SAGITTAL SPINAL ALIGNMENT IN LONG-TERM SURFERS OF ETHEKWINI

By

Alexander Mudge

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I, Alexander Mudge, do hereby declare that this dissertation is representative of my own work in both conception and execution (except where acknowledgments indicate to the contrary).

Alexander Mudge	**Date**

Approved for final examination:

Prof. Julian D. Pillay	**Date**

DEDICATION

To the ocean, the wind, and the tides - without which this beautiful dance we call surfing would not be possible.

ACKNOWLEDGMENTS

To my wife, my best friend and love... my adventure buddy – thank you for living life by my side. You are my guiding light, and I would get so lost without you.

To my parents – thank you for your love, trust, and support through this journey. I got here thanks to you.

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To my study participants: Thank you for sacrificing your valuable time, and energy... and for braving the Corona virus to take part in this study.

To the lecturers, staff, and clinicians at the Durban University of Technology: thank you for providing me with the tools to build a solid foundation to what promises to be an epic journey in chiropractic.

ABSTRACT

Background: Sagittal spinal alignment and posture deteriorate with age, but may be affected by physical activity. Surfers catch and ride breaking waves using a surfboard, which they paddle while prone with their spine extended. Spinal extension exercise is generally beneficial to postural development with age. This study aimed to investigate whether an association exists between long-term surfing and the progression of sagittal spinal alignment and posture i.e. cervical lordosis (C-angle (flex and Cobb)), thoracic kyphosis (T-angle (flex and Cobb)), lumbar lordosis (L-angle (flex and Cobb)), and sagittal posture (Posture Number) in ostensibly healthy males over the age of 50. The objectives of this study included: 1) Assessing the. C, T, L-angles, and Posture Numbers in long-term male surfers and physically active non-surfer ; 2) Determining whether any significant differences exist between the selected sagittal spinal alignment and posture parameters within or between the surfing and non-surfing groups; and 3) Determining the association, if any, between age, years of surfing and selected spinal alignment parameters.

Methodology: 52 males over the age of 50 underwent a case history and postural examination. Their C, T, and L-angles were plotted onto graph paper to analyse using BiomechFlex. Anterior and lateral full-body photographs were taken to analyse using Posture Pro version 8. The generated statistics were analysed using STATA version 16. The summary measures used included the mean, median, standard deviation, range and percentiles of spinal angle and posture variables, as well as the age, anthropometric variables, activity hours per week and activity years.

Results: The mean body mass index (BMI) of the S group (24.9kg/m^2) was significantly lower than the 27.6kg/m^2 mean of the NS group, p=0.00. The average time spent on activities per week was over 3 hours in both groups (S group - 3.28hrs and NS groups - 4.67hrs, p=0.0004). On average, the S group (45.6 years) had been practising surfing for significantly more years than the NS group (32 years) had been practising their respective primary activities, p=0.0008. There were no significant differences between the S and NS groups in terms of C- (flex p=0.6234), T- (flex p=0.5758 and Cobb p= 0.5518), or L-angles (flex p=0.6171 and Cobb p=0.6142), or Posture Number (p=0.5348). The T-angles (flex and Cobb) obtained from both NS and S groups were greater than 40º, which is classified as hyperkyphotic. There was a positive correlation between age and Posture Number in the S group (r = 0.4307 and p-value = 0.0316), but not the NS group. There was a significant association between Posture Number and T-angle (flex *p*=0.027 and Cobb *p*=0.026). The NS group had a 2.15º (flex) and 2.09º (Cobb) greater T-angles for any given posture Number. The NS group had an average of 2.9º (flex) and 2.23º (Cobb) lower L-angles than the S group for any given BMI. Thus, surfing may suggest benefit of surfing to sagittal spinal alignment and posture.

Conclusion: The results of this study show that long-term surfing is beneficial to the aging individual in terms of body composition. However, it is no more effective at mediating the effect of age on sagittal spinal alignment and posture than other forms of physical activity included in this study. Nevertheless, slight differences between the NS and S groups were present, which may indicate that the biomechanical or even postural effects/adaptations of long-term surfing differ from those of other activities. These subtle differences indicate the need for further research around physical activity, sagittal spinal alignment and posture.

Key words: Sagittal spinal alignment, posture, age, surfing, physical activity

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DEFINITIONS

Activity years: the number of years that participants had practised their selected primary physical activities, i.e. surfing or other.

Age-related hyperkyphosis: a kyphosis angle greater than 40°, which is the 95th percentile of normal for young adults, that occurs due to aging (Katzman *et al.* 2010)

Biomech Flex: a computer application that calculates the angles of the cervical, thoracic, and lumbar spinal curvatures from the flexicurve measurements using a third order polynomial.

Body Mass Index (BMI): a number calculated from an individual's height and weight - body mass divided by body height squared, and is expressed in units of kg/m^2.

C-angle (Cobb): The Cobb angle of the cervical lordosis – estimated from the C-angle (flex) by the Biomech Flex computer application.

C-angle (flex): the angle of the cervical lordosis as calculated from the curve obtained by moulding the flexicurve ruler to the cervical spine.

Flexicurve ruler: a strip of metal covered in plastic to form a flexible ruler.

Kyphosis: The posterior convex curvature that occurs normally in the thoracic spine and sacrum - the thoracic and sacral kyphoses are primary curvatures that develop during the foetal period in relation to the foetal position (Moore, Dalley and Agur 2010)

L-angle (C0bb): The Cobb angle of the lumbar lordosis – estimated from the L-angle (flex) by the Biomech Flex computer application.

L-angle (flex): the angle of the lumbar lordosis as calculated from the curve obtained by moulding the flexicurve ruler to the lumbar spine.

Lordosis: The posterior concave curvature that occurs normally in the cervical and lumbar spines - the cervical and lumbar lordoses are secondary curvatures that result from extension from the flexed foetal position. They begin to appear in the late foetal period but do not become obvious until infancy (Moore, Dalley and Agur 2010)

Non-Surfers: For this study - physically active individuals who do not participate in surfing

Posture: The position in which someone holds his or her body

Posture Number™: a number used to quantify sagittal posture by comparing a line connecting anatomical landmarks in the sagittal plain from a straight plumb line. Higher Posture Number means greater deviation from the plumb line.

PosturePro™: a software product for posture analysis that operates by locating joint angles and measuring various distances between body points (Geslak, Gray and Bresingham 2007)

Sagittal spinal alignment: Alignment of the spinal vertebrae when viewed from the side (in the sagittal plane)

Spinal extension exercise: Exercises prescribed for strengthening the extensor muscles of the spine.

Surfer: A person who participates in the sport of surfing – for this study "surfers" referred specifically to those participating in stand-up surfing.

Surfing: the sport of riding waves - surfers catch ocean, river, or man-made waves, and glide across the surface of the water until the wave breaks and loses its energy

T-angle (Cobb): The Cobb angle of the thoracic kyphosis – estimated from the T-angle (flex) by the Biomech Flex computer application.

T-angle (flex): the angle of the thoracic kyphosis as calculated from the curve obtained by moulding the flexicurve ruler to the thoracic spine.

1 INTRODUCTION

1.1 Background

Human spinal alignment and posture are dynamic and adaptable and are affected by factors such as age, physical activity and pathology (Yochum and Rowe 2005; Moore, Dalley and Agur 2010). General trends indicate deterioration of sagittal spinal alignment and posture as age increases past the fourth-to-fifth decade of life (Boyle, Milne and Singer 2002; Katzman *et al.* 2010; Katzman, Vittinghoff and Kado 2011; Roghani *et al.* 2017; Merrill *et al.* 2018; Pan *et al.* 2018b). Examples of changes which may occur with increased age include increases in cervical lordosis (CL) and thoracic kyphosis (TK), as well as decreased lumbar lordosis (LL) (Boyle, Milne and Singer 2002; Katzman *et al.* 2010; Katzman, Vittinghoff and Kado 2011; Skaf *et al.* 2011; Dreischarf *et al.* 2014; Asai *et al.* 2017; Chen *et al.* 2017; Merrill *et al.* 2018). Postural change, especially thoracic kyphosis (age-related hyperkyphosis), has been linked to poor physical function, higher fall risk, lower self-reported quality of life and even higher mortality rates among the elderly (Boyle, Milne and Singer 2002; Katzman *et al.* 2010; Katzman, Vittinghoff and Kado 2011; Skaf *et al.* 2011; Dreischarf *et al.* 2014; Asai *et al.* 2017; Chen *et al.* 2017; Merrill *et al.* 2018).

Pathological processes and injuries may cause significant alterations to normal spinal alignment and posture development (Yochum and Rowe 2005; Moore, Dalley and Agur 2010). These pathological processes can be congenital or acquired and range from serious to benign and may appear acutely or develop over prolonged periods (Yochum and Rowe 2005; Moore, Dalley and Agur 2010; Walker *et al.* 2014). Common pathological conditions which have been linked to postural deterioration include osteoporosis and osteoarthritis (Walker *et al.* 2014; Roghani *et al.* 2017). Osteoporosis affects bone mineral density and is a major risk factor for vertebral compression fractures. Osteoarthritis, or degenerative joint disease (DJD), affects the intervertebral disks and eventually the vertebral bodies as well (Katzman *et al.* 2010; Roghani *et al.* 2017). Injuries, such as vertebral compression fractures, are common among the elderly and often lead to postural change and disability (Yochum and Rowe 2005; Moore, Dalley and Agur 2010; Roghani *et al.* 2017). However, up to 70% of cases of age-related hyperkyphosis show no evidence of underlying fractures (Roghani *et al.* 2017). Huang *et al.* (2006) suggested that ARHK is a risk factor for suffering from future compression fractures. A sedentary lifestyle and obesity also contribute to postural deterioration and may contribute to multiple systemic pathologies such as hypertension and diabetes mellitus type II (Walker *et al.* 2014; Pan *et al.* 2018b; Jankowicz-Szymanska *et al.* 2019).

In many cases, the age-related changes to spinal alignment and posture can be mitigated through the implementation of spinal strengthening and flexibility, as well as breathing exercise programmes (Ball *et al.* 2009; Kado 2009; Katzman *et al.* 2010; Bansal, Katzman and Giangregorio 2014; González-Gálvez, Gea-García and Marcos-Pardo 2019). Physical activities such as yoga, Thai Chi and dancing may also be beneficial to maintaining proper spinal alignment and posture (Choi, Moon and Song 2005; Tekur *et al.* 2008; Greendale *et al.* 2009; Kruusamae *et al.* 2015). Specifically designed exercise programmes have been created to target problems such as age-related hyperkyphosis (ARHK) and low back pain, but physical activity, in general, is beneficial to spinal alignment and posture. (Ostrowska, Rozek-Mroz and Giemza 2003; Katzman *et al.* 2007; Ball *et al.* 2009; Greendale *et al.* 2009; Kado 2009; Fusco *et al.* 2011; Kiers *et al.* 2013; Bansal, Katzman and Giangregorio 2014; Jang, Kim and Kim 2015; Kruusamae *et al.* 2015; Iunes *et al.* 2016; Jang *et al.* 2017; Katzman *et al.* 2017b).

Surfing is a form of physical activity that involves paddling a surfboard on the water surface in order to catch and ride waves. This sport generally takes place in the ocean but can happen in places such as rivers and tidal bores where water moves over uneven ground to form waves (Warshaw 2011). Though the goal of surfing is ultimately to ride waves, most of the time in a surf session is spent in paddling – paddling to get to the waves, paddling to get into or stay in position to catch the waves and paddling to catch the waves by matching their speed (Meir *et al.* 1991; Farley, Harris and Kilding 2012; Secomb, Sheppard and Dascombe 2015; LaLanne *et al.* 2017; dos Santos 2018). The surfer must paddle his/her board with his/her arms while lying in a prone position on top of the board. The paddling position requires prolonged periods of spinal extension to lift the chest off the board to allow for the full range of motion of the shoulders and arms. It also enables the head to lift so that the surfer may observe their surroundings (Metcalfe and Kelly 2012; Furness *et al.* 2016; dos Santos 2018). If performed and maintained correctly this position may act as a form of spinal extension exercise (Furness *et al.* 2016; dos Santos 2018).

There is much research to suggest that prolonged spinal extension exercise is beneficial to maintaining (and regaining) optimal sagittal spinal alignment and posture (Ball *et al.* 2009; Cruz-Ferreira *et al.* 2011; Fusco *et al.* 2011; Bansal, Katzman and Giangregorio 2014; Gordon and Bloxham 2016; Roghani *et al.* 2017; Pan *et al.* 2018b; González-Gálvez, Gea-García and Marcos-Pardo 2019). However, limited research exists regarding the potential correlation between age, long-term surfing, and sagittal spinal alignment. Therefore, this study will investigate whether a correlation does exist between age, long-term surfing, and sagittal spinal alignment.

1.2 Research aims and objectives

1.2.1 Aim

This study aims to investigate whether an association exists between long-term surfing and sagittal spinal alignment anomalies e.g. cervical lordosis (CL), thoracic kyphosis (TK), and lumbar lordosis (LL) in ostensibly healthy males over the age of 50.

1.2.2 Objectives

The specific objectives include:

Assessing the selected sagittal spinal alignment and posture parameters (i.e. CL, TK, and LL) as well as posture number in long-term male surfers and non-surfing physically active males;

Determining whether any significant differences exist between the selected sagittal spinal alignment parameters within or between the surfing and non-surfing groups;

Determining the association, if any, between age, years of surfing and selected spinal alignment parameters.

1.3 Rationale of the study

It is well known that with increasing age come certain postural changes including an increase in the cervical lordosis (CL), thoracic kyphosis (TK) , as well as a decrease in lumbar lordosis (LL) (Ball *et al.* 2009; Asai *et al.* 2017). It is known that these altered postural states may contribute to poor biomechanical function related to the ability to lift the arms above the head (Lewis, Wright and Green 2005) as well as positioning and movement of the head and neck (Quek *et al.* 2013). It has also been suggested that better posture is associated with a higher quality of life in the later stages of life (Kado *et al.* 2005; Katzman *et al.* 2010; Quek *et al.* 2013; Oe *et al.* 2015; Roghani *et al.* 2017), and that posture and control thereof can be improved and maintained by physical activity.

Research on the effects that surfing may have on the age-related postural changes, specifically on sagittal spinal alignment, which occur in later life is limited (Furness *et al.* 2016; dos Santos 2018).

The duration of a typical surf session ranges from twenty minutes (competitive heats) to two hours or more (Mendez-Villanueva and Bishop 2005; Farley, Harris and Kilding 2012; Secomb, Sheppard and Dascombe 2015). Surfers spend from 48% to 60% of the duration of a surfing session paddling; approximately 42% of the duration in a sitting position waiting for waves and about 5% of the duration actually surfing (Meir *et al.* 1991; Mendez-Villanueva and Bishop 2005; Farley, Harris and Kilding 2012; Secomb, Sheppard and Dascombe 2015; LaLanne *et al.* 2017; dos Santos 2018). To paddle the surfer adopts a prone position with spinal extension and shoulder retraction (Mendez-Villanueva and Bishop 2005; Furness *et al.* 2016; dos Santos 2018). It can, therefore, be postulated that surfing could have positive effects on the development of sagittal spinal alignment and posture with increasing exposure, over time.

By identifying common sagittal spinal alignment changes within the aging surfing population, practitioners may gain some insight into the treatment and conditioning goals for younger, developing surfers. Attention could also be drawn to the potential benefits of implementation of surfing, (or minimally the surfboard paddling position), into conventional athletic training, rehabilitation, and corrective exercise programmes.

1.4 Delineation of Chapters

In Chapter 1, sagittal spinal alignment and posture as it relates to age, physical activity (with an emphasis on surfing), and pathology are introduced. The research aims and objectives, as well as the research rationale, are also presented.

In Chapter 2, the relevant literature is presented as it pertains to sagittal spinal alignment and its relevant anatomy. The association of sagittal spinal alignment with age, physical activity (emphasizing the biomechanics of surfboard paddling) and pathology are also outlined.

In Chapter 3, the research methodology is presented. This includes the research design, data collection and statistical analysis methodologies. Sampling methods (purposive and snowball), participant recruitment (surfers vs. non-surfers), and measurement tools for sagittal spinal alignment and posture (flexicurve ruler and PosturePro) are outlined. The data reduction and analysis procedures are also discussed.

In Chapter4, the results of the study are presented and interpreted. The mean spinal curvature angles, as well as the mean Posture Number, will be presented according to the mean age and years spent surfing.

In Chapter 5, the results of the study will be discussed as they pertain to the relevant literature regarding the effect of age and physical activity on sagittal spinal alignment and posture,

In chapter 6, a conclusion to the research will be presented along with strengths and limitations of the present study, as well as recommendations for future research.

2 LITERATURE REVIEW

2.1 Introduction

Human spinal alignment and posture changes and develops throughout a lifetime and is affected by factors such as age, physical activity (or lack thereof), as well as pathology and injury (Yochum and Rowe 2005; Moore, Dalley and Agur 2010). Generally, major changes can occur in childhood, adolescence, early and even late adulthood. However, the exact timing of postural development is unclear (Yochum and Rowe 2005; Moore, Dalley and Agur 2010; Been and Kalichman 2014).

Even though the exact timing may vary, spinal alignment and posture generally begins to deteriorate after the age of forty-fifty years in healthy individuals, and this is especially true of sagittal spinal alignment - when viewed from the side (Gelb *et al.* 1995; Boyle, Milne and Singer 2002; Intolo *et al.* 2009; Farley *et al.* 2012; Hasegawa *et al.* 2016; Asai *et al.* 2017; Chen *et al.* 2017; Pan *et al.* 2018b). The steady deterioration in spinal alignment and posture may be slowed by certain physical activities. However, some activities are more effective than others (Ostrowska, Rozek-Mroz and Giemza 2003; Choi, Moon and Song 2005; Kado *et al.* 2005; Katzman *et al.* 2007; Tekur *et al.* 2008; Ball *et al.* 2009; Greendale *et al.* 2009; Kado 2009; Katzman *et al.* 2010; Cruz-Ferreira *et al.* 2011; Fusco *et al.* 2011; Kiers *et al.* 2013; Bansal, Katzman and Giangregorio 2014; Been and Kalichman 2014; Jang, Kim and Kim 2015; Iunes *et al.* 2016; Jang *et al.* 2017; Katzman *et al.* 2017a; Katzman *et al.* 2017c; Roghani *et al.* 2017).

To date only limited research has been conducted on the mechanical and physiological demands of surfing, hence very little is known about the possible long term effect of surfing on spinal alignment (dos Santos 2018). In this chapter, the relevant literature, which relates to spinal alignment, age, and physical activity (with a focus on surfing), will be outlined and discussed.

2.2 Surfing

The term “surfing” has no concrete definition, but when referring to ocean activities the word relates to riding a wave (the surf), either with or without a surf craft such as a surfboard, bodyboard, or even a boat (Finney and Houston 1996; Warshaw 2011).

One of the earliest definitions of surfing was proposed by Ben Finney, the first university-trained historian to examine surfing as a sport, as “catching a wave on a float of any size, made from any material”(Warshaw 2011). However, today the world knows surfing as “stand-up riding a wave that curls or breaks” (Warshaw 2011).

In this study, the term “surfing” will refer to the activity of riding breaking waves towards shore while standing upright on a surfboard. The term “surfers” will be used to describe the individuals who partake in this activity.

Most surfboards are not buoyant enough to float while a person stands upright on it while it is stationary, so surfers need to paddle their boards with their arms while in a prone position on top of the board (Robison 2010). Only once the surfer has matched the speed of the wave he/she is aiming to catch and the board starts to plane over the water surface can they make their way to their feet (Robison 2010).

Metcalfe and Kelly (2012) described surfing as a “stochastic activity”. This means that it is an activity that is comprised of bouts of high-intensity exercise interspersed with intervals of medium-intensity exercise.

They also outlined the activities that make up a typical surf session as follows:

> **The paddle out:** The surfer must make her/his way to the line-up (the area beyond the breaking waves). Typically the surfer will assume a prone position on his/her board and propel themselves mainly with their arms. This results in a state of vertebral hyperextension, with only the abdomen in contact with the surfboard. This position allows for the full range of motion in the shoulders, while also allowing the surfer to observe her/his surroundings. Depending on ocean conditions the paddle-out might also involve “duck-diving”, which is the action of forcefully driving the surfboard under approaching waves before resurfacing and resuming the paddle-out. This may be required several times before the surfer reaches the line-up. (Metcalfe and Kelly 2012)
>
> **Sitting and manoeuvring into position:** Once the surfer has reached the line-up they may be able to sit balanced on her/his board, facing out to sea while waiting for approaching waves. They may also be required to continue paddling to position themselves to catch a wave or to counteract the effect of drifting due to wind or rip currents. (Metcalfe and Kelly 2012)

Power strokes: Once the surfer has selected a wave he/she must turn to face the shore (away from the oncoming wave), get into the paddling position and perform four or five (maybe more) powerful paddle strokes to accelerate onto the approaching wave. (Metcalfe and Kelly 2012)

The pop-up: Once on the wave the surfer must quickly make their way from a prone position to an upright, standing one. This involves pushing the chest off the board with the arms, popping up the hips and placing one foot between the hands to assume a side-on position. Generally, the stance assumed by a surfer is a quarter-to-half squat with the feet slightly wider than the shoulders with one foot positioned near the rear end of the board and the other foot near the middle (Metcalfe and Kelly 2012).

Manoeuvring the board: Once standing the surfer must manoeuvre their board along the unbroken face of the wave. Force is applied to the board through the legs and feet, which allows the board to turn on the wave face (Metcalfe and Kelly 2012).

