal canal is essential for the diagnosis of patients with spinal stenosis or tumors. The significant differences observed in the SCD and IPD between the ethnic groups of this study indicate that normative reference values should be based on ethnicity and gender. This is in keeping with the recommendation of the literature which reported the influence of ethnicity and gender on these radiographic parameters. Therefore the SCD and IPD should be evaluated according to ethnicity and gender in a South African context. The trends observed in this study will assist South African health care practitioners with the evaluation of post-surgical and post-traumatic states and for the presence of stenosis or tumors specific to patient ethnicity and gender.

6.2 RECOMMENDATIONS

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

- A larger population-based study should be conducted utilizing the latest digitized diagnostic imaging modalities such as radiographs, CT and MRI scans so that potential errors during manual assessment are reduced. This will determine whether the trends observed in this study are similar to the broader population in South Africa.

- The results of this study be published in a peer-reviewed accredited journal and presented to the relevant health care professionals such as spinal surgeons, radiologists and chiropractors at the appropriate conferences and seminars so that they are aware of the trends in the normative reference values of the selected radiographic parameters.

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APPENDIX A

FREE NECK X-RAYS

IF YOU ARE MALE, HEALTHY AND BETWEEN THE AGES OF 18 - 45 YEARS YOU MAY BE ELIGIBLE TO PARTICIPATE IN MY RESEARCH

IF YOU ARE INTERESTED AND WANT TO FIND OUT MORE:

CONTACT: ASHVEER

CHIROPRACTIC DAY CLINIC, DURBAN UNIVERSITY OF TECHNOLOGY

0798980329/ 031 – 3732205

YOU WILL BE OFFERED ONE FREE TREATMENT AFTER PARTICIPATING IN THIS STUDY

APPENDIX B

LETTER OF INFORMATION

Date:

Dear Participant, welcome to my research project.

Title of Research: Ethnic variations of selected cervical spine radiographic parameters of males in KwaZulu Natal.

Name of student: Ashveer Roopnarian
Contact number: 0798980329

Name of supervisor: Dr. J. Shaik (M.Tech.Chiro; M.Med.Sci. (SM))
Contact number: 031-3732588

Name of co-supervisor: Dr. V. Boodhoo (M.Tech.Chiro)
Contact number: 031-2077968

You have been selected to be part of the research programme. This research programme will evaluate the normal x-ray values of certain measurements on an x-ray of the neck in 80 apparently healthy young to middle aged males across four ethnic groups.

Eighty people, twenty, for each ethnic group will be required to complete this study.

To be part of this study you must

- Be male and between the ages of 18-45 years.
- Give informed consent to participate in the research.
- Be free of neck pain and should not have any significant medical complaints in the history or physical examination.
- Be of Black, White, Coloured or Indian ethnic 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 can begin.
- Have arthritic disease in the neck, surgery or trauma to the spine determined in the initial consultation at the Chiropractic Day Clinic.
- Any neck pain or injuries sustained to the neck between the initial consultation and the radiographic appointment (i.e. the appointment when x-rays of your neck are taken)
- Have had any injury to your neck such as whiplash prior to your taking part in this study

Benefits to the participant

- You will have a full medical history, physical examination and cervical spine orthopaedic assessment performed.

- You will receive a set of your cervical spine x-rays free of charge.
- You will be eligible for one free treatment at the Chiropractic Day Clinic if you develop neck or back pain within one-month of your x-ray consultation.
- An x-ray report together with a summary of the results of this study will be sent to you via post once this study is completed.

Reason/s why the subject may be withdrawn from the study without your consent

- If you sustain any injuries to the neck 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.

Cost of the Study
There is no cost to you for any aspect of this research.

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). By being x-rayed, you are being exposed to radiation. However, the dose is minimal and there are no anticipated side-effects.

Confidentiality
All personal details and relevant information gathered through the research process will only be accessible by the researcher (Ashveer Roopnarian) and supervisor (Dr. Junaid Shaik). 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.

Persons to contact in the event of any problems or queries
Mr. Vikesh Singh, Faculty of Health Sciences Officer, 031 373 2701

I………………………………………… (Subjects 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 Ashveer Roopnarian to my satisfaction. Furthermore, I fully understand that I may withdraw from this study without any adverse consequences and my future health care will not be compromised. I, therefore, voluntarily agree to participate in the study.

Participant's name (print)……………………………. Signature …………………….

Date……….

Researcher's name……………………………… Signature ……………………..
Date……….

Witness name …………………………………… Signature ……………………...
Date……….

APPENDIX C
Case History

DURBAN UNIVERSITY of TECHNOLOGY

DURBAN UNIVERSITY OF TECHNOLOGY
CHIROPRACTIC DAY CLINIC
CASE HISTORY

DURBAN UNIVERSITY of TECHNOLOGY

Patient: ______________________ Date: __________

File # : __________ Age: __________

Sex : __________ Occupation: __________________

Intern : ____________________ Signature __________________

FOR CLINICIANS USE ONLY:

Initial visit
Clinician: Signature :

Case History:

Examination:
Previous: Current:

X-Ray Studies:
Previous: Current:

Clinical Path. lab:
Previous: Current:

CASE STATUS:

PTT: Signature: Date:

CONDITIONAL:
Reason for Conditional:

Signature: Date:

Conditions met in Visit No: Signed into PTT: Date:

Case Summary signed off: Date:

Intern's Case History:

1. **Source of History:**

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

3. **Present Illness:**

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

4. **Other Complaints:**

5. **Past Medical History:**

< General Health Status

< Childhood Illnesses

< Adult Illnesses

< Psychiatric Illnesses

< Accidents/Injuries

< Surgery

< Hospitalizations

6. Current health status and life-style:

< Allergies

< Immunizations

< Screening Tests incl. x-rays

< Environmental Hazards (Home, School, Work)

< Exercise and Leisure

< Sleep Patterns

< Diet

< Current Medication
Analgesics/week:

< Tobacco

< Alcohol

< Social Drugs

7. Immediate Family Medical History:

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

8. Psychosocial history:

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

9. Review of Systems

< General

< Skin

< Head

< Eyes

< Ears

< Nose/Sinuses

< Mouth/Throat

< Neck

< Breasts

< Respiratory

< Cardiac

< Gastro-intestinal

< Urinary

< Genital

< Vascular

< Musculoskeletal

< Neurologic

< Haematologic

< Endocrine

< Psvchiatric

APPENDIX D
Physical Examination

Durban University of Technology
PHYSICAL EXAMINATION: SENIOR

Patient Name : ______________________ **File no :**__________ **Date :**__________
Student : **Signature :**

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

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

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

Clinician: **Signature :**

APPENDIX E
Cervical Spine Orthopedic Regional

DURBAN UNIVERSITY OF TECHNOLOGY
REGIONAL EXAMINATION - CERVICAL SPINE

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

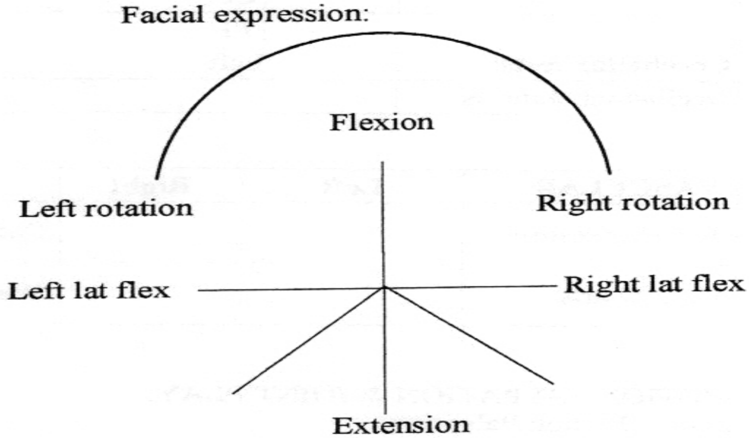
Date: .... Student: ....

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

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

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

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



PALPATION:
Lymph nodes
Thyroid Gland
Trachea

ORTHOPAEDIC EXAMINATION:

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

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

NEUROLOGICAL EXAMINATION:

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

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

Reflexes	**Left**	**Right**
C5		
C6		
C7		

Cerebellar tests:	Left	Right
Disdiadochokinesis		

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

MOTION PALPATION & JOINT PLAY:

Left: Motion Palpation:
Joint Play:

Right: Motion Palpation:
Joint Play:

BASIC EXAM: SHOULDER:

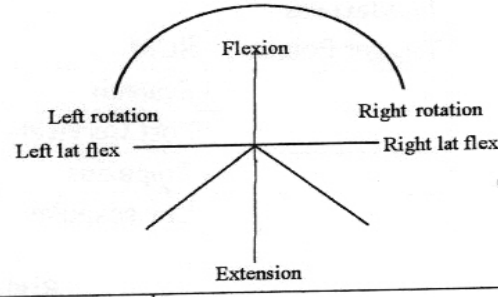
Case History:

ROM: Active:
Passive:
RIM:
Orthopaedic:
Neuro:
Vascular:

BASIC EXAM: THORACIC SPINE:

Case History:

ROM:



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

APPENDIX F
Data Collection Sheet

Demographic data: Males

No.	File No.	Code	Age	Occupation	Height	Weight
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
CL: Cervical Lordosis

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

SCD: Sagittal Canal Diameter (mm)

No	Code	C2	C3	C4	C5	C6	C7	No	Code	C2	C3	C4	C5	C6	C7
1								11							
2								12							
3								13							
4								14							
5								15							
6								16							
7								17							
8								18							
9								19							
10								20							
									Average						
									Range						

IPD: Interpedicular Distance (mm)

No	Code	C3	C4	C5	C6	C7	No	Code	C3	C4	C5	C6	C7
1							11						
2							12						
3							13						
4							14						
5							15						
6							16						
7							17						
8							18						
9							19						
10							20						
								Average					
								Range					

CGL: Cervical Gravity Line (mm)

Number	Code	CGL Anterior to C7 Vertebral Body (mm)	CGL at C7 Vertebral Body	CGL Posterior to Vertebral Body (mm)
1				
2				
3				
4				
5				
6				
7				
8				
9				
10				
11				
12				
13				
14				
15				
16				
17				
18				
19				
20				
	Average			
	Range			

APPENDIX G
Ethics Clearance Certificate

DURBAN UNIVERSITY of TECHNOLOGY

Faculty of Health Sciences

ETHICS CLEARANCE CERTIFICATE

Student Name	Ashveer Roopnarian	Student No	20402549
Ethics Reference	034/10	Date of FRC Approval	13.08.2010
Qualification	M. Tech. Chiropractic		
Research Title:	Ethnic variations of selected cervical spine radiographic parameters of males in KwaZulu Natal.		

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

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

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

[redacted]

5 AUGUST 2010.
DATE

5 August 2010
DATE

11/8/2010.
DATE

11/08/2010.

SIGNATURE: CHAIRPERSON OF RESEARCH ETHICS COMMITTEE