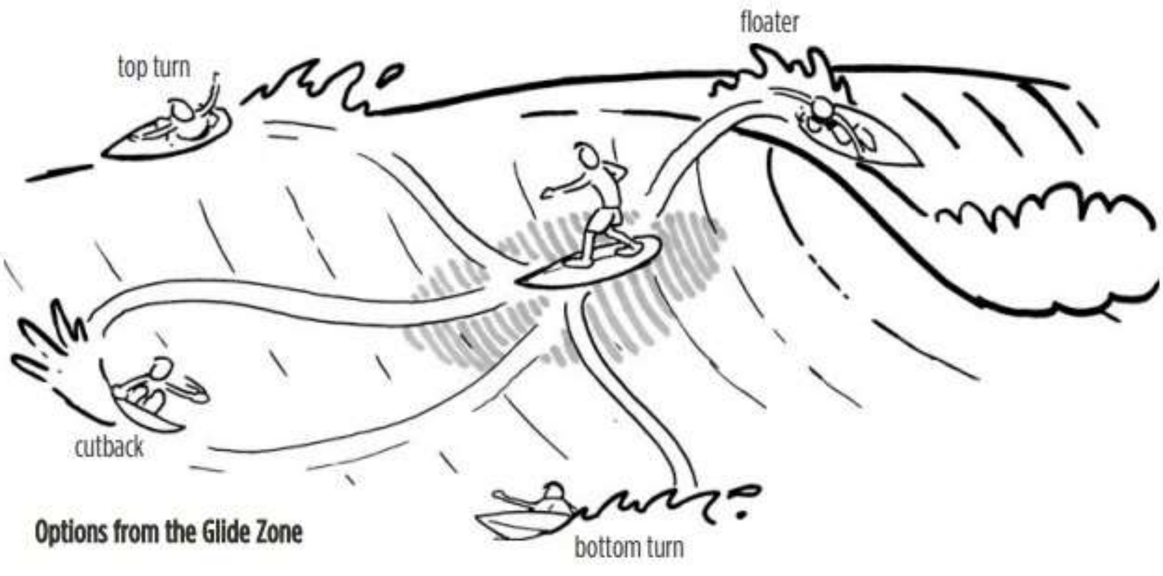

Figure 2.1 Basic surfboard manoeuvres (Robison 2010)

This sequence of typical activities is performed over and over again, possibly for hours on end, until the end of the surf session.

Multiple studies have concluded that the time spent on each of the above-mentioned activities is not equally distributed (Meir *et al.* 1991; Mendez-Villanueva and Bishop

2005; Everline 2007; Frank *et al.* 2009; Farley, Harris and Kilding 2012; Metcalfe and Kelly 2012; Secomb, Sheppard and Dascombe 2015). The duration of a typical surf session ranges from twenty minutes, in competitive heats, to two hours or more for recreational sessions (Mendez-Villanueva and Bishop 2005; Farley, Harris and Kilding 2012; Secomb, Sheppard and Dascombe 2015). Most of the time in a typical surf session is spent paddling - around 44% - 60%, while approximately 35% of the time is spent sitting waiting for waves, with only around 5% of the time spent actually riding waves (Meir *et al.* 1991; Mendez-Villanueva and Bishop 2005; Everline 2007; Frank *et al.* 2009; Farley, Harris and Kilding 2012; Metcalfe and Kelly 2012; Secomb, Sheppard and Dascombe 2015). Any remaining time in the session is dedicated to activities such as duck-diving and board retrieval (Meir *et al.* 1991; Mendez-Villanueva and Bishop 2005; Everline 2007; Frank *et al.* 2009; Farley, Harris and Kilding 2012; Metcalfe and Kelly 2012; Secomb, Sheppard and Dascombe 2015).

Due to the physiological and mechanical demand of surfboard paddling on the muscles and other connective tissues that comprise the spinal complex, this activity in itself may be considered a spinal extension exercise (Everline 2007; Farley, Harris and Kilding 2012; Nathanson 2013; Furness *et al.* 2014; Furness 2015b; Furness *et al.* 2016). As discussed later in this chapter exercise programmes that incorporate spinal extensor strengthening exercises, breathing exercises and balance exercises have been shown to positively influence sagittal spinal alignment in older individuals.

2.3 Anatomical planes and structures relevant to spinal alignment

2.3.1 The anatomical planes

According to Moore, Dalley and Agur (2010), four imaginary planes intersect the body in the anatomical position. The anatomical position refers to the body as though the person were standing upright with the head, eyes, and toes facing forwards; the arms by the sides with the palms of the hands facing forward, and the feet hip-distance apart with the feet parallel (Moore, Dalley and Agur 2010).

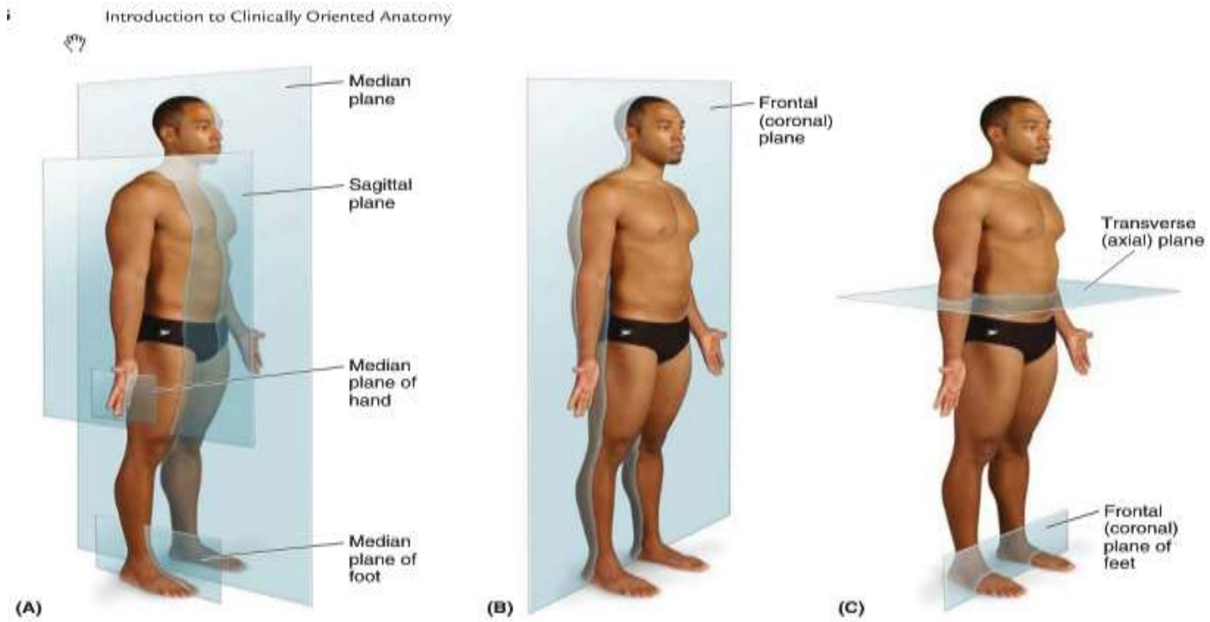

Figure 2.2 Anatomical planes (Moore, Dalley and Agur 2010)

Moore, Dalley and Agur (2010) defined the four anatomical planes as follows:

- **Median plane:** the vertical plane that passes longitudinally through the body dividing it into left and right halves. The median plane is sometimes referred to as the midline of the body.
- **Sagittal Plane:** any vertical plane that passes through the body parallel to the median plane.
- **Frontal (coronal) plane:** any vertical plane that passes through the body at a right angle to the median plane.
- T**ransverse plane:** any horizontal plane that passes through the body at a right angle to the median and frontal plane, thus dividing the body into upper (superior) and lower (inferior) segments.

Thus, sagittal spinal alignment refers to the alignment of spinal vertebrae when viewed from the side i.e. the sagittal plane, while the alignment of the vertebrae from the anterior view (from the front) is referred to as frontal spinal alignment (Berthonnaud *et al.* 2005; Roussouly *et al.* 2005; Yochum and Rowe 2005; Boulay *et al.* 2006; Moore, Dalley and Agur 2010; Bruno *et al.* 2012; Asai *et al.* 2017).

2.3.2 The vertebral column

The vertebral column typically consists of thirty-three vertebrae that can be arranged into five regions: seven cervical vertebrae, twelve thoracic vertebrae, five lumbar vertebrae, five sacral, and four coccygeal vertebrae (**figure 2.2**) (Moore, Dalley and Agur 2010). In adulthood, the sacral vertebrae fuse to form the sacrum, and the coccygeal vertebrae fuse to form the coccyx, which means that motion can only occur between the superior twenty-five vertebrae (Moore, Dalley and Agur 2010). Though the movement between adjacent vertebrae is limited, in aggregate the vertebrae and the intervertebral discs (IVDs) connecting them form a rigid yet flexible column that houses and protects the spinal cord. (Yochum and Rowe 2005; Moore, Dalley and Agur 2010)

The adult vertebral column is typically 72-75cm long and extends from the base of the skull (cranium) to the apex of the coccyx (Moore, Dalley and Agur 2010). It consists of bones, called vertebrae, which are interspaced superiorly and inferiorly by fibrocartilaginous inter vertebral discs (IVDs) (Moore, Dalley and Agur 2010). The functional components of the typical vertebra (**figure 2.3 A)** consist of the vertebral body, vertebral arch (which consists of two pedicles and two laminae), and the seven processes i.e. transverse processes, spinous process, two superior and two inferior articular processes. (Yochum and Rowe 2005; Moore, Dalley and Agur 2010)

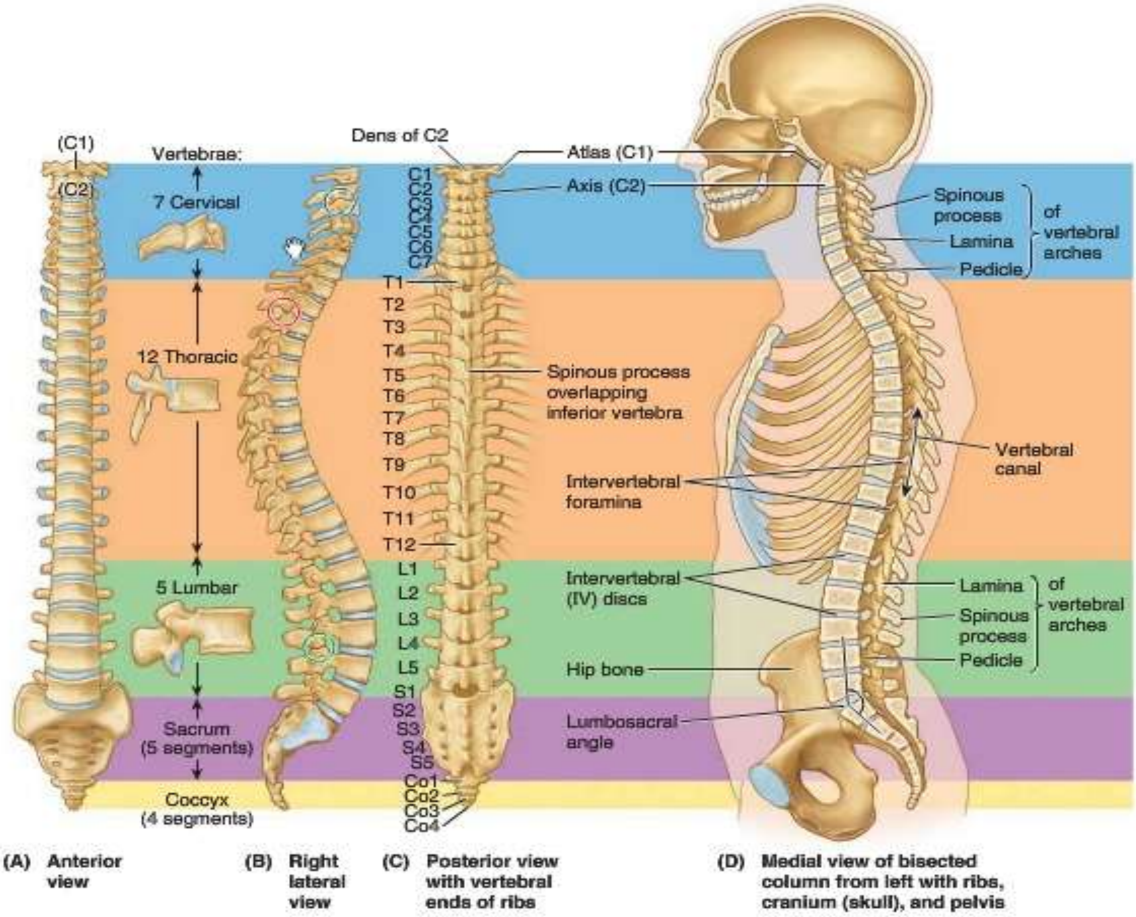

Figure 2.3 The five regions of the vertebral column (Moore, Dalley and Agur 2010)

The superior articular processes articulate with the inferior articular processes of the vertebra above to form the *zygapophysial joints* (facet joints) (**figure 2.3 D**) (Moore, Dalley and Agur 2010). The flexibility of the vertebral column is controlled by these articulations, and their orientations vary between the spinal regions. In the cervical spine (C-spine) the superior facets are angled to face up, in, and back (oblique) while the inferior facets are angled to fit the superior in a smooth articulation. This orientation facilitates flexion, extension, and lateral flexion (Moore, Dalley and Agur 2010). In the thoracic spine (T-spine) the facets are oriented at almost vertical, with the superior facets directed posteriorly and slightly laterally, and the inferior facets directed anteriorly and slightly medially. This allows for rotation and some lateral flexion (Moore, Dalley and Agur 2010).

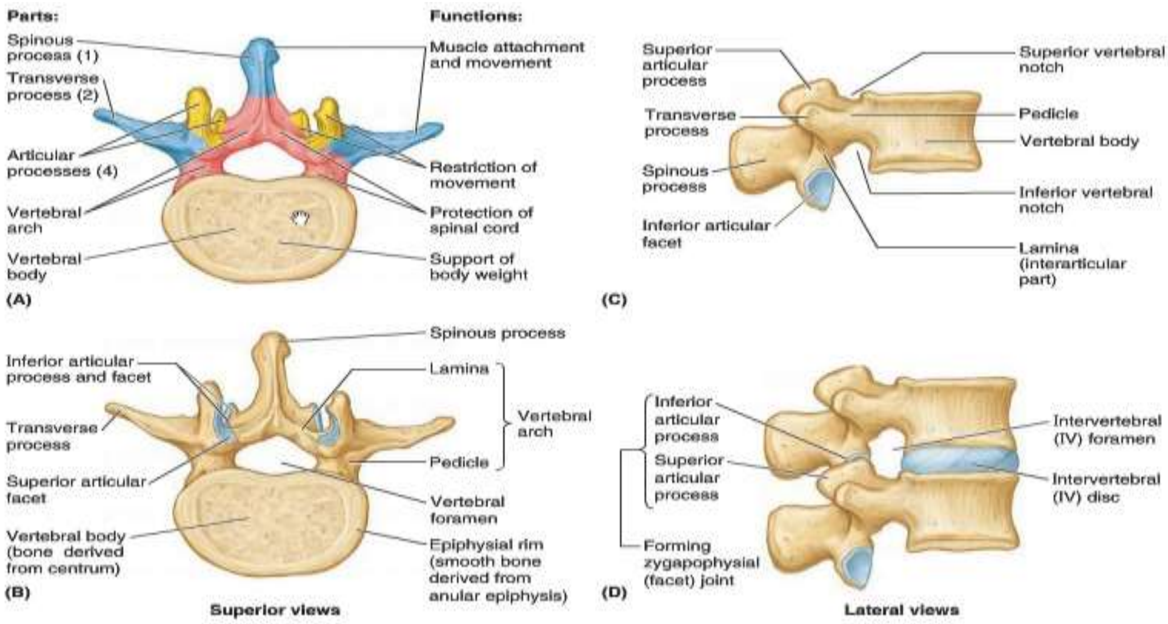

Figure 2.4 Classic vertebral characteristics as represented by the 2nd lumbar vertebra (Moore, Dalley and Agur 2010)

The Lumbar facets are directed near vertical as well, with the superior facets facing posteromedially (or medially at the inferior end) and inferior facets facing anterolaterally (or laterally). This allows for flexion, extension, and lateral flexion, but prohibits rotation (Yochum and Rowe 2005; Moore, Dalley and Agur 2010).

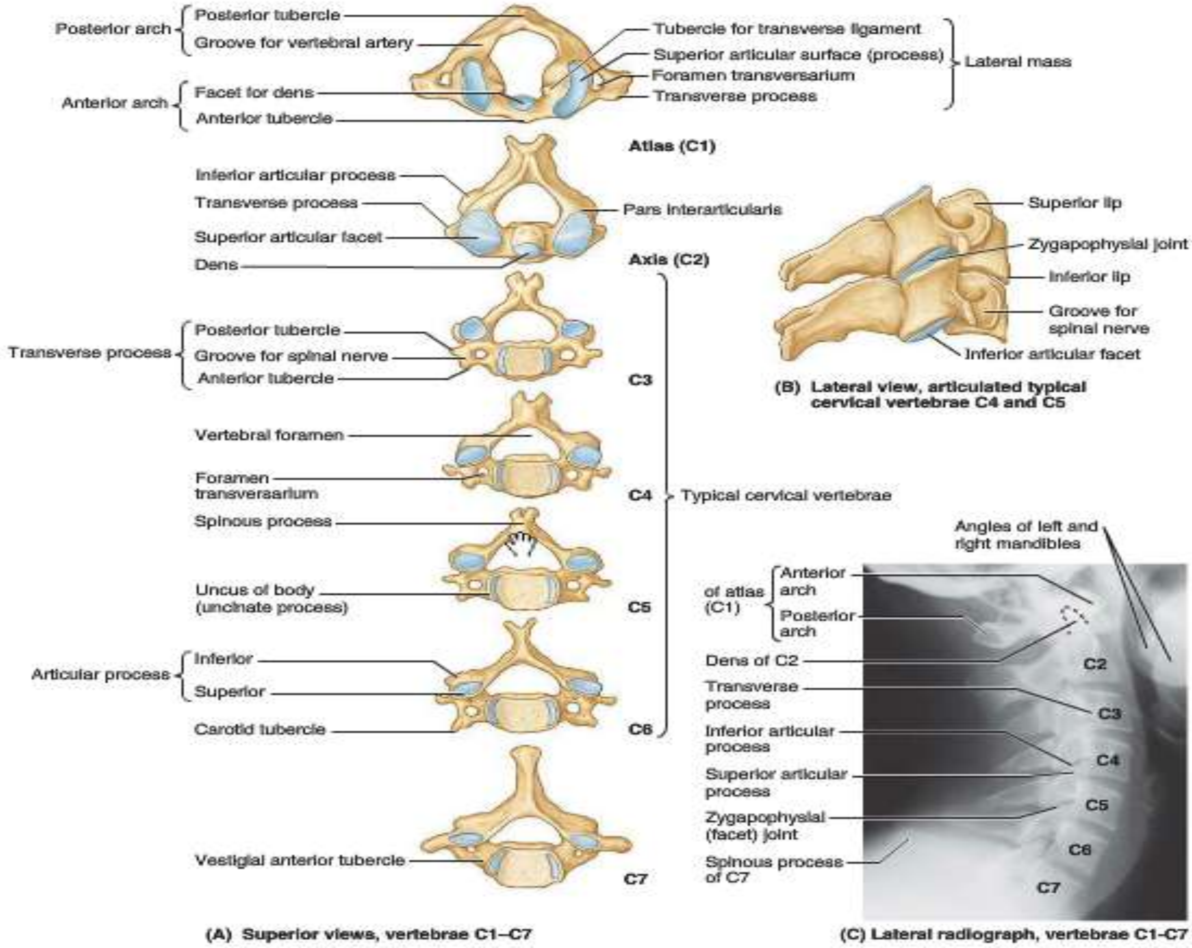

Figure 2.5 Characteristics of typical cervical vertebrae (Moore, Dalley and Agur 2010)

The shapes of the vertebrae differ between the spinal regions and play a role in maintaining the spinal curvatures (Yochum and Rowe 2005; Moore, Dalley and Agur 2010). The most important characteristics of the spinal column, when it relates to the curvature, are the shape and size of the vertebral bodies and their IVDs. (Yochum and Rowe 2005; Moore, Dalley and Agur 2010)

Table 2-1 Characteristics of typical cervical vertebrae (Moore, Dalley and Agur 2010)

Part of vertebra	Characteristics
Vertebral body	Small Narrower anteroposteriorly than from side to side The superior surface is concave and the inferior surface is convex Has uncinate processes
Vertebral foramen	Triangular Large
Transverse Processes	Has transverse foramina, and anterior and posterior tubercles Vertebral arteries and their accompanying venous and sympathetic plexuses travel through the transverse foramina of all cervical vertebrae. Trans verse foramina are unique to the C-spine.
Articular processes	Superior facets directed supero-posteriorly Inferior facets directed infero-anteriorly Obliquely placed facets are nearly horizontal in this region
Spinous processes	Short (C3-C5) and bifid (C3-C6) C6 has a long process C7 has the longest process of the C-spine (Vertebra prominent)

*C1, C2, and C7 are atypical vertebrae

2.3.2.1 Cervical vertebrae

The C-spine has the smallest of the 24 movable vertebrae which is due to the relatively little weight-bearing in the area when compared to the lower segments (Yochum and Rowe 2005; Moore, Dalley and Agur 2010). However, the IVDs in the C-spine, while still thinner than those in the lower regions, are relatively thick compared to their vertebrae (Yochum and Rowe 2005; Moore, Dalley and Agur 2010). This relative thickness of the IDVs combined with the near-horizontal orientation of the facet joints, as well as the relatively little surrounding body mass provides the C-spine with the greatest degree and variety of movement (Yochum and

Rowe 2005; Moore, Dalley and Agur 2010). The unique features of the cervical vertebrae are illustrated in Figure 2.4 and described in Table 2 -1. (Yochum and Rowe 2005; Moore, Dalley and Agur 2010)

2.3.2.2 Thoracic vertebrae

Table 2-2 Characteristics of typical thoracic vertebrae (Moore, Dalley and Agur 2010)

Part	Characteristics
Vertebral body	Heart-shaped Costal facets (one or two) for articulation with rib heads
Vertebral foramen	Circular and smaller than those in the cervical and lumbar regions
Transverse processes	Long and strong and extends posterolaterally Gets shorter from T1 – T12 T1 –T10 have facets for articulation with tubercles of ribs
Articular processes	Nearly vertical articular facets Superior facets directed posteriorly and slightly laterally Inferior facets directed anteriorly and slightly medially Planes of facets lie on an arc combined in the vertebral body
Spinous processes	Long Slopes posteroinferiorly Tips extend to the level of the vertebral body below

The thoracic vertebrae (T1-T12) are located in the upper back (Yochum and Rowe 2005; Moore, Dalley and Agur 2010). One of their primary functions is to form articulations with the ribs, which is the reason for the primary distinguishing characteristic of these vertebrae – the costal facets (Yochum and Rowe 2005; Moore, Dalley and Agur 2010). T5-T8 present with all the features of typical thoracic vertebrae as laid out in Table 2-2, while T1-4 share some characteristics with cervical vertebrae e.g. T1 has an elongated spinous process, almost as long as that of C7 (Yochum and Rowe 2005; Moore, Dalley and Agur 2010). The lower thoracic vertebrae (T9-12) share some characteristics with the lumbar vertebrae e.g. tubercles resembling the accessory process (Yochum and Rowe 2005; Moore, Dalley and Agur 2010). However, the greatest amount of transition occurs solely across T12 (Yochum and Rowe 2005; Moore, Dalley and Agur 2010). The orientation of the facet joints in this region of the spine is such that it permits a great degree of rotation. However, those same orientations, along with overlapping spinous processes and the connection to the sternum through the ribs make flexion and extension in the T-spine almost non-existent. (Yochum and Rowe 2005; Moore, Dalley and Agur 2010). Moreover, it is not uncommon for the thoracic vertebrae to have an anterior wedge which is angled at least 5º more than its adjacent segments (Yochum and Rowe 2005; Moore, Dalley and Agur 2010). This may be exaggerated in some cases in T11 and T12, but may also occur in L1 as a congenital variant (Yochum and Rowe 2005). This wedging of the vertebral bodies contributes significantly to the degree of kyphosis in the T-spine and might be exaggerated by conditions such as vertebral compression fractures, often associated with osteoporosis (Yochum and Rowe 2005; Moore, Dalley and Agur 2010; Walker *et al.* 2014).

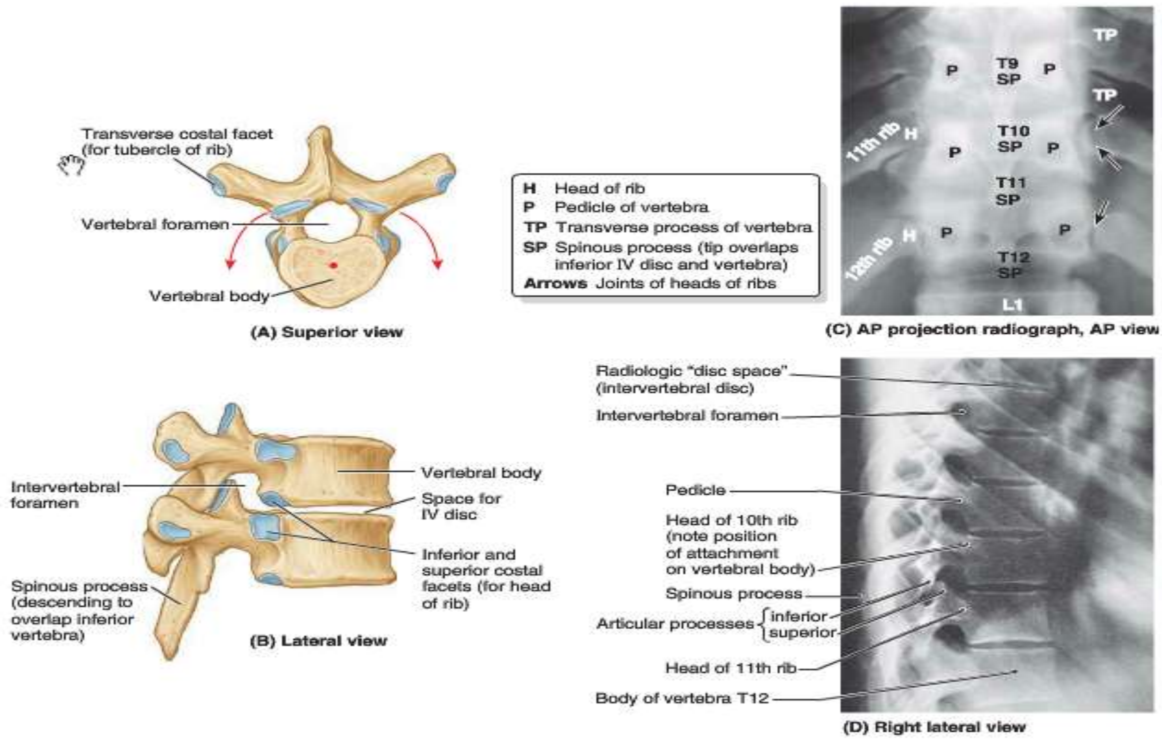

Figure 2.6 Characteristics of typical thoracic vertebrae (Moore, Dalley and Agur 2010)

2.3.2.3 Lumbar vertebrae

Characteristics of typical lumbar vertebrae are illustrated in Figure 2.7 and laid out in Table 2-3. Found in the lower back between the thoracic cage and the sacrum, these vertebrae have extremely large vertebral bodies that increase in thickness as the level moves inferiorly (Yochum and Rowe 2005; Moore, Dalley and Agur 2010). They account for a considerable amount of the thickness of the lower trunk when viewed in the mid-sagittal plane (Moore, Dalley and Agur 2010). The 5th lumbar vertebra is distinct in that it has the largest vertebral body and transverse processes of the 25 movable vertebrae (Yochum and Rowe 2005; Moore, Dalley and Agur 2010). The L5 vertebral body is also noticeably taller anteriorly (causing a wedge shape), and this is largely responsible for the lumbosacral angle; the angle formed between the long axes of the lumbar spine and the sacrum (Yochum and Rowe 2005; Moore, Dalley and Agur 2010).

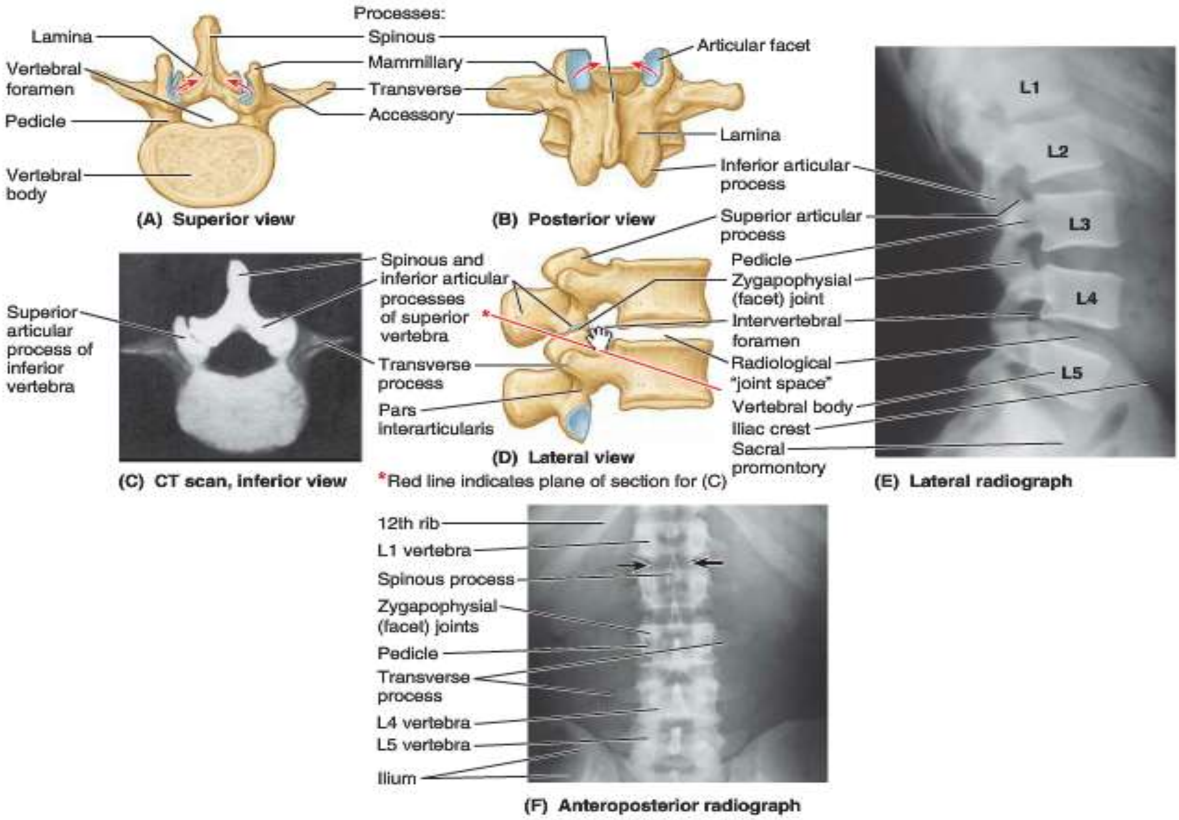

Figure 2.7 Characteristics of typical lumbar vertebrae (Moore, Dalley and Agur 2010)

Table 2-3 Characteristics of typical lumbar vertebrae (Moore, Dalley and Agur 2010)

Part	Characteristics
Vertebral body	Massive Kidney shaped in the superior view
Vertebral foramen	Triangular Larger than in thoracic vertebrae, but smaller than in cervical vertebrae
Transverse processes	Long and slender Has accessory process on the posterior surface of the base of each process
Articular processes	Nearly vertical facets Superior facets directed posteromedially/medially Inferior facets directed anterolaterally/laterally Has mammillary processes on posterior surfaces of each superior articular facet
Spinous processes	Short Thick Broad Hatchet shaped

2.3.3 Musculature

The muscles that affect the movement, positioning, and stability of the spinal column can be divided into two groups: Intrinsic/deep group (those which directly affect the movements of the spine and retain posture) and extrinsic, which contains the superficial and intermediate layers of muscle (those that affect the movement of the limbs and aid respiration, in that order) (Moore, Dalley and Agur 2010).

2.3.3.1 Extrinsic back muscles

The superficial layer of the extrinsic back muscles is made up of the trapezius, levator scapulae, rhomboids, and latisimus dorsi (Moore, Dalley and Agur 2010). They attach the spinal column to the shoulder girdle and humerus and are thus the muscles that produce and control movement in the upper limbs, vital for surfboard paddling. (Moore, Dalley and Agur 2010).

The intermediate layer of the extrinsic group is made up of the serratus posterior superior and inferior. These muscles are commonly assumed to serve a respiratory function, but more likely play a proprioceptive role(Moore, Dalley and Agur 2010). These are described in detail in Table 2-4

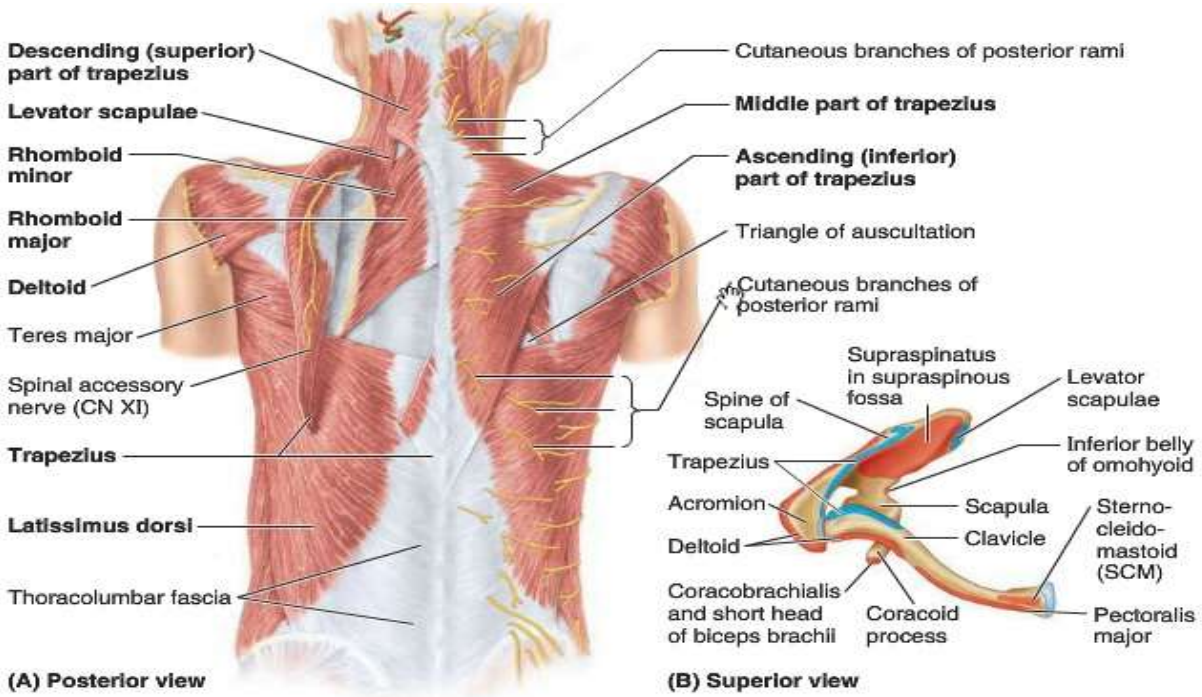

Figure 2.8 Posterior Axio-appendicular muscles (Moore, Dalley and Agur 2010)

Table 2-4 Extrinsic superficial posterior back muscles (Moore, Dalley and Agur 2010)

Muscle	Proximal attachment	Distal attachment	Innervation	Muscle action
Superficial posterior Axio-appendicular (extrinsic shoulder) muscles				
Trapezius	The medial third of the superior nuchal line External occipital protuberance Nuchal ligament Spinous processes of C7-T12	Lateral third of clavicles Acromion The spine of the scapulae	The spinal accessory nerve (CN XI) for motor fibres C3 and C4 spinal nerves for pain and proprioceptive	Descending part elevates scapula Ascending parts depress the scapula The middle part (and all parts combined) retracts scapulae Descending and ascending parts act together to superiorly rotate the glenoid cavity
Latisimus dorsi	Spinous processes of inferior 6 thoracic vertebrae Thoracolumbar fascia Iliac crest Inferior 3-4 ribs	The floor of intertubercular sulcus of humerus	Thoracodorsal nerve (C6, C7, C8)	Extends Adducts Medially rotates humerus Raises body toward arms during climbing

Table 2-5 Extrinsic deep posterior back muscles (Moore, Dalley and Agur 2010)

Muscle	Proximal attachment	Distal attachment	Innervation	Muscle action
Deep posterior Axio-appendicular (extrinsic shoulder) muscles				
Levator scapulae	Posterior tubercle of spinous processes of C1-C4 vertebrae	Medial border of scapulae superior to the root of the scapular spine	Dorsal scapular (C4, C5) and cervical (C3, C4) nerves	Elevates scapulae and rotates the glenoid cavities inferiorly by rotating the scapulae
Rhomboid major and minor	Minor: Nuchal ligament and spinous processes of C7 and T1 vertebrae Major: Spinous processes of T2-T5	Minor: smooth triangular area at medial end of the scapular spine Major: Medial border of the scapula from the level of the spine to the inferior angle	Dorsal scapular nerve (C4, C5)	Retract scapula and rotates the glenoid cavity inferiorly Fixes scapulae to the thoracic wall

2.3.3.2 Intrinsic Back muscles

This group of muscles is responsible for the movement and stabilization of the spine, as well as maintaining posture (Moore, Dalley and Agur 2010). The intrinsic back muscles can be divided into three layers, namely superficial, intermediate and deep (Moore, Dalley and Agur 2010).

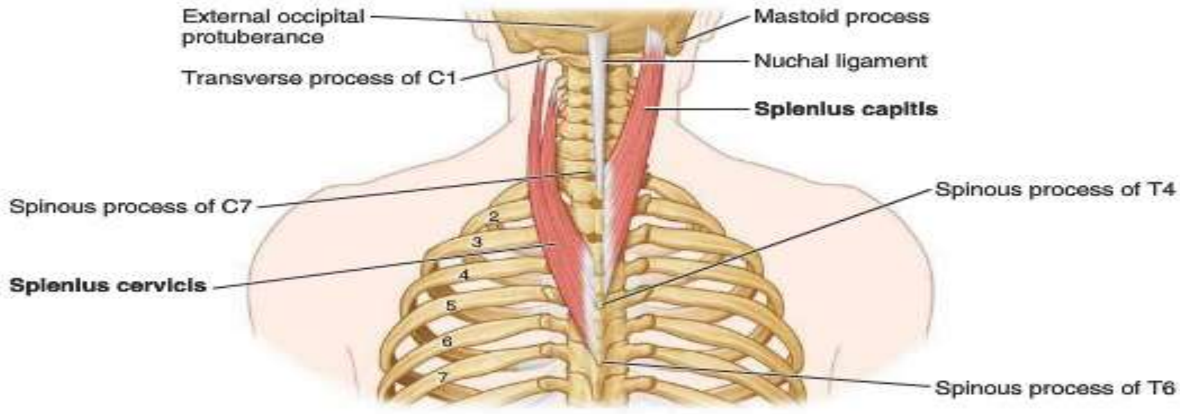

Figure 2.9 Superficial intrinsic back muscles (Moore, Dalley and Agur 2010)

The superficial layer (displayed in figure 2.7 and described in Table 2-5) consists of the splenius capitis and splenius cervicis, which originate in the midline from the spinous processes of the lower cervical vertebrae and attach to the cranium as well as the upper cervical transverse processes, respectively (Moore, Dalley and Agur 2010).

Table 2-6 Superficial intrinsic back muscles (Moore, Dalley and Agur 2010)

Muscle	Proximal attachment	Distal attachment	Nerve supply	Main action
Splenius	Nuchal ligament and the spinous process of C7-T8 vertebrae	Splenius capitis: the fibres run superolateral to the mastoid process of the temporal bone and lateral third of the superior nuchal line of the occipital bone Splenius cervicis: tubercles of transverse processes of C1-C3 or C4 vertebrae	Posterior rami of spinal nerves	Acting unilaterally: laterally flexes the neck and rotates the head to the side of active muscle Acting bilaterally: extends head and neck

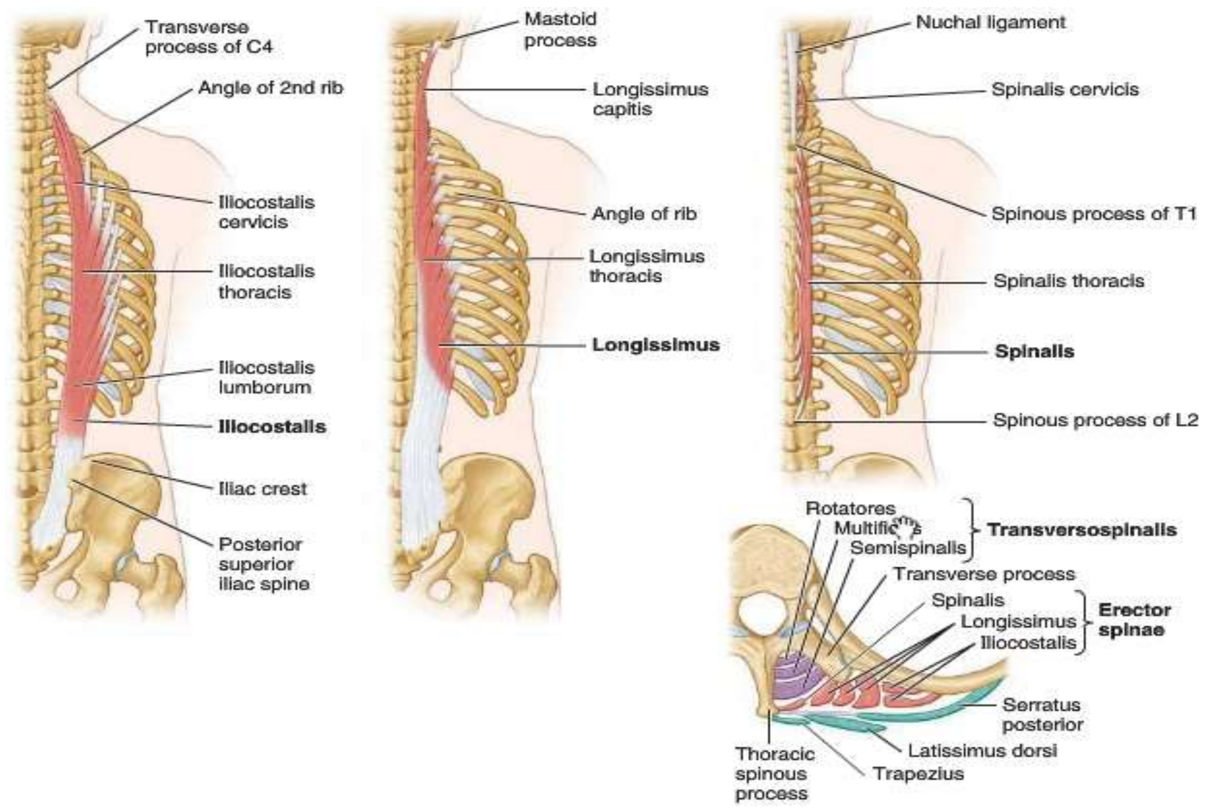

Figure 2.10 The middle/intermediate layer of intrinsic back muscles (erector spinae) (Moore, Dalley and Agur 2010)

The intermediate layer of the intrinsic muscles (figure 2.8 and table 2-6) is also known as the erector spinae and lie in the groove created posteriorly by the spinous and transverse processes, bilaterally (Moore, Dalley and Agur 2010). It consists of three columns: iliocostalis (lateral), longisimus (intermediate), spinalis (medial), which are each divided into regions according to their superior attachment e.g. iliocostalis lumborum, - thoracis, or – cervicis (Moore, Dalley and Agur 2010). The three erector spinae columns share a common origin – a broad tendon that attaches posteriorly to the iliac crest, the posterior aspect of the sacrum, the sacral and iliac ligaments, and the sacral and inferior lumbar spinous processes (Moore, Dalley and Agur 2010).

The deep layer of the intrinsic muscle group of the spine is also known as the transversospinalis muscles and consist of the semispinalis, multifidus, and rotatores (Moore, Dalley and Agur 2010). These muscles originate from transverse processes of vertebrae in each spinal region and extend superiorly to attach to spinous processes of vertebrae positioned more superiorly (Moore, Dalley and Agur 2010). This group is illustrated in Figure 2.9 and described in further detail in table 2-7.

Table 2-7 Intermediate layer of intrinsic back muscles (erector spinae) (Moore, Dalley and Agur 2010)

Muscle	Proximal attachment	Distal attachment	Nerve supply	Main action
Erector Spinae: Iliocostalis Longisimus Spinalis	Arises from a broad tendon from the posterior part of the iliac crest, posterior surface of the sacrum, sacroiliac ligaments, sacral and inferior lumbar spinous processes, and supraspinous ligaments	Iliocostalis: lumborum, thoracis, and cervicis; the fibres run superiorly to angles of lower ribs and cervical TVP's Longisimus: thoracis, cervicis, and capitis; fibres run superiorly to ribs between angles and tubercles to TVPs in the thoracic and cervical regions, and the mastoid process of the temporal bone. Spinalis: thoracis, cervicis, and capitis; fibres run superiorly to spinous processes in the upper thoracic region and the cranium	Posterior rami of spinal nerves	Acting bilaterally: extends vertebral column and head As the back is flexed it controls movement via eccentric contraction Acting unilaterally: laterally flexes the vertebral column.

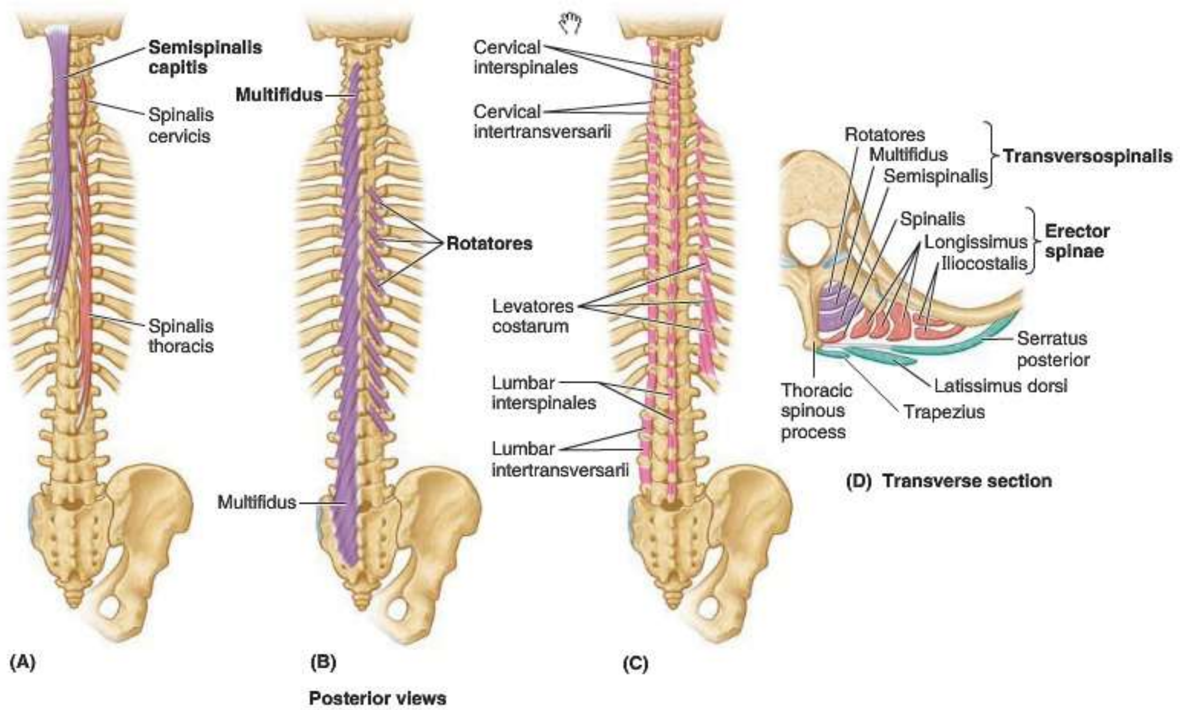

Figure 2.11 Muscles of the deep layer of intrinsic back muscles

The weakness of these muscles, which aid and contribute to the extension of the spine, is a major risk factor for developing significant postural aberrations such as increased cervical lordosis and thoracic kyphosis, as well as decreased lumbar lordosis in later stages of life. (Ball *et al.* 2009; Bansal, Katzman and Giangregorio 2014; Dreischarf *et al.* 2014; Chen *et al.* 2017; Katzman *et al.* 2017b)

Table 2-8 Deep layers of intrinsic back muscles (Transversospinalis) (Moore, Dalley and Agur 2010)

Muscles	Proximal attachment	Distal attachment	Nerve supply	Main actions
Deep Layer				
Transversospinalis: Semispinalis Multifidus Rotatores	TVP's semispinalis: originates from TVPs of C4-T12 vertebrae Multifidus: Originates from the posterior sacrum, posterior superior iliac spine, aponeurosis of erector spinae, sacroiliac ligaments, the mammillary process of lumbar vertebrae, TVPs of T1-T3, articular facets of C4-C7 Rotatores: Originates from TVPs of vertebrae, best developed in the thoracic spine	SP's of more superior vertebrae. Semispinalis: thoracic, cervicis, capitis; fibres run superiorly to the occipital bone and SP's in the thoracic and cervical region, stretching 4-6 segments. Multifidus: thickest in the lumbar region, fibres pass obliquely and superomedially for the entire length of SP's, located 2-4 segments superior to proximal attachments Rotatores: fibres pass superomedially to attach to the junction of the laminae and TVP or SP of vertebral segment immediately (brevis) or 2 (longus) segments superior to the proximal attachment	Posterior rami of spinal nerves	Extension Semispinalis: extends head, cervical, and thoracic regions and rotates them contralaterally Multifidus: stabilize vertebrae during local movement of the vertebral column Rotatores: stabilizes vertebrae and assists with local rotatory and extension movements. Also has a proprioceptive function

Table 2-9 Minor deep layers of intrinsic back muscles (Transversospinalis) (Moore, Dalley and Agur 2010)

Muscles	Proximal attachment	Distal attachment	Nerve supply	Main actions
Minor deep layer				
Interspinales	Superior surfaces or SP's of cervical and lumbar vertebrae	Inferior surfaces of SP's of vertebra superior to the vertebra of proximal attachment	Posterior rami of spinal nerves	Aids in extension and rotation of the vertebral column
Intertransversarii	TVP's of cervical and lumbar vertebrae	TVP's of adjacent vertebra	Posterior and anterior rami of spinal nerves	Aids with stability and lateral flexion of the vertebral column
Levatores costarum	Tips of TVPs of C7 and T1-T11 vertebrae	Passes inferolaterally and inserts on rib between tubercle and angle	Posterior rami of spinal nerves	Elevates ribs to assist with respiration Aids in lateral flexion of the spinal column

Though all the muscles in the back are important for general ambulation, the spinal extensor muscles are most involved in maintaining proper sagittal spinal alignment and upright posture (Moore, Dalley and Agur 2010). Weakness and atrophy of these muscles, specifically the erector spinae and multifidus, has been noted as a major contributing factor to the development of age-related hyperkyphosis (Roghani *et al.* 2017; Pan *et al.* 2018b; González-Gálvez, Gea-García and Marcos-Pardo 2019).

2.4 Spinal curvatures

As illustrated in figure 2.12 the human spinal column is a single C-shaped curve at birth, which is concave anteriorly. However, this changes as we age and the musculoskeletal system develops (Yochum and Rowe 2005; Moore, Dalley and Agur 2010). From the initial C-curve, the spine develops four distinct curvatures. The two kyphotic curvatures are concave anteriorly and are located in the thoracic and sacral regions (Yochum and Rowe 2005; Moore, Dalley and Agur 2010). These curves persist from the foetal stage and are thus known as the primary curvatures (Yochum and Rowe 2005; Moore, Dalley and Agur 2010). The lordotic curvatures are concave posteriorly and are located in the cervical and lumbar regions (Yochum and Rowe 2005; Moore, Dalley and Agur 2010). The cervical lordosis begins to develop at six months when the infant starts to lift and support its head from a prone position, while the lumbar lordosis begins to develop at around eighteen months when the child starts sitting, standing, and walking (Yochum and Rowe 2005; Moore, Dalley and Agur 2010). Both primary and secondary curvatures change in degree during different stages of life. (Yochum and Rowe 2005; Moore, Dalley and Agur 2010)

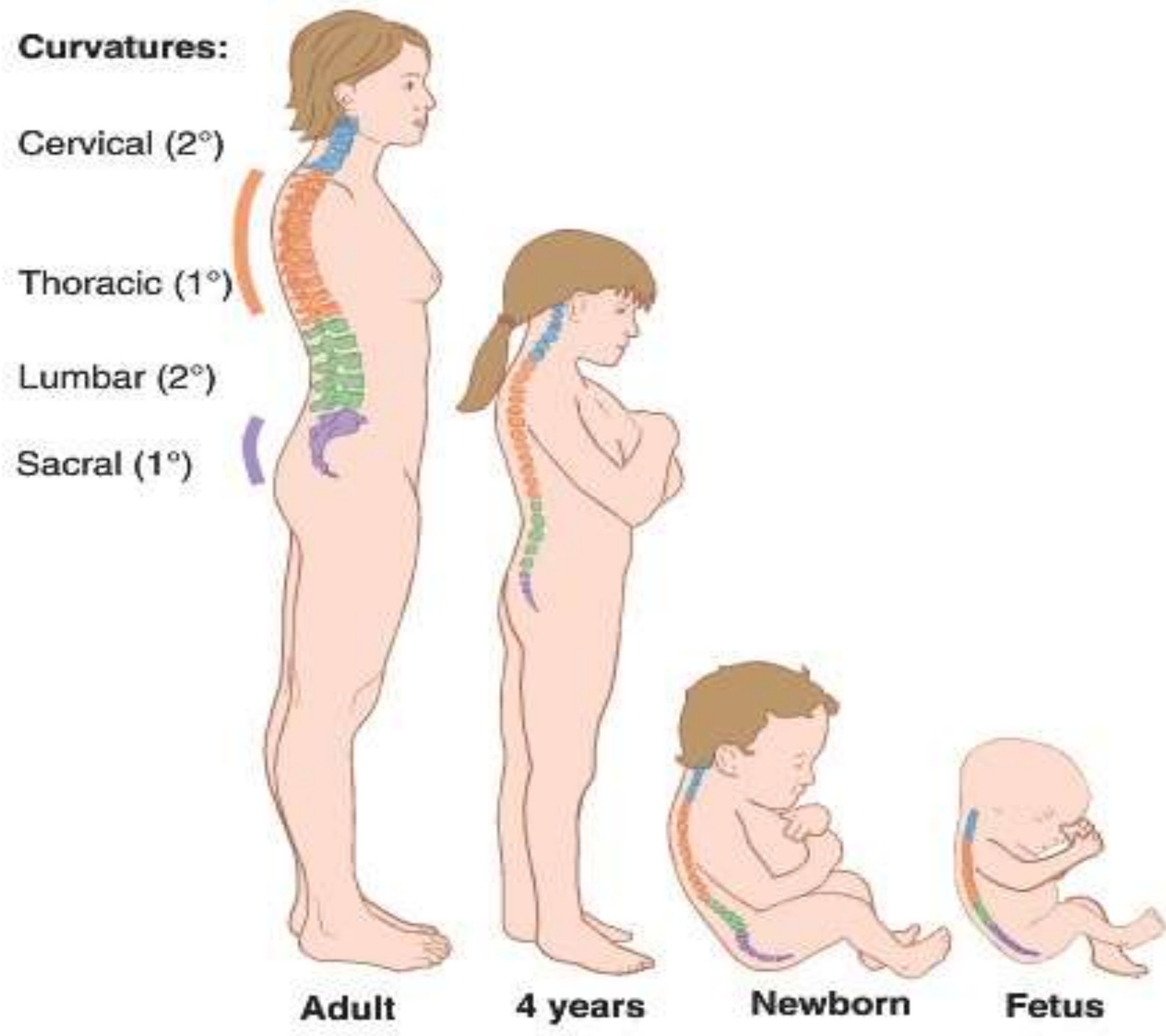

Figure 2.12 Vertebral column curvatures (Moore, Dalley and Agur 2010)

The curvatures in the spine play the role of the shock absorber by adding additional flexibility on top of what is provided by the IVDs (Yochum and Rowe 2005; Moore, Dalley and Agur 2010). When weight-bearing in the spinal column increases both the IVDs and the curvatures are compressed (Yochum and Rowe 2005; Moore, Dalley and Agur 2010). The flexibility of the IVDs is passive (limited by facet joints and spinal ligaments), while that of the curvatures is considered dynamic. This means that the accentuation of curvatures that happens due to weight-bearing is actively resisted by antagonistic muscle contraction, which ads an element of control (Moore, Dalley and Agur 2010).

The degree of spinal curvature depends on several internal factors such as the shape of the vertebral bodies and IVDs; as well as external factors that can be broadly assigned three categories including age, physical activity, and pathology and injury (Moore, Dalley and Agur 2010).

2.5 Factors that affect the spinal curvatures

Spinal alignment and overall posture may be affected by several factors. These include natural progression with age, sex and physical activity, as well as pathology and injury (Ostrowska, Rozek-Mroz and Giemza 2003; Kado *et al.* 2005; Greendale *et al.* 2009; Takeda *et al.* 2009; Katzman *et al.* 2010; Cruz-Ferreira *et al.* 2011; Fusco *et al.* 2011; Oe *et al.* 2015; Hasegawa *et al.* 2016; Asai *et al.* 2017; Roghani *et al.* 2017; Yukawa *et al.* 2018). The effect that pathology has on the spine may occur acutely or may develop over time and may also affect different individuals at different stages of life and to varying degrees (Yochum and Rowe 2005; Moore, Dalley and Agur 2010). However, spinal alignment constantly develops throughout life, and even individuals not affected by spinal pathology tend along the same track with increasing age. That is to say that increasing age is generally associated with deteriorating posture and spinal alignment (Milne and Lauder 1974; Gelb *et al.* 1995; Kado *et al.* 2004; Bartynski *et al.* 2005; Kado *et al.* 2005; Huang *et al.* 2006; Kado *et al.* 2007; Intolo *et al.* 2009; Takeda *et al.* 2009; Bansal, Katzman and Giangregorio 2014; Dreischarf *et al.* 2014; Hasegawa *et al.* 2016; Asai *et al.* 2017; Chen *et al.* 2017; Roghani *et al.* 2017; Pan *et al.* 2018b). It has been shown that physically active individuals tend to maintain better spinal alignment and posture throughout life, though to differing degrees (Ostrowska, Rozek-Mroz and Giemza 2003; Tekur *et al.* 2008; Frank *et al.* 2009; Greendale *et al.* 2009; Cruz-Ferreira *et al.* 2011; Fusco *et al.* 2011). Each of the aforementioned factors is discussed below.

2.5.1 Age and sex

As individuals age, the spinal column must resist the forces of gravity and habit to maintain its optimal upright alignment (Yochum and Rowe 2005; Moore, Dalley and Agur 2010). As age advances past the fourth-to-fifth decade of life, there seems to be a tendency to decreased lumbar lordosis, increased cervical lordosis, and especially increased thoracic kyphosis values. However, these values differ between sexes (Milne and Lauder 1974; Amonoo-Kuofi 1992; Gelb *et al.* 1995; Boyle, Milne and Singer 2002; Ostrowska, Rozek-Mroz and Giemza 2003; Kado *et al.* 2004; Bartynski *et al.* 2005; Kado *et al.* 2005; Huang *et al.* 2006; Kado *et al.* 2007; Takeda *et al.* 2009; Katzman *et al.* 2010; Quek *et al.* 2013; Barrett, McCreesh and Lewis 2014; Been and Kalichman 2014; Dreischarf *et al.* 2014; Oe *et al.* 2015; Hasegawa *et al.* 2016; Asai *et al.* 2017; Roghani *et al.* 2017; Merrill *et al.* 2018; Pan *et al.* 2018b; Yukawa *et al.* 2018). These changes do not occur in isolation. Hasegawa *et al.* (2016) conducted a cross-sectional cohort study of 126 healthy adult volunteers, attempting to clarify the relationship between age, sagittal spinal alignment, balance, and health-related quality of life (HRQL). They found a positive correlation between age, McGregor slope, thoracic kyphosis, and pelvic tilt. Sagittal-vertical-axis, T1-pelvic angle, sacrofemoral angle, knee flexion angle and ankle flexion angle also increased with increasing age. They concluded that even in healthy individuals spinopelvic alignment changes with age. However, standing whole body posture compensates to maintain horizontal gaze and that HRQL is related to aging and spinopelvic alignment (Hasegawa *et al.* 2016).

Asai *et al.* (2017) studied the lateral standing radiographs of large cohorts totalling 1461 participants (466 men and 995 women) to clarify the effect of age on spinopelvic alignment by providing normal values. All the included parameters were significantly associated with age as follows: sagittal vertical axis, thoracic kyphosis, and pelvic tilt increased, while lumbar lordosis decreased with advancing age (Asai *et al.* 2017). There was also a statistically significant difference between the sexes in thoracic kyphosis (larger in males), lumbar lordosis, pelvic tilt, and pelvic incidence (larger in females) (Asai *et al.* 2017).

Yukawa *et al.* (2018) conducted a similar study in which they attempted to establish normative data for parameters of spinopelvic and sagittal spinal alignment, gender-related differences, and age-related changes in asymptomatic subjects. Their cohort consisted of full length free standing spinal radiographs of 626 volunteers made up of at least fifty of each gender per decade from third to eighth (Yukawa *et al.* 2018). They concluded that an increase in cervical lordosis, pelvic tilt, and sagittal vertical axis, as well as a decrease in lumbar lordosis and the sacral slope, was associated with advancing age (Yukawa *et al.* 2018). They also found a significant difference in cervical lordosis, thoracic kyphosis, pelvic incidence, pelvic tilt, and the sagittal vertical axis between sexes (Yukawa *et al.* 2018).

This steady postural deterioration plays a role in many of the challenges that face the aging population, such as decreased postural control, muscular weakness, and decreased range of motion – indirectly contributing to higher rates of falls, and even, higher mortality rates (Huang *et al.* 2006; Kado *et al.* 2007; Frank *et al.* 2009; Kado 2009; Fehlings *et al.* 2015; Fernandes *et al.* 2018). As an example, in a systematic review, Fernandes *et al.* (2018) investigated the effect of postural change on fall rates and/or postural imbalance in community-dwelling older adults. They reviewed seventeen articles from an original yield of 1734 articles. They concluded that thoracic hyperkyphosis, decreased lumbar lordosis and decreased plantar arch seem to contribute to increased postural instability, thus increasing fall risk (Fernandes *et al.* 2018). Though interrelated, each of the spinal curvatures, if altered, may affect the health of the individual in different ways. These are discussed below.

Cervical lordosis, according to Chen *et al.* (2017), seems to increase with age. In their cross-sectional study of 120 asymptomatic individuals divided into four groups of thirty per group, according to age, they found a steady increase of thoracic inlet angle, neck tilt, T1-slope, and increased cervical lordosis angle with advancing age (Chen *et al.* 2017). Other studies have found similar shifts in cervical alignment with age. For example, Boyle, Milne and Singer (2002) retrospectively examined 172 lateral cervicothoracic radiographs of individuals (113 males and 59 females) and found that the inflexion point between the cervical lordosis and thoracic kyphosis tends to migrate cranially with age and that the cervical apex undergoes a similar cranial shift (Boyle, Milne and Singer 2002). However, their study seemed to indicate flattening of the cervical lordosis with age, especially in men (Boyle, Milne and Singer 2002). In a survey of available cervical spine literature, Ames *et al.* (2013) suggested that cervical alignment is related to both thoracolumbar and spinopelvic alignment and that a correlation seems to exist between sagittal C-spine alignment and health-related quality of life.

Oe *et al.* (2015) conducted a cohort study reviewing whole spine and pelvic radiographs of 656 volunteers, 50-89 years of age, to investigate the influence of age and sex on cervical sagittal alignment. They found significantly higher C2-C7 sagittal vertical angle measurements in males across all age groups. They also reported that higher C2-C7 sagittal vertical axis, T1-slope, and cervical lordosis values negatively affected health-related quality of life (HRQL) (Oe *et al.* 2015). Pan *et al.* (2018a) conducted a systematic review of thirty-four cross-sectional studies on the effect of age and sex on the cervical range of motion. They found that cervical ROM decreased steadily with age, starting earlier and ending later in males. The results were not continuous across the age spectrum, but females tended to maintain greater ROM across the spectrum (Pan *et al.* 2018a).

Thoracic hyperkyphosis is a common problem in aging individuals (Roghani *et al.* 2017). In young adulthood, the kyphotic angle is on average 20º-29º (Katzman *et al.* 2010; Roghani *et al.* 2017). This value starts to increase once the individual has passed the age of forty years, with the most notable increase arising between the ages of fifty and seventy years (Katzman *et al.* 2010; Asai *et al.* 2017; Roghani *et al.* 2017; Pan *et al.* 2018b). Once the kyphotic angle increases over 40º it is termed hyperkyphosis. Hyperkyphosis due to the aging process is termed age-related hyperkyphosis (ARHK) (Kado 2009; Katzman *et al.* 2010; Katzman, Vittinghoff and Kado 2011; Bruno *et al.* 2012; Bansal, Katzman and Giangregorio 2014; Jang, Kim and Kim 2015; Katzman *et al.* 2017a; Roghani *et al.* 2017)

In a systematic review of forty-five studies that looked at in vivo thoracic kyphosis and kinematics Pan *et al.* (2018b) stated that with advancing age thoracic kyphosis increases by about 3º per decade and thoracic range of motion (ROM) decreases by about 5º per decade. These changes occurred mainly in the lower region i.e. T6-T12 (Pan *et al.* 2018b). They also found that the literature that describes sex differences in thoracic kyphosis and range of motion is somewhat contradictory and that obesity was significantly associated with a decreased thoracic range of motion.

Roghani *et al.* (2017) conducted a systematic review on the contributing factors and consequences of age-related hyperkyphosis by reviewing seventy-seven observational studies and cohorts from 1955 to 2016. Their review found that ARHK affects as many as 20-40% of individuals over the age of sixty and that 60-70% of severe ARHK cases had no underlying osteoporosis or vertebral compression fracture (Roghani *et al.* 2017). They described degenerative disc disease (DJD), genetic predisposition, and especially weakness of the back extensor muscles as risk factors for developing ARHK, stating that back extensor strength and endurance are vital for maintaining normal posture and alignment.

Katzman *et al.* (2010) and Roghani *et al.* (2017) outlined the clinical consequences of a hyperkyphotic posture as follows: 1) Impaired pulmonary function through mechanical restriction that limits vital capacity, 2) Functional limitations e.g. decreased cervical and shoulder range of motion, decreased grip strength, decreased gait speed, and increased postural sway, 3) Increased risk of falling due to impaired postural control and balance leading to increased fracture risk, 4) Diminished health-related quality of life (due to the aforementioned factors), and 5) Increased mortality rates.

Lumbar lordosis is reportedly also affected by factors such as age, sex, BMI, race, and physical activity. Increasing age is generally associated with decreased lordotic angle, with the biggest change happening only after the sixth decade of life (Milne and Lauder 1974; Amonoo-Kuofi 1992; Takeda *et al.* 2009; Been and Kalichman 2014; Asai *et al.* 2017; Yukawa *et al.* 2018).

Skaf *et al.* (2011) conducted a retrospective analysis of 2247 MRIs of patients with low back or sciatic type pain to assess the correlation between age and level of intervertebral disc herniation as it is associated with lumbar lordotic values. Their results indicated that young patients had higher lumbar lordotic angles (LLA), and, if present, disc herniation at low lumbar levels (L4-5, L5-S1), while older patients had high-level herniation (L1-2, L2-3, L3-4) in low LLA group, and low-level herniation in high LLA group (Skaf *et al.* 2011). They suggested that lumbar lordosis decreases with age as the lumbar discs start to degenerate from the lower levels, migrating superiorly as age advances (Skaf *et al.* 2011).They then concluded that age and lumbar lordosis (Cobb angle) can serve as indicators for lumbar disc herniation. This did not differ between sexes (Skaf *et al.* 2011).

Chun *et al.* (2017) systematically reviewed thirteen observational studies to examine the difference in lumbar lordosis between those with and those without low back pain and to investigate factors that might influence this association. Their results indicated a strong association between low back pain and decreased lumbar lordotic curvature, especially when compared to healthy age-matched controls (Chun *et al.* 2017).

Yukawa *et al.* (2019) conducted a prospective imaging cohort of 627 asymptomatic volunteers to investigate sex-based differences and age-related changes of lumbar sagittal alignment. They found a steady decrease in lumbar lordosis with advancing age, particularly between the age of 60-70 (Yukawa *et al.* 2019). ROM decreased with advancing age, extension decreased more than flexion, and females demonstrated larger lordotic angle and ROM across the age spectrum (Yukawa *et al.* 2019).

2.5.2 Physical Activity

Numerous studies have demonstrated that physical activity has a positive effect on sagittal spinal alignment and posture, whether it be in children, athletes, middle-aged adults or the elderly (Yochum and Rowe 2005; Katzman *et al.* 2007; Moore, Dalley and Agur 2010; Katzman *et al.* 2017c; González-Gálvez, Gea-García and Marcos-Pardo 2019). On the other hand, sedentary lifestyles and obesity contribute to the detriment of spinal alignment (Womersley and May 2006; Todd, Bennett and Christie 2007; Jung *et al.* 2016; ku Song and sik Kang 2016; Jankowicz-Szymanska *et al.* 2019).

Physical activity does not need to be performed for prolonged periods to be beneficial. For example, López-Miñarro *et al.* (2012) found that in fifty-five adult volunteers performing a 30 minute hamstring stretching protocol had immediate effects on certain functional and postural parameters such as higher active straight leg raise capability and decreased thoracic kyphosis value in the sit and reach test. Different physical activities also affect spinal alignment differently, but generally physical activity has positive effects on postural control and spinal alignment (Choi, Moon and Song 2005; Katzman *et al.* 2007; Frank *et al.* 2009; Greendale *et al.* 2009; Fusco *et al.* 2011; Kiers *et al.* 2013; Kruusamae *et al.* 2015; Gordon and Bloxham 2016; Iunes *et al.* 2016).

Greendale *et al.* (2009) conducted a two-group, randomised, and controlled, single-masked trial to investigate whether a specifically designed yoga intervention could reduce hyperkyphotic posture. They found that participating in a one-hour yoga practice for three hours per week over twenty-four weeks significantly reduced kyphotic angle measurement in both men and women over the age of sixty with kyphotic angles of forty degrees (flexicurve angle) or more (Greendale *et al.* 2009). Tekur *et al.* (2008) also demonstrated the beneficial effects of yoga on posture and back pain when they compared the effect of an intensive short-term yoga programme with a physical exercise programme. Yoga was more effective at relieving chronic low back pain than a general physical exercise programme (Tekur *et al.* 2008).

Kruusamae *et al.* (2015) conducted an observational study that compared the thoracic kyphosis and lumbar lordosis of dance sport athletes to that of track and field athletes. They found that dance sport athletes had smaller values for both lumbar lordosis and thoracic kyphosis i.e. a smaller S-curve, and suggested that these changes are permanent, rather than temporary (Kruusamae *et al.* 2015)

Iunes *et al.* (2016) compared ballet dancers of varying degrees of experience to age-matched controls and found specific postural adjustments when comparing ballet dancers who have been practicing one-to-three years versus nine years. Kiers *et al.* (2013) concluded in their systematic review of thirty-nine articles from an initial yield of 2058, that postural sway decreases from sedentary to athletic individuals and even more in high-level athletes. Choi, Moon and Song (2005) demonstrated the positive effect of Thai Chi on physical fitness parameters including knee and ankle muscle strength, balance, flexibility, and mobility in institutionalised older adults. Their study looked at Thai Chi as an intervention for fall prevention by improving strength and balance. Frank *et al.* (2009) conducted a small study comparing parameters of neuromuscular function in long-term surfers versus age-matched non-surfers. They found significantly less muscle force fluctuation in the steadiness tests, as well as less postural sway with eyes closed and on soft surfaces in surfers than the control group (Frank *et al.* 2009). These findings demonstrate the positive effect of general physical activity on sagittal spinal alignment and posture control.

In recent years it has become known that exercise programmes that focus on spinal extensor strengthening and endurance and spinal flexibility, as well as breathing techniques can slow down, halt, or even reverse the progression of hyperkyphosis development, especially when related to age (ARHK) (Katzman *et al.* 2007; Ball *et al.* 2009; Greendale *et al.* 2009; Kado 2009; Katzman *et al.* 2010; Fusco *et al.* 2011; Bansal, Katzman and Giangregorio 2014; Jang, Kim and Kim 2015; Jang *et al.* 2017; Katzman *et al.* 2017a; Katzman *et al.* 2017c). In a systematic review on the effect of exercise on hyperkyphotic posture in adults over the age of forty-five Bansal, Katzman and Giangregorio (2014) observed that in high-quality studies there seemed to be a positive correlation between exercise and reduced hyperkyphotic posture. However, they stated that more high quality randomised controlled trials were necessary (Bansal, Katzman and Giangregorio 2014). Another systematic review on the effect of exercise on sagittal spinal alignment by González-Gálvez, Gea-García and Marcos-Pardo (2019) showed that exercise programmes might have positive effects on thoracic kyphosis (strengthening more than stretching), but no obvious effect was apparent in lumbar lordosis. Though changes to spinal alignment due to surfing have been suggested, to the researcher's knowledge no studies have been conducted to determine whether years of surfing affects the sagittal spinal alignment and posture of the aging individual or not (Furness *et al.* 2016).

2.5.3 Pathology and/or Injury

Pathologic and traumatic events that affect the bone and/or the surrounding soft tissue of the spinal column may cause a variety of sagittal and frontal alignment abnormalities (Yochum and Rowe 2005; Moore, Dalley and Agur 2010; Walker *et al.* 2014). Examples include Scheuermann's disease, ankylosing spondylitis, and most commonly osteoporosis (Yochum and Rowe 2005). Osteoporosis places individuals at increased risk of developing compression fractures of the vertebral bodies due to decreased bone density and fall risk in the elderly (Yochum and Rowe 2005; Moore, Dalley and Agur 2010; Walker *et al.* 2014). If the extent of the fracture is great enough it causes an increase in the angle of the region where the fracture occurred, i.e. wedge vertebrae (Yochum and Rowe 2005; Moore, Dalley and Agur 2010; Walker *et al.* 2014). For a long time, it was thought that ARHK occurred almost exclusively as a direct result of thoracic compression fractures. However, 20-40% of ARHK cases present without any underlying fractures (Bartynski *et al.* 2005; Katzman *et al.* 2010; Roghani *et al.* 2017). It now seems that increased kyphotic angle and a stooped posture are risk factors for developing compression fractures (Bruno *et al.* 2012; Roghani *et al.* 2017).

Pathology may also present as congenital anomalies that affect spinal development (Yochum and Rowe 2005). Congenital anomalies affecting the spinal column generally affect either the shape of the vertebrae, the division between segments, or both (Yochum and Rowe 2005; Moore, Dalley and Agur 2010; Walker *et al.* 2014). Examples include congenital block vertebrae and Klippel-Feil syndrome, butterfly vertebrae, hemivertebrae (lateral, dorsal or ventral), and Spina Bifida (Yochum and Rowe 2005; Moore, Dalley and Agur 2010; Walker *et al.* 2014)

Injuries that may alter spinal alignment generally occur due to trauma and include vertebral compression fracture, fracture of any of the posterior elements of the vertebrae e.g. pedicles, laminae, or processes; and injury to the intervertebral disk e.g. a ruptured or a herniated disk (Yochum and Rowe 2005; Walker *et al.* 2014).

Surgical interventions are often required when dealing with pathological conditions of the spine, whether they are of a congenital or acquired nature. These interventions often involve the mechanical fusion of multiple spinal segments and inevitably result in alterations to spinal alignment (Yochum and Rowe 2005; Walker *et al.* 2014).

Due to the magnitude of the effect that pathological processes may have on spinal alignment, persons who suffer from any such condition which may radically affect their spinal alignment will not be included in this study.

2.6 Surfboard paddling as an activity promoting spinal extension

Surfing is a multi-faceted activity that requires both upper and lower body strength and endurance (dos Santos 2018). It places a wide range of physiological and biomechanical demands on the musculoskeletal, cardiovascular and respiratory systems of the body (Meir *et al.* 1991; Mendez-Villanueva and Bishop 2005; Frank *et al.* 2009; Farley, Harris and Kilding 2012; Secomb, Sheppard and Dascombe 2015; Furness *et al.* 2016; LaLanne *et al.* 2017; dos Santos 2018). According to dos Santos (2018) surfing has two distinct phases: vertical (standing) and horizontal (prone). The vertical phase includes standing on the board and performing manoeuvres, here the lower-body plays the dominant role(dos Santos 2018). Whereas the dominant role of the horizontal phase is that of the upper-body and mainly involves paddling (dos Santos 2018). The activities that make up a typical surf session either occur within these two phases, or occur as transitional activities, which includes wipe-out and board retrieval, duck-diving, and sitting (while waiting for a wave/resting after a paddle) (Meir *et al.* 1991; Mendez-Villanueva and Bishop 2005; Farley, Harris and Kilding 2012; Secomb, Sheppard and Dascombe 2015; Furness *et al.* 2016; LaLanne *et al.* 2017; dos Santos 2018). The percentage of time spent paddling (usually more than 50%) during a surf-session is disproportionately high when compared to the other activities that make up that session. These include sitting (35-50%), actually surfing a wave (around 5%), and other miscellaneous activities such as duck diving and board retrieval (2.5% for competitive and up to 16% in recreational surfing) (Meir *et al.* 1991; Mendez-Villanueva and Bishop 2005; Everline 2007; Farley, Harris and Kilding 2012; Secomb, Sheppard and Dascombe 2015; Furness *et al.* 2016; LaLanne *et al.* 2017; dos Santos 2018).

2.6.1 Physiological demands of surfboard paddling

Secomb, Sheppard and Dascombe (2015) sub-categorised surfboard paddling to include sprint paddling and endurance paddling in their time-motion analysis of a two-hour surf training session. Endurance paddling is generally done when paddling to the line-up from the beach or after riding a wave, whereas sprint paddling is employed to catch desired waves (Secomb, Sheppard and Dascombe 2015). Multiple studies have been conducted confirming that surfing places a high demand on both the anaerobic (sprint paddling) and aerobic (endurance paddling) energy systems of the body, utilizing the glycolysis, creatine phosphate and adenosine triphosphate pathways. This is mainly due to the high percentage of time spent paddling (Meir *et al.* 1991; Mendez-Villanueva and Bishop 2005; Everline 2007; Farley, Harris and Kilding 2012; Secomb, Sheppard and Dascombe 2015; LaLanne *et al.* 2017; dos Santos 2018).

Meir *et al.* (1991) analysed the heart rates and estimated energy expenditure of six male surfers during approximately one hour of recreational surfing. They found that recreational surfing was comparable with other sporting activities as relates to energy expenditure, e.g. freestyle swimming, tennis and cycling. Secomb, Sheppard and

Dascombe (2015) performed a time-motion analysis of a two-hour recreational surf training session to provide a qualitative and descriptive analysis of the activities and physiological requirements of a surfing session. They concluded that although recreational surfing is generally done at a lower intensity than competitive surfing, near-maximal bouts of exertion still occur; and that surf training sessions and competitive heats place high physical and metabolic demands on surfers (Secomb, Sheppard and Dascombe 2015).

Farley, Harris and Kilding (2012) conducted a descriptive study in which they monitored heart rate, GPS and video footage to describe surfers' heart rates, activity duration, velocity and distances covered in a competitive situation. They found that due to the stochastic nature of surfing, competitive surfers have highly variable heart rates throughout a surf session. They can spend up to 60% of a session at 56-74% of age-predicted maximal heart rate, 19% of a session at 46% age-predicted maximal heart rate, and 3% at 83% of age-predicted maximal heart rate (Farley, Harris and Kilding 2012).

LaLanne *et al.* (2017) investigated whether activity levels and cardiovascular response to surfing changed with advancing age. They found that recreational surfing is performed at lower intensity levels than competitive surfing and that cardiovascular response to surfing activities decreases with age (LaLanne *et al.* 2017). However, they also stated that when expressed as an age-predicted maximum, the mean heart rate increased significantly with age (LaLanne *et al.* 2017).

dos Santos (2018) conducted a descriptive study to describe the energetic profile of a surfing paddling cycle, and the effects of endurance paddling and rest periods on sprint paddling in terms of upper limb propulsive force and maximal paddling velocity. They found that blood lactate levels reached maximum levels after endurance paddling and that after the first cycle of endurance and sprint paddling fatigue starts to affect subsequent cycles, even with adequate rest intervals (dos Santos 2018). They also noted that multiple energy sources are utilised during a surf session and that each type of paddling was associated with different energy pathways (dos Santos 2018).

2.6.2 Biomechanics of surfboard paddling

While paddling, typically the surfer will assume a prone position on his/her board and propel themselves mainly with their arms, which results in a state of vertebral hyperextension, with only the abdomen in contact with the surfboard (Everline 2007; Metcalfe and Kelly 2012; dos Santos 2018). This position is optimal for surfboard paddling for three reasons: 1) the surfer can control the lift of the nose of the board out of the water to enable paddling, 2) it allows for greater arm clearance over the water, and 3) it allows the head of the surfer to face the direction of paddling (Furness *et al.* 2014).

It is especially important for the thoracic spine to maintain its extended position because it serves as an important biomechanical link between the cervical and lumbar spines, as well as the shoulders while paddling (Everline 2007). Any decrease in thoracic extension during the paddling cycle could cause compensatory extension in the lumbar or cervical spines which would result in increased pressure being placed on these regions (Meir *et al.* 2012; Furness *et al.* 2014; Furness *et al.* 2016). The lumbar facet joints are especially vulnerable, as they get forced into their close-packed position for prolonged periods (Yochum and Rowe 2005; Moore, Dalley and Agur 2010; Furness *et al.* 2014). Decreased thoracic extension while paddling may also alter shoulder biomechanics, which may lead to over-use injuries or impingement of sub-acromial structures (Furness *et al.* 2014).

Furness *et al.* (2016) conducted a study that attempted to develop a reliable thoracic sagittal mobility assessment; to assess the reliability of existing thoracic rotation measurement techniques, and to evaluate thoracic kyphosis in elite male surfers They found that elite surfers had significantly greater thoracic rotation than age-matched controls. They also coincidentally noticed that the surfing population had a significantly lower neutral thoracic kyphosis angle. In that study, they noted that the hypothesised explanation for the lower kyphotic values among surfers “may be due to the activity requirements of surfing” (Furness *et al.* 2016). This refers to the prolonged paddling periods creating a high demand for spinal extension, especially in the thoracic spine (Furness *et al.* 2016).

2.6.3 Surfing Injuries

Surfing injuries may occur acutely or may develop over time into chronic ailments (Furness 2015a). Furness (2015a) conducted a review of the literature on acute and chronic injuries in recreational and competitive surfers according to location, mechanism, type, risk factors incidence and methodologies used to gather injury-specific data. Acute injuries were mostly of muscular (31.3%), articular (28.7%), skin (28.7%) and nerve (6.9) origin, most commonly to the shoulder, ankle, and head and face (Furness 2015a). These injuries occurred due to direct trauma with a surfboard or the ocean floor (47.1%), paddling (10.9%), duck diving (4.6%), wave riding (32.7%) and performing aerial manoeuvres (4.6%) (Furness 2015a).

Furness *et al.* (2014) and Furness (2015a) found that the areas of the body with the highest rate of chronic injury among surfers are the lumbar spine (23.2%) and shoulder, (22.4%) and knee (12.1%) (Furness *et al.* 2014; Furness 2015a).The mechanism of low back injury was reported to be 25.9% due to rotational forces during turning, and 38.5% occurring due to the prolonged paddling and lying on the surfboard(Furness *et al.* 2014; Furness 2015a) Shoulder injuries were most commonly attributed to prolonged paddling (45.9%) and were more likely to be severe enough for the surfer to seek medical advice or treatment (Furness *et al.* 2014; Furness 2015a). Chronic knee injuries mostly originated within the joint (85.6%) with the most common mechanism being turning manoeuvres.

It has been suggested that the thoracic spine is a vital link between the lumbar spine and the shoulders and that impaired thoracic mobility and exaggerated kyphosis could be a contributing factor to developing injuries in both these areas (Furness 2015b; Furness *et al.* 2016). Reduced thoracic mobility and extension may lead to increased pressure on the cervical and lumbar regions through compensatory extension. This may increase pressure on the lumbar region and hips while turning the surfboard during wave riding (Furness 2015b; Furness *et al.* 2015; Furness *et al.* 2016). Decreased thoracic extension or excessive kyphosis during paddling might cause protraction and inferior rotation of the scapulae, which could lead to impingement of the sub-acromial structures such as the bursa or sub-acromial tendons (especially supraspinatus) (Furness *et al.* 2014; Furness 2015b; Furness *et al.* 2016)

2.6.4 Health benefits

Benefits of proper surf practice and technique include, among others: 1) Physiological benefits i.e. improved muscular strength and endurance, improved aerobic and anaerobic respiration across the age spectrum, and even improved bone mineral density in older males. Surfers across the entire age spectrum are achieving and maintaining heart rate levels which are consistent with cardiovascular guidelines for exercise by the World Health Organisation (Meir *et al.* 1991; Mendez-Villanueva and Bishop 2005; Everline 2007; Climstein *et al.* 2015; Furness 2015b; LaLanne *et al.* 2017; dos Santos 2018); 2) Biomechanical benefits i.e. maintaining cervical, thoracic, and lumbar range of motion, as well as improving postural and balance control (Frank *et al.* 2009; Furness 2015b; Furness *et al.* 2016; dos Santos 2018); 3) Psychological benefits such as high subjective quality of life ratings (Warshaw 2011; Morgan and Coutts 2016). However, the use of improper technique may lead to the development of several chronic injuries (Mendez-Villanueva and Bishop 2005; Nathanson 2013; Furness *et al.* 2014). These injuries occur mainly due to mechanical stresses and the repetitive nature of the typical movements associated with surfing (Meir *et al.* 2012; Nathanson 2013; Furness *et al.* 2014).

Thus, if surfing activities are performed with proper technique it is reasonable to assume that it is a beneficial activity for the aging individual and it may be beneficial to multiple aspects of their well-being, including sagittal spinal alignment and posture, specifically thoracic kyphosis (Furness *et al.* 2016; LaLanne *et al.* 2017).

2.7 Conclusion

Sagittal spinal alignment changes occur throughout life, generally deteriorating in the elderly years with significant changes in cervical and lumbar lordosis and especially thoracic kyphosis. Though related strongly with age, these changes may also be affected by physical activity (or lack thereof) and pathology. Research indicates that improper spinal alignment and posture, especially later in life, may contribute to a significant decrease in functional ability, with increase in spinal or other musculoskeletal pains, decreased HRQL, and even higher mortality rates (Roghani *et al.* 2017).

Exercise programmes that include spinal extensor strengthening exercises, breathing exercises, and balance exercises are beneficial to the development and maintenance of optimal posture and sagittal spinal alignment, especially for those over the age of fifty (González-Gálvez, Gea-García and Marcos-Pardo 2019). Due to the prone position of spinal extension assumed by surfers while paddling, as well as the high aerobic and anaerobic demand of the activity, surfboard paddling may be beneficial to the sagittal spinal alignment of aging individuals (Furness *et al.* 2016).

3 METHODOLOGY

3.1 Introduction

In this chapter, the research design, location, sampling methods, measurement tools, research procedure, ethical guidelines, data reduction, and data analysis will be discussed.

3.2 Study design

An observational study design set within the quantitative paradigm was applied to compare sagittal spinal alignment and posture measures of surfers and physically active non-surfers in eThekwini.

3.3 Study location:

This research was conducted at the Durban University of Technology Chiropractic day clinic, Durban, KZN. Participants were to report to the clinic, to complete a case history and undergo a postural assessment. However, due to the global Covid-19 pandemic and the fact that the target population for this study is considered high-risk for infection, as well as the limited travel regulations set out by the Covid-19 pandemic national governmental response (DoH:SA 2020; World Health Organization 2020), participants were given another option. Participants could opt to have the researcher meet them at a location more convenient to them, where the case history and postural examination could be completed.

3.4 Sample group

Two groups were included in this research: 1) A control group, consisting of physically active individuals who did not participate in surfing, 2) A surfer group, consisting of individuals who were actively surfing. Participants in both groups must have been over the age of fifty years, as the biggest change in sagittal spinal alignment is documented to occur after the fifth decade of life (Katzman *et al.* 2010; Roghani *et al.* 2017).

3.5 Research parameters

The sagittal spinal alignment parameters measured included cervical lordosis, thoracic kyphosis, and lumbar lordosis angles as measured with a flexicurve ruler (C, T, and L-angles (flex)) Biomech Flex then used the flex value to estimate a Cobb value for each region. The postural parameters that were used included the Posture Number™ as calculated by the PosturePro photographic postural analysis software.

Additional information was recorded including age, hours per week, as well as years spent practising their primary physical activities, and anthropometric variables including height, weight, and body-mass index (BMI)

3.6 Measurement tools

This study utilised both the FlexiCurve ruler – a flexible metal strip covered with plastic and marked in millimetres to form a 70cm flexible ruler (figure 3.5 (a)); and "PosturePro" software to examine the participants' sagittal spinal alignment and posture respectively. The angles produced by the curvatures of the flexicurve measurements were calculated using the Biomech Flex computer application for the C, T, and L-spine. The most cost-effective of these is the FlexiCurve; however, PosturePro software was already available at the DUT chiropractic clinic, where the study was conducted. Both these tools have been proven reliable and valid in the literature (Lundon, Li and Bibershtein 1998; Yanagawa *et al.* 2000; Greendale *et al.* 2011; de Oliveira *et al.* 2012; do Rosário 2014; Raupp *et al.* 2017; Senthil *et al.* 2017; Mehta *et al.* 2018)

3.7 Sample size

EThekwini Surf-Riders Association reported total membership of 75 competitive surfers as of April 2020. Of these, 62 were male and 13 were female; 15 male and no female affiliates were over the age of 50. However, email correspondence with a representative of the organization revealed that only surfers who compete at the South African Surfing Championships affiliate with them. Thus their membership was not representative of the actual number of surfers in the eThekwini district (Thompson 2020).

Correspondence with eThekwini Surf-Riders Association revealed that available information about the recreational surfing population in the eThekwini district is very limited. Thus, it was not possible to accurately estimate the size of the surfing population in the eThekwini district, and so the following method was used to calculate the sample size for this research, according to Faul *et al.* (2009).

Thoracic kyphosis was used as the variable in the calculation, as this was the most notable postural alteration that occurred with age (Milne and Lauder 1974; Takeda *et al.* 2009; Katzman *et al.* 2010; Hasegawa *et al.* 2016; Asai *et al.* 2017; Roghani *et al.* 2017; Yukawa *et al.* 2018). The paper, "Sagittal spinopelvic alignment in adults: The Wakayama Spine Study", reported a mean of 37.8 degrees and a standard deviation of 9.1 degrees for thoracic kyphosis for men in the age group 60 – 69 (Asai *et al.* 2017). To detect a difference of 6.1 degrees in thoracic kyphosis with the assumption that the standard deviation for the over 50 group was 9.1 degrees and the standard deviation for the under 50 group was 6.2 degrees, with a 5% level of significance and a power of 80%. The sample size for each group was calculated to be 26, for a total of 52 participants. The calculations were done using GPower version 3.1 and OpenEpi version 3 - open-source calculator (Faul *et al.* 2009).

3.8 Participant recruitment/sampling method

Convenience snowball sampling methods were applied to recruit participants. Convenience sampling (or haphazard/accidental sampling) is a type of non-probability or non-random sampling where criteria such as geographical location, accessibility, and willingness to participate are met by certain members of the target population (Etikan, Musa and Alkassim 2016). This method is generally easy, affordable and subjects are readily available, however, this type of sampling is more likely to be biased, as in this case the population is limited to surfers and physically active individuals in the eThekwini district(Etikan, Musa and Alkassim 2016).

Snowball sampling is a type of convenience sampling that is used to recruit a sample when standard sampling methods are either impossible or impractical e.g. unaffordably expensive (Handcock and Gile 2011). In this case, participants were asked to refer their physically active and surfing network to the study. Though snowball sampling is a very practical method of recruiting a sample population, the resulting sample is non-probabilistic (Handcock and Gile 2011). This means that not all individuals in the population had an equal chance of participating in the study.

The researcher approached individual surfers and physically active individuals on Durban and surrounding beaches in the eThekwini district to inform them of the study and to request participation as well as spread awareness through word of mouth.

Surf-lifesaving clubs, surf associations, surf shops, running clubs, cycling clubs and gyms in the Durban and surrounding areas were approached to relay information about the study to their members and customers.

Advertisements in the form of a poster (Appendix B) and a flyer (Appendix B) were further used to convey information about the study.

3.9 Inclusion and exclusion criteria

3.9.1 Group 1: (Non-surfers/control group)

Inclusion criteria:

- Over 50 years of age.
- Participation in at least 3 hours of physical activity (purposeful exercise) per week.
- Participation in said physical activity for at least 3 years.

Exclusion criteria:

- Known structural spinal anomalies (e.g. structural scoliosis or block vertebrae, congenital, or acquired)
- Musculoskeletal deformities as determined by the postural exam.
- Spinal surgery (e.g. spinal vertebral fusion)
- Chronic respiratory conditions (e.g. chronic bronchitis/Emphysema)

3.9.2 Group 2: (Surfer group)

Inclusion criteria:

- Over 50 years of age.

- Must participate actively in stand-up surfing for a minimum of 3 hours per week
- Surfing history of at least 3 years

Exclusion criteria:

- Known structural spinal anomalies (e.g. structural scoliosis or block vertebrae, congenital, or acquired)
- Musculoskeletal deformities as determined by the postural exam.
- Spinal surgery (e.g. spinal vertebral fusion)
- Chronic respiratory conditions (e.g. chronic bronchitis/Emphysema)

Demographic variables including age and occupation, as well as anthropometric variables including weight, height, BMI (Body Mass Index) number of years surfed/active, and time spent surfing/active per week were also recorded.

As for female surfers, the surfing population in Durban was primarily male, thus, obtaining a sufficiently large sample of female surfers would have proven problematic (Thompson 2020). The effect of age on sagittal spinal alignment also differs between females and males (Roghani *et al.* 2017). Thus, females were excluded from this study.

3.10 Study procedure

Upon obtaining ethical approval from the Institutional Research Ethics Comity – IREC number 090/19 (DUT), DUT gatekeeper permission (Research directorate), and Chiropractic Clinic gatekeeper permission (DUT), data collection commenced. As shown in figure 3.1 participants were required to complete a brief medical history, and undergo a brief postural examination to determine if any notable musculoskeletal deformities may have affected postural development. Participants' names were not included in the medical history or postural examination to maintain anonymity.

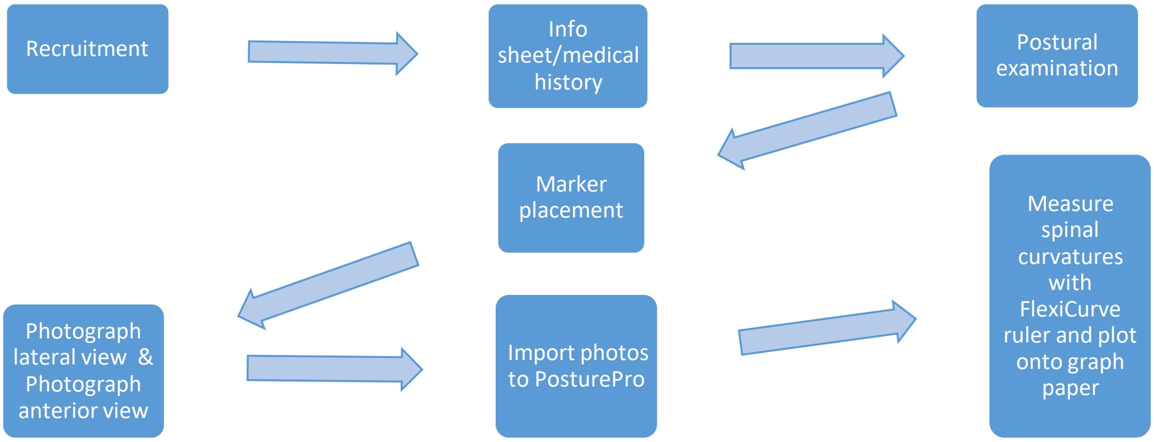

Figure 3-1 – Research procedure

Once considered eligible, participants were instructed according to the PosturePro 8 user manual. Markers were placed at the centres of the right ear, shoulder, hip, knee, and just anterior to the lateral malleolus of the ankle for the lateral view. For the anterior view, the landmarks used were bilateral: the earlobes or eyes, shoulders (acromioclavicular joints), hips (anterior superior iliac spine (ASIS)), knees (patella mid-point) and ankles (medial malleolus). Once the markers were set in place the, participants were positioned on a marker 2.5m from the Canon digital camera. Both lateral and anterior aspect photographs were captured and were then imported to PosturePro for analysis. In the lateral view, the PosturePro software connected the markers on the photograph to form a multi-segmented line. It compared this line to a straight plumb line and then generated a Posture Number™ according to the level of deviation from the plumb line. A number zero indicates no deviation from the plumb line, while higher numbers suggest greater deviation from the straight plumb line (Ventura Designs 2012).

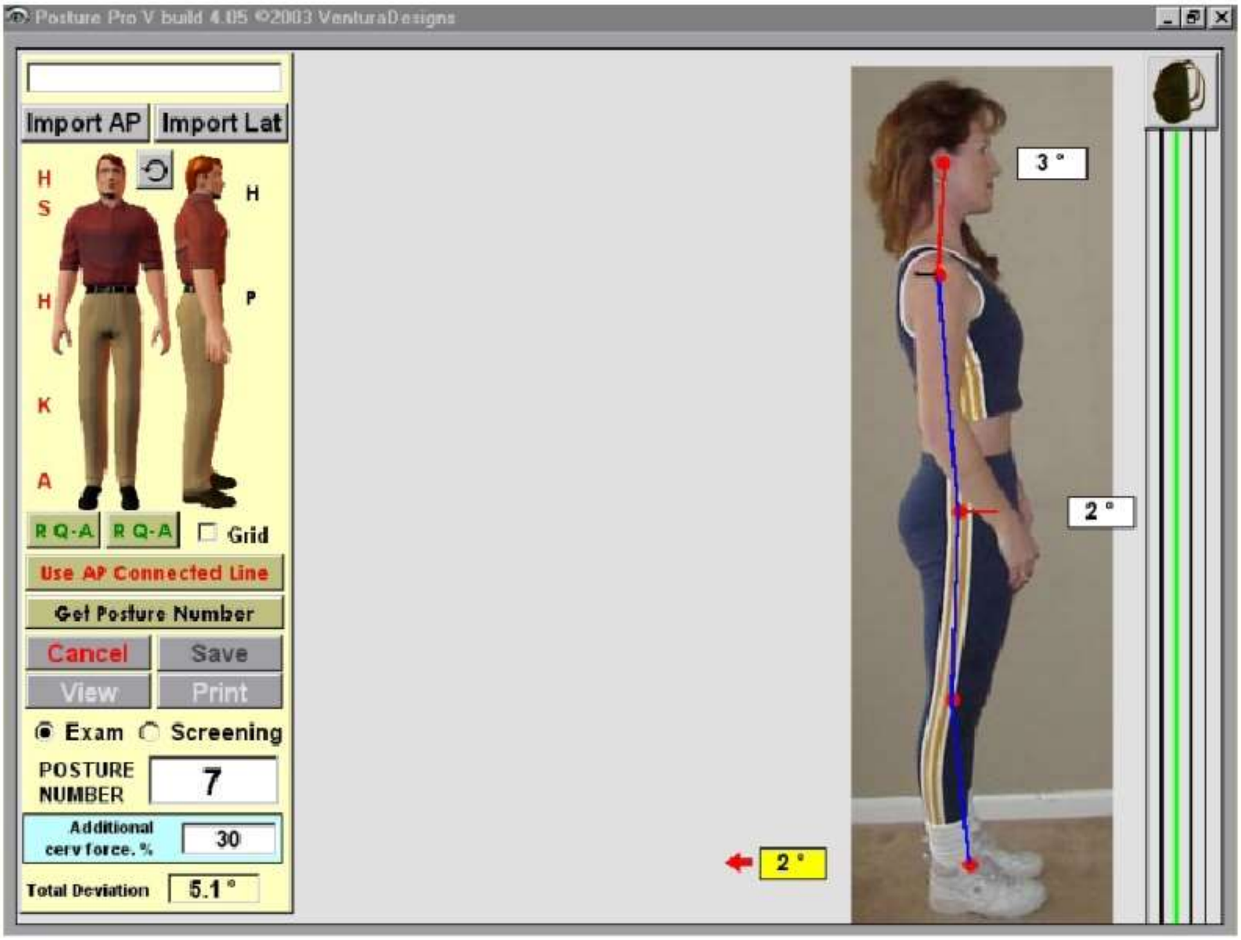

Figure 3-2 Posture number as calculated by PosturePro (Ventura Designs 2012)

The spinal curvatures were then measured using the FlexiCurve ruler. The cervical spine was measured according to the procedure set out by Raupp *et al.* (2017) as illustrated in figure 3.3. To measure the cervical spine the external occipital protuberance (C0), atlas posterior tubercle (C1), and C2, C7, T1, and T2 spinous processes were palpated and marked. The participants were then instructed to sit, close their eyes, lower and raise the head twice, stop in the neutral position, open the eyes, and look toward the horizon without moving. The flexicurve was immediately moulded to the skin covering the cervical spine, and then a whiteboard marker was used directly on the flexicurve to mark the points corresponding to the anatomical marks on the skin. Once marked the flexicurve was carefully removed and placed on graph paper to be traced. (Raupp *et al.* 2017)

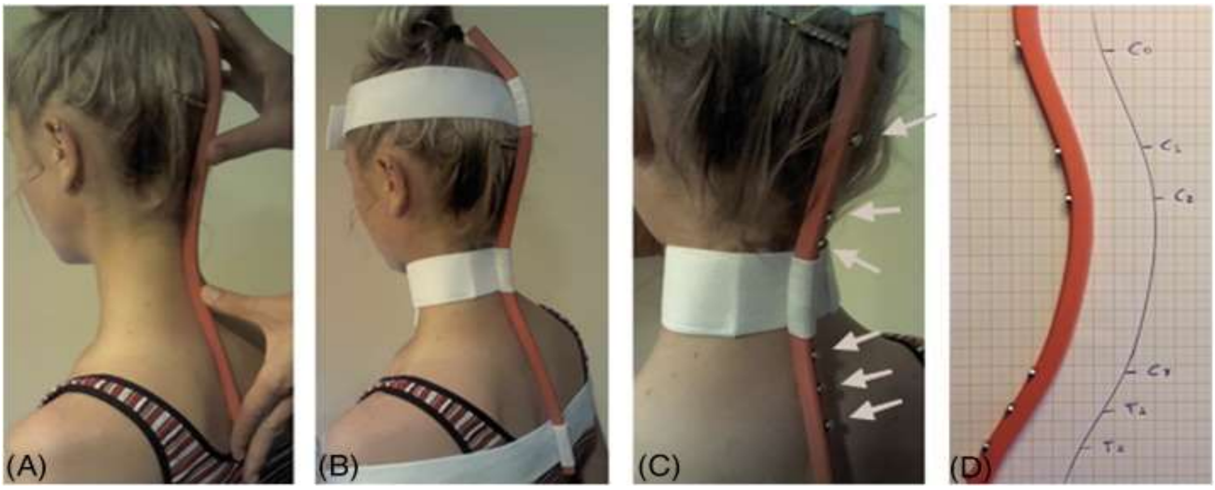

Figure 3-3 Evaluation using the flexicurve: moulding the flexicurve to the shape of the cervical spine (A); fixing it with Velcro strips (B); identifying the anatomical points on the flexicurve with magnetic markers (C); transferring the shape to graph paper (D) (Raupp *et al.* 2017).

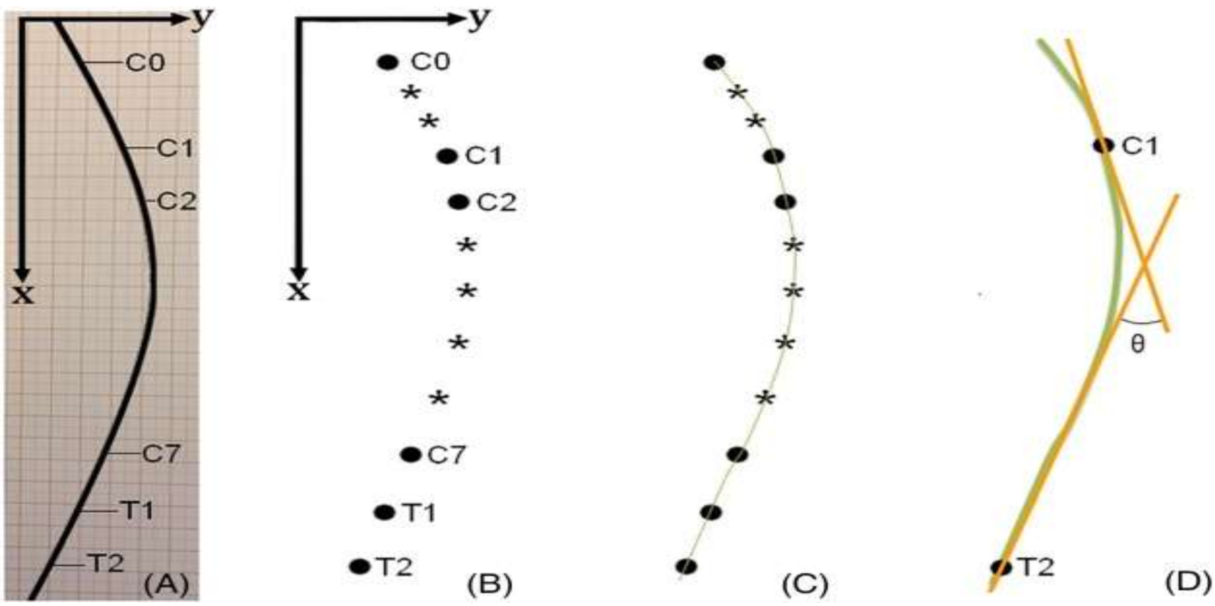

Figure 3-4 Analysis using the flexicurve: defining the Cartesian system on the outline of the cervical spine (A); including 6 equidistant intermediate points (B); third-order polynomial produced by the software (C); representation of the calculated flexicurve angle (D) (Raupp *et al.* 2017)

To evaluate thoracic and lumbar curvatures together the protocol described by de Oliveira *et al.* (2012) was used as illustrated in figure 3.5. The participants were positioned standing with parallel bare feet, their spine in regular posture, and their shoulders and elbows flexed to 90 degrees and resting against a wall to prevent any possible movement at the time of flexicurve moulding. The spinous processes of C7, T1, T12, L1, L5, and S1 were palpated and marked and a whiteboard marker was used directly on the flexicurve to mark the points corresponding to the anatomical marks on the skin. Once marked the flexicurve was carefully removed and placed on graph paper to be traced (figure 3.6 (a)) With the outline of the spine on graph paper, a system of Cartesian coordinates was defined with the x-axis representing the cranial-caudal direction, and the y-axis representing the anterior-posterior direction (de Oliveira *et al.* 2012; Raupp *et al.* 2017).

(a) (b) (c)

Figure 3-5 (a) Flexicurve; (b) moulding the flexicurve to the spine, lateral view; (c) moulding the flexicurve to the spine, posterior view (de Oliveira *et al.* 2012).

The paired (x and y) coordinates of each anatomical point, together with 6 intermediate points along each curve, were entered into BIOMEC-FLEX software (www.ufrgs.br/biomec/) for calculation, as illustrated in figures 3.5 and 3.6. For the C-spine, two equidistant intermediate points were placed between C0 and C1, and another four were placed between C2 and C7. For the T- and L-spines, six equidistant intermediate points were entered between the superior and inferior markers of each curve (between T1 and T12 for the T-spine, and L1 and L5 for the L-spine). By use of the point coordinates (C-spine: C0-T1, T-spine: C7-L1, and L-spine: T12-S1) the software produced a third-order polynomial representing each curvature. It then calculated the flexicurve angle (C, T, and L-angles (flex)) between straight lines that formed tangents with the points representing C1 and T2 (C-angle (flex)). For the T- and L-spines perpendicular lines to the tangents at T1 and T12 (T-spine), and L1 and L5 (L-spine) were drawn. Their respective angles were then measured at the intersection points of the perpendicular lines in the T-spine (*θ*) (T-angle (flex)) and L-spine (*α*) (L-angle (flex)). Biomech Flex then used the (flex) values to estimate the Cobb angle of each spinal region i.e. C, T, and L-angles (Cobb) (de Oliveira *et al.* 2012; Raupp *et al.* 2017).

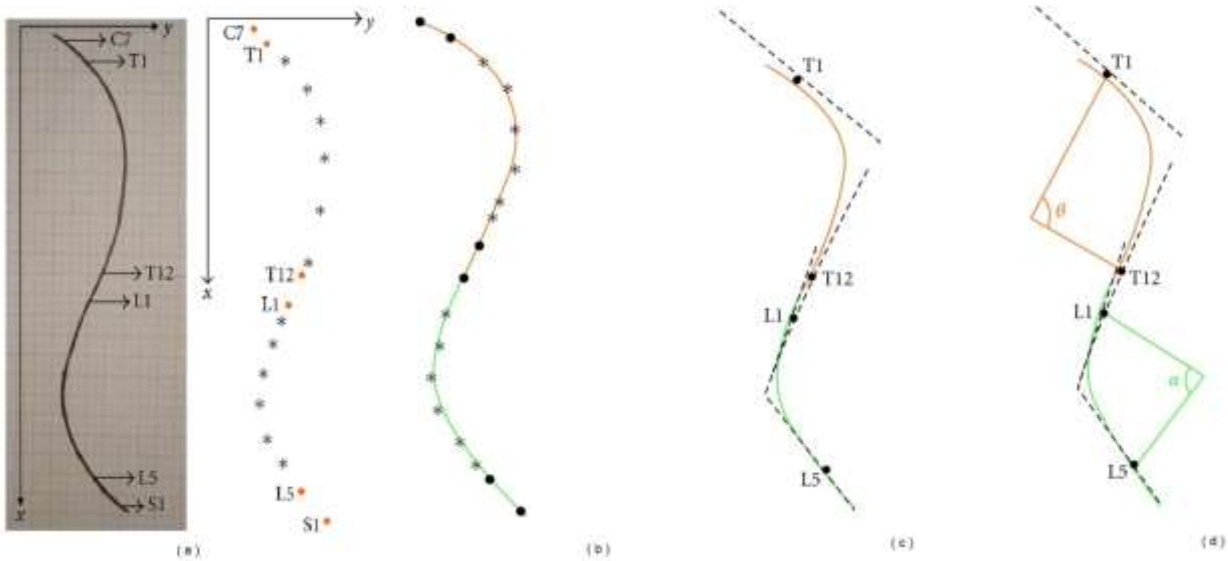

Figure 3-6 (a) Outline on graph paper of the spine and points representing the shape of the lumbar and thoracic curvatures; (b) drawing of the curvatures obtained using two 3rd polynomial; (c) drawing the tangents on the limit points of the curvatures (T1/T12 for thoracic, L1/L5 for lumbar); (d) drawing the straight lines perpendicular to the tangents and establishing the thoracic (*θ*) and lumbar (*α*) angles (de Oliveira *et al.* 2012).

3.11 Ethical considerations

Autonomy – Participants were not forced or coerced into participation. Participation was completely voluntary, and they were free to leave the study at any time (Allan 2016). This was communicated to the participant verbally and was included in the informed consent form (Appendix A)

Justice – All participants were treated fairly and without prejudice (Allan 2016). Although there were specific inclusion and exclusion criteria to the study participants were not discriminated against based on any other criteria, e.g. race, or level of surfing.

Non-maleficence– All possible steps were taken to minimise harm befalling participants, whether foreseen or unforeseen. If harm did come to a participant necessary steps were taken to minimise the distress experienced (Allan 2016). This study was a very low risk as it did not involve any invasive investigative procedures, nor any form of treatment. Therefore, it was highly unlikely that harm should befall a participant during this study. All relevant permissions, including permission from the institutional research ethics comity (IREC) and head of department (HoD) at DUT, gatekeeper permission, and permission to conduct the study at the DUT chiropractic day clinic was obtained.

Beneficence – By conducting this study, the researcher was acting for the greater good of the surfing community, as well as the individuals involved (Allan 2016). This was done by revealing any negative effects that surfing may have on the body in the long run.

Informed consent - Participants were required to provide written consent by signing the informed consent form (Appendix A) (Allan 2016).

Confidentiality and anonymity – This ensured that no personal information retrieved about any individual throughout this study was made available to the public (Allan 2016). This was achieved by keeping the questionnaire form under lock and key along with the measurement results. The Posture-Pro data was kept on a separate USB flash drive, which will stay in the possession of the researcher until such time it needs to be destroyed.

3.12 Statistical analysis

An Excel spreadsheet was used to enter the data. Data were analysed using STATA Version 16 (StataCorp. 2019). The mean, median, standard deviation, range and percentiles were found and used as the summary measures for the spinal angle and posture variables, as well as the age and anthropometric variables. Side-by-side box-plots, histograms and scatter plots were used to present the distribution of these variables visually.

The level of significance that was used for all tests in this study was 5% and any p-value less than 0.05 indicated that the results obtained were statistically significant. The statistical tests used to evaluate the data generated by this research are briefly mentioned below.

The Shapiro-Wilk test is a test that can be used to ascertain whether a variable does in fact follow a normal distribution. The null hypothesis would be that the data follow a normal distribution, while the alternative hypothesis would be that the data do not follow a normal distribution. The W-value represents the distribution pattern, with a value closer to one indicating that the data follow a normal distribution. The closer the W-value is to zero the further the distribution is from normal. A p-value greater than 0.05 indicates that the null hypothesis is not rejected and that the normal assumption for the data is plausible. In that case the independent samples t-test can be used to test for difference between the means of the selected groups.

The independent samples t-test is used to test whether there is any significant difference in the means of the variable of interest for two independent groups. In this study, the groups are the surfer (S group) and non-surfer (NS group) groups. A requirement for using this t-test is that the variables in question follow normal distribution. A t-statistic with a large absolute value that exceeds the t-critical value for a given level of significance indicates that there is a difference between the means of the variable for the two groups. Alternatively, a corresponding p-value for the test that is less than 0.05 indicates that there is evidence of a statistically significant difference in the means of the variable when testing at a 5% level.

If the normal distribution assumption is violated for a variable then a nonparametric equivalent test may be used. The nonparametric Wilcoxon-Mann-Whitney (WMW) test can be used to test whether the shape of the distributions of two independent variables is the same. The null hypothesis for this test is that the two population distributions from which the samples are drawn are the same, and the alternative hypothesis is that the distributions are different. Thus, a p-value less than 0.05 would indicate a significant difference in the shape of the population distributions for the two groups.

To test for correlation between different variables the Pearson correlation coefficient was used. This test measures the strength of the linear association between two variables. An r-value of zero indicates no correlation, whereas a positive r-value indicates a positive correlation, and a negative r-value indicates a negative correlation. The closer the r-value is to one or negative one, the stronger the correlation - positive or negative, respectively. Correlation can be described as low, medium, or high.

Linear regression is a statistical method that can be used to examine the relationship between two or more variables. Specifically, these models examine the influence of a linear combination of one or more independent variables on a dependent variable and take the form $\hat{y} = b_0 + b_1 x_1 + b_2 x_2 + b_3 x_3 + b_4 x_4$. The symbols $b_0, \ldots, b_4$ are called the regression coefficients. In the context of this study, linear models are used to determine whether spinal angles can be predicted from variables, such as Posture Number, BMI and length of active years, which were measured in this study.

4 RESULTS

4.1 Introduction

In this chapter the statistical analyses and findings of the study are presented. This includes information about the participants' history, including primary physical activity, occupation, significant injuries and surgery. In addition, information about age, years spent surfing and being physically active and anthropometric variables, including BMI, was included. Most importantly, this chapter includes information about sagittal spinal alignment (spinal angles - C, T, and L-spines), and posture (Posture Number) of participants.

4.2 Participants

Fifty-two physically active males over the age of 50 years agreed to participate in the study. Participants recruited from beaches, surf-lifesaving clubs, surf associations, sport shops, running clubs, cycling clubs, paddling clubs and gyms within the eThekwini district were divided into two groups: Non-surfers (NS group) and Surfers (S group). Three of the participants presented with exclusion criteria, and were thus not included in the study, two from the NS group and one from the S group. This brought the total number of participants to 49, with 24 in the NS group and 25 in the S group.

The participants were questioned about their medical history to determine the presence of any conditions that may alter sagittal spinal alignment and posture. This included information about significant accidents, injuries, and surgery, their primary form of physical activity (NS group only, as the primary activity of the S group is surfing), and their occupation. Only three individuals presented with exclusion criteria and had to be excluded, namely: C5-6 & C6-7 disc replacement, grade 1 L5 spondylolysis, bilateral hip replacement, vertebral fusion at C4-5, and a hip resurface surgery that lead to leg length inequality, which in turn lead to postural aberration at an early age.

4.3 Age and anthropometric variables

Error! Reference source not found. below presents the summary measures, amely the mean, standard deviation, minimum and maximum for the variables age, height, weight, and BMI. The independent samples t-test was used to test whether the means for the variables mentioned earlier differed for the NS and S groups. The t-statistic value and corresponding p-value are also given in the table.

Table 4-1 Summary measures for age and anthropometric variables

Variable	Group	Mean	Std. Dev.	Min	Max	t-value	p-value
Age (yrs)	NS	57.9	5.8	50.0	71.0	-1.44	0.16
What	S	60.2	5.6	52.0	72.0		
Height (cm)	NS	179.9	6.9	167.0	192.0	1.93	0.061
	S	176.6	5.0	167.0	191.0		
Weight (kg)	NS	89.6	13.6	66.0	116.0	3.60	0.00*
	S	77.7	9.0	60.0	98.0		
BMI (kg/m²)	NS	27.6	3.4	21.8	34.4	2.98	0.00*
	S	24.9	2.9	19.6	30.9		

The age of the NS group ranged from a minimum of 50 years to a maximum of 71 years, with a mean of 57.9 years, and a standard deviation of 5.8. Similarly, the age of the S group ranged from 52 to 72 years with a mean of 60.2 years, and a standard deviation of 5.6. The p-value of 0.16 for the test of equal means indicates that there is no significant difference between the mean age of the NS and S groups. This ensures that the age effect between the NS and S groups is minimal, and that any differences between the sagittal spinal alignment and posture parameters detected between the two groups would be due to other factors, such as physical activity.

Height and weight of the participants were obtained to calculate BMI, as presented above in **Error! Reference source not found.**1. The NS group showed heights ranging from 167-192cm, a mean height of 179.9cm and standard deviation 6.9, while that of the S group ranged from 167-191cm with a mean height of 176.64cm, and a standard deviation of 5.0. The independent samples t-test did not indicate a significant difference in the means for height for the NS and S groups (p=0.061). Thus, the heights of the participants were similar between the two groups.

The weight of participants in the NS group ranged from 66-116kg, with a mean weight of 89.6kg, and a standard deviation of 13.6. The S group weighed between 60-98kg, with a mean weight of 77.4kg, and a standard deviation of 9.0. This meant that the BMI of the NS group ranged from 21.8-34.4, with a mean BMI of 27.6, while the S group presented with BMI ranging from 19.59-30.93, with a mean BMI of 24.9.

The weight and BMI had p-values less than 0.05 indicating that there was a significant difference in mean weight and BMI between the NS and S groups. From **Error! Reference source not found.** above it can be seen that the means for weight nd BMI for the NS group are significantly higher than that of the S group. This result classified the mean value of BMI for the S group in the normal range (BMI 18.5 - 25), whereas the NS group mean BMI was classified as overweight (BMI 25 - 30) according to the World Health Organization (dos Santos 2018).

4.4 Primary activity and occupation

While the primary activity for the S group was surfing, the primary forms of activity varied greatly within the NS group, as demonstrated in

Table 4-2 below. Among the 24 participants in the NS group, cycling was the most common primary activity where n=4 (16.7%), while gym training and triathlon were the second most common where n=3 (12.5%).

Table 4-2 Primary activity for NS group

Main Activity	Frequency (n)	Percent (%)
Boxing/combat training	1	4.2
Cycling	4	20.8
Gym training	3	12.5
Paddling	2	8.3
Squash	1	4.2
Surf-ski paddling	1	4.2
Swimming	2	8.3
Triathlon	3	12.5
Walking	2	8.3
Walking/running	2	8.3
Water polo	1	4.2
Wind-surfing	1	4.2
Total	24	100.0

Occupation varied widely within both the NS and S groups. Engineering and sales positions were the most common occupations among both groups, each contributing 16.3% to the total sample. However, due to the wide variety of occupations in both groups the correlation between occupation and sagittal spinal alignment and posture parameters were not tested.

4.5 Time spent practising primary activities

4.5.1 Hours per week

The summary measures of the number of hours spent practising the primary activities per week are presented below, in

Table 4-3.

Table 4-3 Summary measures for hours of practise per week

Variable	Group	Mean	Std. Dev.	Min	Max	p-value
Minimum hours	NS	4.67	1.55	2	8	0.0004
	S	3.28	1.06	2	6	
Maximum hours	NS	7.08	2.34	3	12	0.1358
	S	6.20	1.98	3	10	

The non-parametric Wilcoxon-Mann-Whitney (WMW) test revealed that the distribution of the minimum number of hours per week was the same for the S and NS group. The exact p-value for this test is 0.0004. This means that there is a significant difference in the distribution of the minimum hours of activity per week between the NS and S groups. The average minimum time the NS groups spent participating in their primary activity per week was 4.67hrs (± 1.55), while the S group spent an average minimum of 3.28hrs (±1.06) surfing per week. In testing whether distribution of the maximum number of hours per week is the same for the NS and S groups, the exact p-value is 0.1358, thus there is no significant difference in the distribution for the maximum number of hours. The smaller mean for minimum time of the S group could be due to the inconsistent nature of ocean and weather conditions. When conditions are poor, (small waves, strong wind, etc.) surfers generally stay in the water for shorter periods of time. However, when conditions permit, surfers will stay in the water for hours on end, and might do so for multiple days in a week, whereas other activities are less dependent on environmental conditions.

4.5.2 Primary activity years

The mean, standard deviation, minimum, maximum and median values of the number of years participants spent practising their primary activity is displayed in Table 4-4 below.

Table 4-4 Summary measures for activity years

Group	Mean	Std. Dev.	Min	Max	Median	p-value
NS	32.0	15.32	5	53	35	0.0008
S	45.6	8.37	25	60	46	

The exact p-value for this group when tested using the nonparametric WMW test was 0.0008. There was thus a significant difference in the shape of the distribution of the variable "activity years" for the NS and S groups. From Table 4-4 it can be seen that the S group had a mean number 45.6 years, while the NS group had a mean number 32 years. The standard deviation of 15.32 years for the NS group is also larger than that of the S group which is 8.37 years, indicating a wider spread in the activity years for the NS group. The larger mean years and smaller standard deviation of the S group indicate that, in general, the S group has been practising their primary activity (surfing) for longer than the NS group had been practising their various primary activities.

4.6 Sagittal Spinal Alignment (spinal angles)

Of the total sample included in this study, 59.0% presented with BMI>25, As a result, the C-angles (Cobb) could not be estimated from the C-angles (flex) as they would have been unreliable. Thus, the statistical power of C-angle (Cobb) was significantly lowered and was not included for analysis.

Table 4-5 below provides the summary measures: mean, standard deviation, minimum, maximum and range for the C, T, and L-spine angles (flex and Cobb).

Slight differences between the groups were reported and are presented graphically later on.

Table 4-5 Summary measures for C, T and L- spinal angles (flex and Cobb)

Variable	Group	Mean	Std. Dev.	Min	Max	Range
C-angle (flex) (^{o})	NS	40.5	17.3	12.8	73	60.2
	S	42.9	16.4	5	68.3	63.3
T-angle (flex) (^{o})	NS	44.7	9.1	34	71.8	37.8
	S	43.1	10.6	23.7	63.2	39.5
T-angle (Cobb) (^{o})	NS	45.3	7.8	36.1	68.6	32.5
	S	43.7	9.3	27.2	61.2	34.0
L-angle (flex) (^{o})	NS	19.8	9.2	1.3	37.5	36.2
	S	20.9	6.7	7.1	33.7	26.6
L-angle (Cobb) (^{o})	NS	24.9	7.0	10.7	38.5	27.8
	S	25.8	5.1	15.2	35.7	20.5

The box plots in Figure 4-1, Figure **4-2**, Figure **4-3**, Figure **4-4**, and Figure **4-5** below show the distribution of the C, T, and L-spine angles for the NS and S groups.

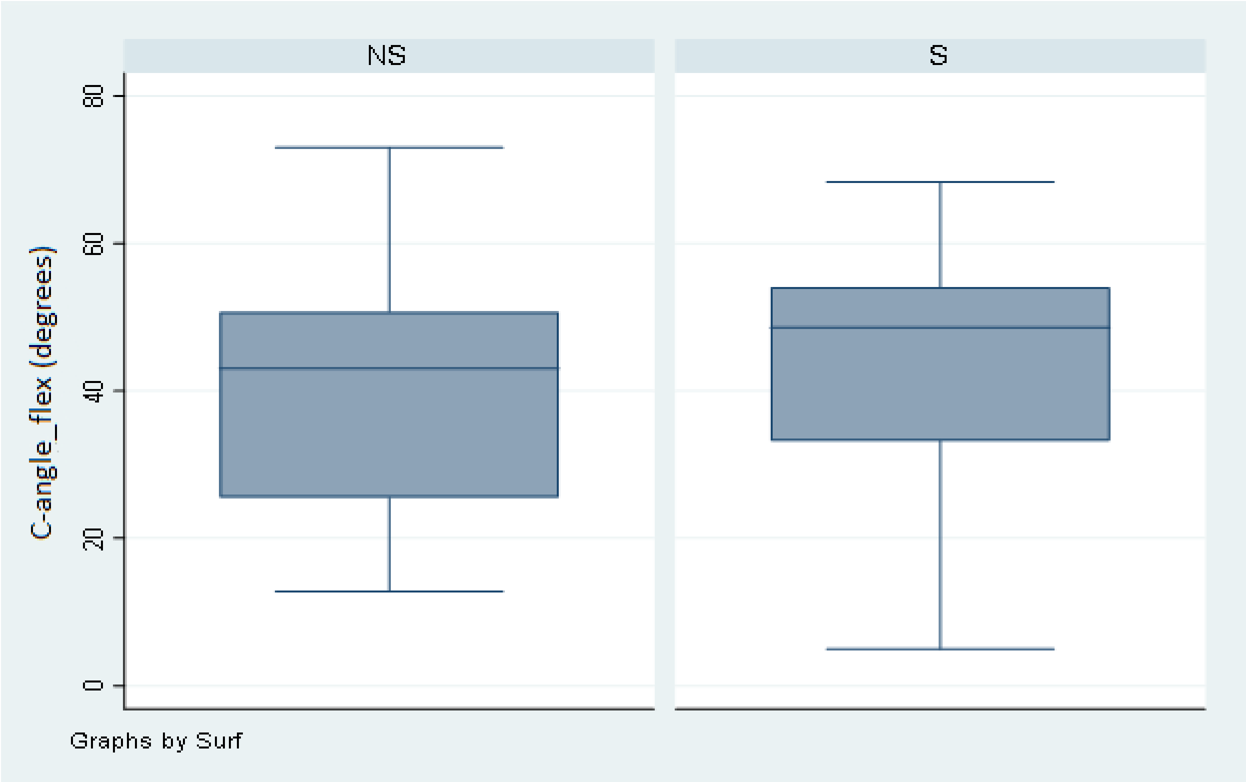

Figure 4-1 Box plot of C-angle (flex) of Non-surfer and Surfer groups

From

Table 4-55 and Figure 4-1 above, the C-angle (flex) of the S group demonstrated a larger range (63.3 degrees (º)) than the NS group (60.2º). The mean of the C-angle (flex) was also larger in the S group (42.9º) than in the NS group (40.5º). This result suggests that the NS group generally had flatter cervical curvatures, thus, surfing may contribute to increased cervical lordosis. However, the statistical significance of this is discussed in Section 4.7.

Figure **4-2** below, presents the range of the T-angle (flex) of the NS and S groups. The S group (39.5º), presented with a greater range of T-angles (flex) than that of the NS group (37.8º). However, the NS group has an outlier with a value of 71.8º. (An outlier is defined as an observation that is outside the boundary of Q3 + 1.5×IQR or Q1 – 1.5×IQR, where Q1 and Q3 are the 1st and 3rd quartiles, respectively and IQR denotes the interquartile range). If the outlier is excluded then it appears as though the range of T-angle (flex) of the S group is larger than that of the NS group, meaning the spread of T-angle (flex) values of the S group were spread wider than the NS group.

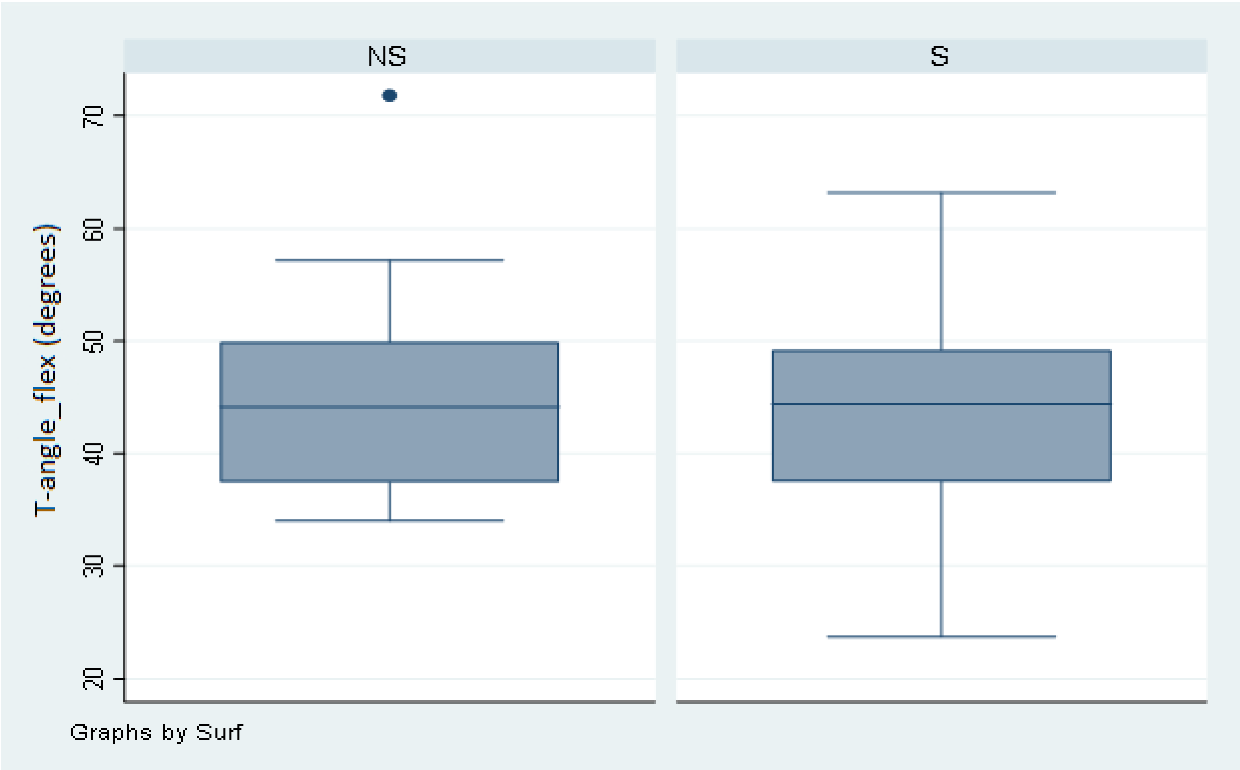

Figure 4-2 **Box plot of T-angle (flex) for Non-surfer and Surfer groups**

However, the middle 50% in both groups were similarly distributed, and the mean T-angle (flex) of the NS group (44.7º) was larger than that of the S group (43.2º). This result suggests that the average curvature of the thoracic kyphosis was flatter in the S group than the NS group. Thus, surfing may attribute to reduced kyphosis values, however, the statistical significance of these results is discussed in Section 4.7.

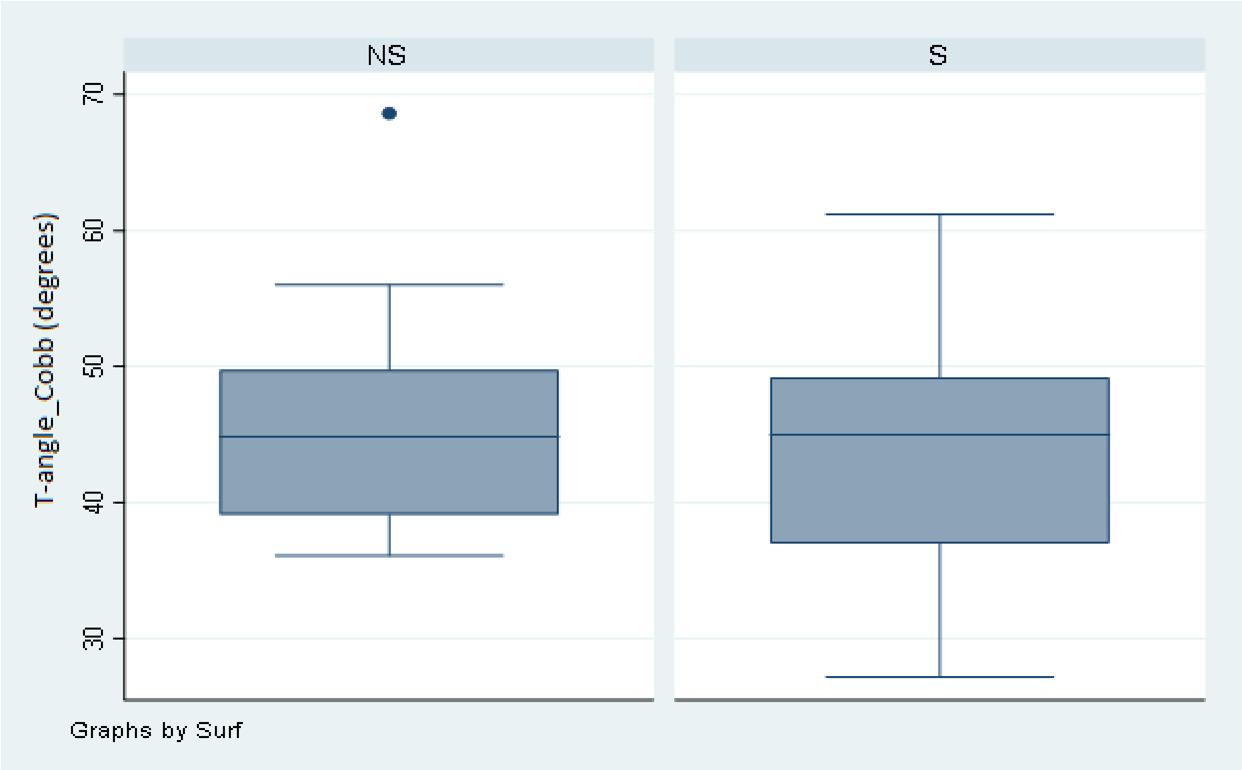

Figure 4-3 **Box plot of T-angle (Cobb) for Non-surfer and Surfer groups**

Figure **4-3**, above illustrates the range of the T-angle (Cobb), which is very similar to that of T-angle (flex), because T-angle (Cobb) was estimated using T-angle (flex). The range of the S group was 34º, while the range of the NS group was 35.2º, indicating a larger range for the NS group. However, if the outlier (with a value of 68.6º) in the NS group is excluded then it appears as though the S group has the larger range T-angles (Cobb). The mean T-angle (Cobb) of the NS group (45.3º) was larger than that of the S group (43.7º). As above, this result suggests that the average curvature of the thoracic kyphosis was flatter in the S group than the NS group. This could indicate possible advantages of surfing to sagittal spinal alignment changes with age, however the statistical significance of this result is discussed in Section 4.7. The median values for the NS and S groups appear to be similar.

Figure **4-4**, below illustrates the L-angle (flex) of the NS and S groups. The NS group had a larger range of L-angles (flex) (36.2º) compared to the S group (26.6º). Thus, the spread of values was greater within the NS group. The interquartile range of the NS group was also greater than the S group, showing that there was more spread in the middle 50% of the L-angle (flex) values of the NS group than in the S group. The mean L-angle (flex) of the S group (20.9 degrees) was larger than that of the NS group (19.8). This suggests that the lumbar lordosis of the S group had a greater degree of curvature than the NS group, which might be a benefit of long-term surfing, however, the statistical significance for this comparison is discussed in Section 4.7.

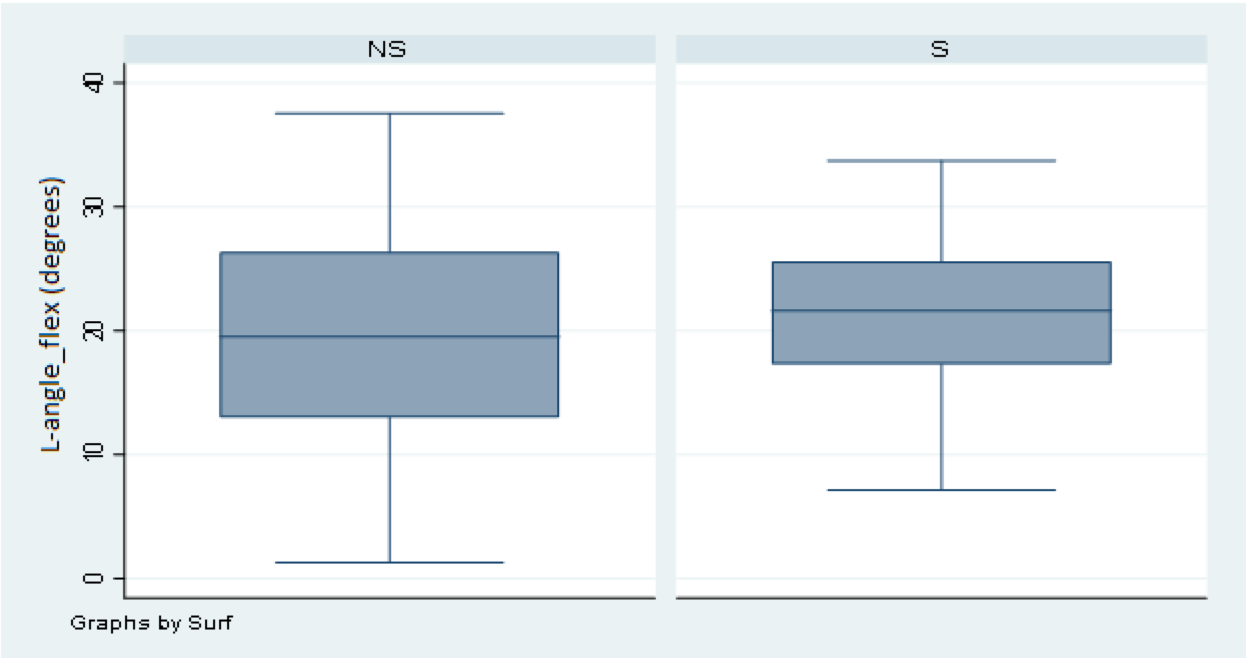

Figure 4-4 **Box plot of L-angle (Flex) for Non-surfer and Surfer groups**

Figure **4-5** below, illustrates the range of L-angle (Cobb) values for the NS and S groups. This is similar to L-angle (flex) because the flex values were used to estimate the Cobb values. The range of L-angle (Cobb) of the NS group (27.8º) was larger than that of the S group (20.5º). The interquartile range for the NS group is also larger than for the S group. This means that there was greater spread among the middle 50% of the NS group than the S group, which can be seen from the wider box. The mean L-angle (Cobb) of the NS group (24.9 degrees) was smaller than that of the S group (25.8), suggesting greater curvature in the lumbar lordosis of the S group. This may indicate an advantage of long-term surfing. However, the statistical significance of this result is discussed Section 4.7.

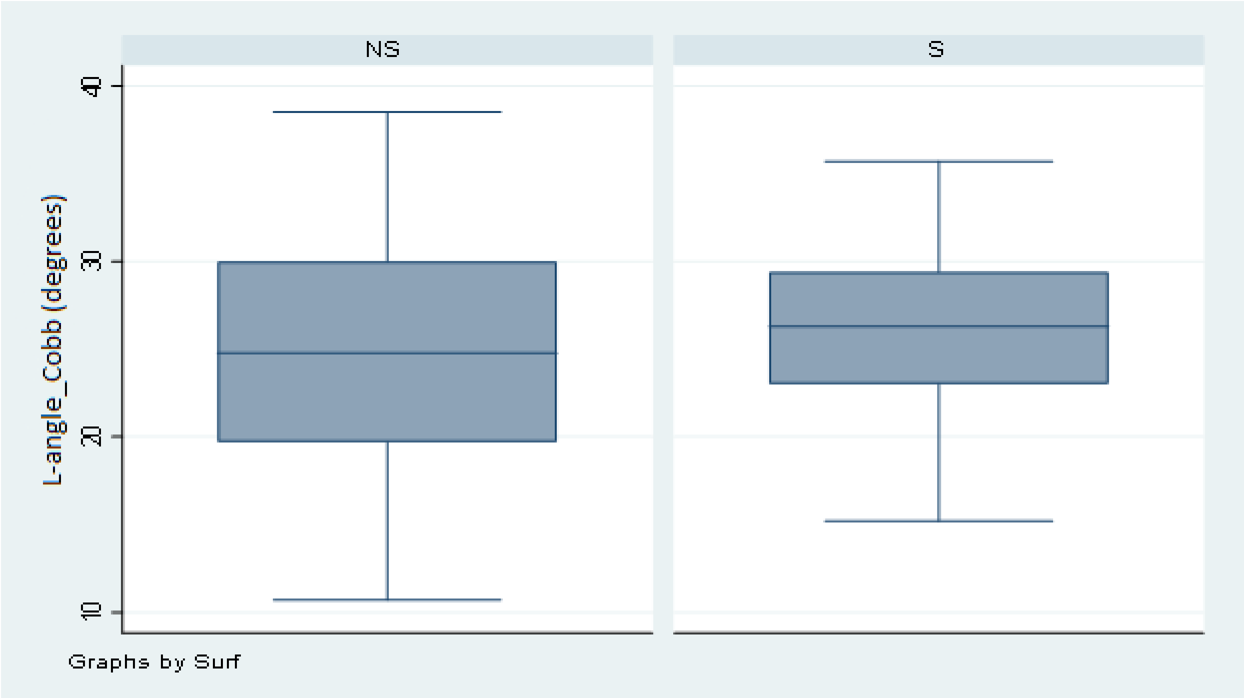

Figure 4-5 **Box plot of L-angle (Cobb) for Non-surfer and Surfer groups**

4.7 Test for equality of means of spinal angles for non-surfer and surfer groups

In this section the mean values of the C, T, and L-angles (flex and Cobb) are compared for the S and NS groups to note whether any differences exist between them.

The Shapiro-Wilk test showed no violation of the normal distribution assumption for the C, T, and L-angles (flex and Cobb), as all the p-values were greater than 0.05. Thus, an independent sample t-test was used to test whether the means of each of the spinal angle variables differed significantly between the NS and S groups.

Table 4-6 below provides the mean, 95% confidence interval (CI), t-value and p-value for each of the spinal angle variables for the NS and S groups.

Table 4-6 Mean, 95% confidence interval, t-value and p-value for spinal angles

Variable	Group	Mean	95% CI	t-value	p-value
C-angle (flex)	NS	40.5	33.2 - 47.8	0.49	0.6234
	S	42.9	36.1 - 49.6		
T-angle (flex)	NS	44.7	40.9 - 48.5	0.56	0.5758
	S	43.1	38.7 - 47.5		
T-angle (Cobb)	NS	45.3	42.0 - 48.6	0.65	0.5518
	S	43.7	39.8 - 47.5		
L-angle (flex)	NS	19.8	15.9 - 23.6	0.50	0.6171
	S	20.9	18.2- 23.7		
L-angle (Cobb)	NS	24.9	21.9 - 27.9	0.51	0.6142
	S	25.8	23.7 - 27.9		

The t-value for the C-angle (flex) is 0.49 with a p-value = 0.6234. This indicates that there is no significant difference between the mean values of C-angle (flex) for the NS and S groups. This suggests that the effect of long-term surfing on cervical lordosis is not significantly different to that of other physical activities in this study.

Similarly, from Table 4-6 it can be seen that all the p-values are greater than 0.05 indicating that there is no evidence of a significant difference in means for the C-angle (flex), T- angle (flex and Cobb) and L-angle (flex and Cobb) for the NS and S groups.

Thus, the results of this section suggest that even though small differences existed between the NS and S groups, the association between long-term surfing and spinal angles was similar to that of other primary activities.

4.8 Comparison of Posture Number of surfers and non-surfers

This research made use of PosturePro to calculate a Posture Number from a lateral photograph. A posture number of 0 indicated no postural deviation, where as higher numbers indicate greater deviation from ideal posture. The frequency distribution of the Posture Numbers of the NS and S groups are displayed in Figure 4-6 below.

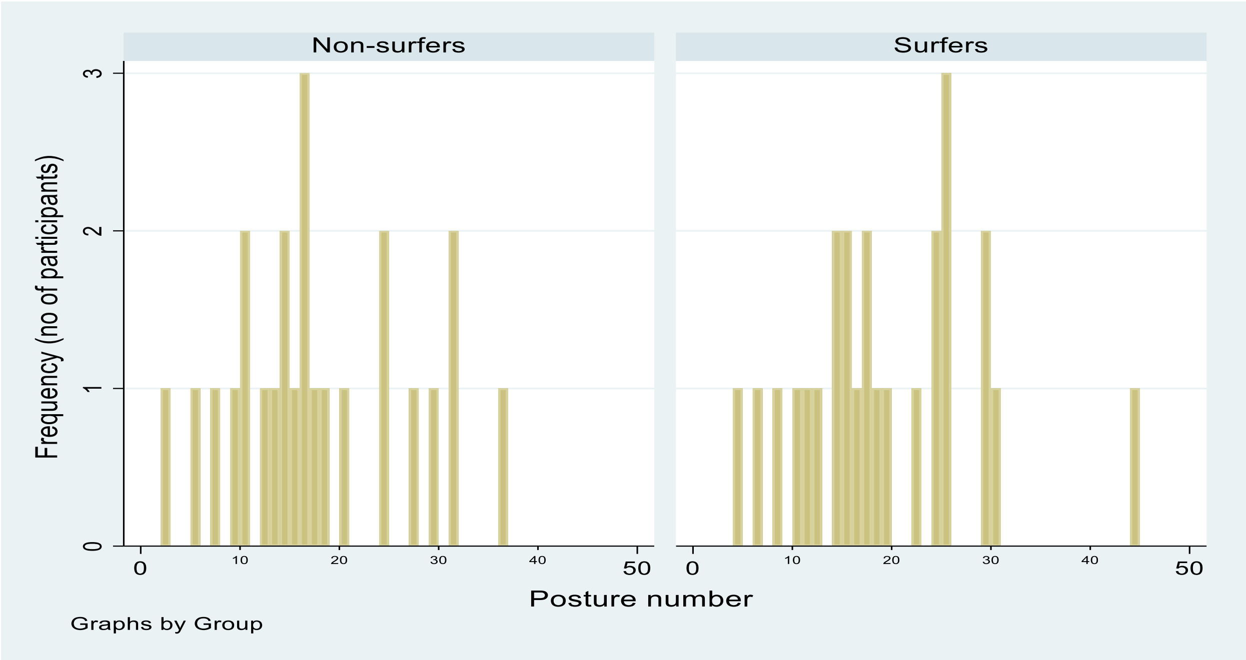

Figure 4-6 Frequency distribution of Posture Number for Non-surfers and Surfers

There was a large range of Posture Numbers within both groups. The smallest Posture Number had a value of 2 in the NS group and the largest value was 45 in the S group. This indicates that both NS and S groups contained individuals with little and large deviation from ideal posture. The WMW test of whether the distribution of Posture Number was the same for the NS and S group gave an exact p-value of 0.5348, indicating that the distribution in Posture Number was similar for the two groups. This result indicates that the sagittal full body posture was not significantly different between the NS and S groups. Thus, the association of surfing with postural development was not significantly different than with other activities in this study.

4.9 Correlation between spinal angles, age, and activity years

In this section the Pearson correlation coefficient was used to investigate whether there was any correlation between the spinal angles, age and activity years. Table 4-7 provides the correlation coefficient and corresponding p-value for age versus each of the spinal angles (C,T, and L-angles (Flex and Cobb)).

As can be seen from Table 4-7 below, the correlation coefficient between age and C-angle (flex) was r =0.1373 with p-value = 0.3469, which is a low correlation. Similarly, for the other spinal angles, the correlations with age were low. There was thus, no significant correlation between age and any of the spinal variables (all p-values >0.05). Therefore, this study differs from other studies that have found significant correlation between age and sagittal spinal alignment parameters. However, even though no clear correlation was identified, the results of this study were similar to others for the same age group. This could be due to those studies including a wider age range.

Table 4-7 Pearson correlation coefficients between age and spinal angles

Age with:	C-angle (flex)	T-angle (flex)	T-angle (Cobb)	L-angle (flex)	L-angle (Cobb)
r-value	0.1373	0.0877	0.0602	0.0831	0.0847
p-value	0.3469	0.5491	0.6810	0.5700	0.5627

In order to see whether there was any correlation between activity years and the C, T and L-spinal angles, the correlation coefficient was calculated for activity years with each of the spinal angles. These results are provided in Table 4-8 below.

Table 4-8 Pearson correlation coefficients between activity years and spinal angles

Activity years with:	C-angle (flex)	T-angle (flex)	T-angle (Cobb)	L-angle (flex)	L-angle (Cobb)
r-value	-0.0202	0.0768	0.0500	0.0842	0.0851
p-value	0.8905	0.6000	0.6851	0.5653	0.5611

As seen in Table 4-8 above, the correlation coefficient between activity years and C-angle (flex) was r= -0.0202 with p-value =0.8905. Similarly, for T, and L-angles (flex and Cobb) the correlation coefficients between activity years and the spinal angle measurements were low, and the p-values were all greater than 0.05 indicating no significant correlations. A separate correlation analysis was run for each of the NS and S groups for both age and activity years with the spinal angles as discussed above. These results also showed very small correlations and all p-values were greater than 0.05, indicating no significant correlation between age or activity years with the spinal angle variables for the NS and S groups. This confirms the earlier suggestion that there is no significant correlation between length of time surfing with the spinal angles when compared to length of time in other activities and spinal angle.

In this study the number of years spent practising an activity did not significantly alter sagittal spinal alignment parameters. This would suggest that in the development of conditions such as age-related hyperkyphosis factors other than long-term physical activity may be of greater importance.

4.10 Correlation between Posture Number, age, and activity years

The Pearson correlation coefficient between Posture Number and age was calculated for the NS and S groups. There was a low-to-medium positive correlation between age and Posture Number with r = 0.4307 and p-value = 0.0316, for the S group which was significant at the 5% level. For the NS group there was a very small negative correlation with r = -0.0363 and p-value = 0.8664, which was not statistically significant. This result suggests that there could be an association between age and sagittal posture, at least in the S group, suggesting that age could be a contributing factor to postural deterioration. This also indicates that despite surfing for many years posture still deteriorated with age. **Error! Reference source not found.** below, shows the lack of correlation of Posture Numbers for both groups in relation to age. There was an unusual observation where a 72-year old surfer had a Posture Number of 45 (circled in red in Figure 4-7).

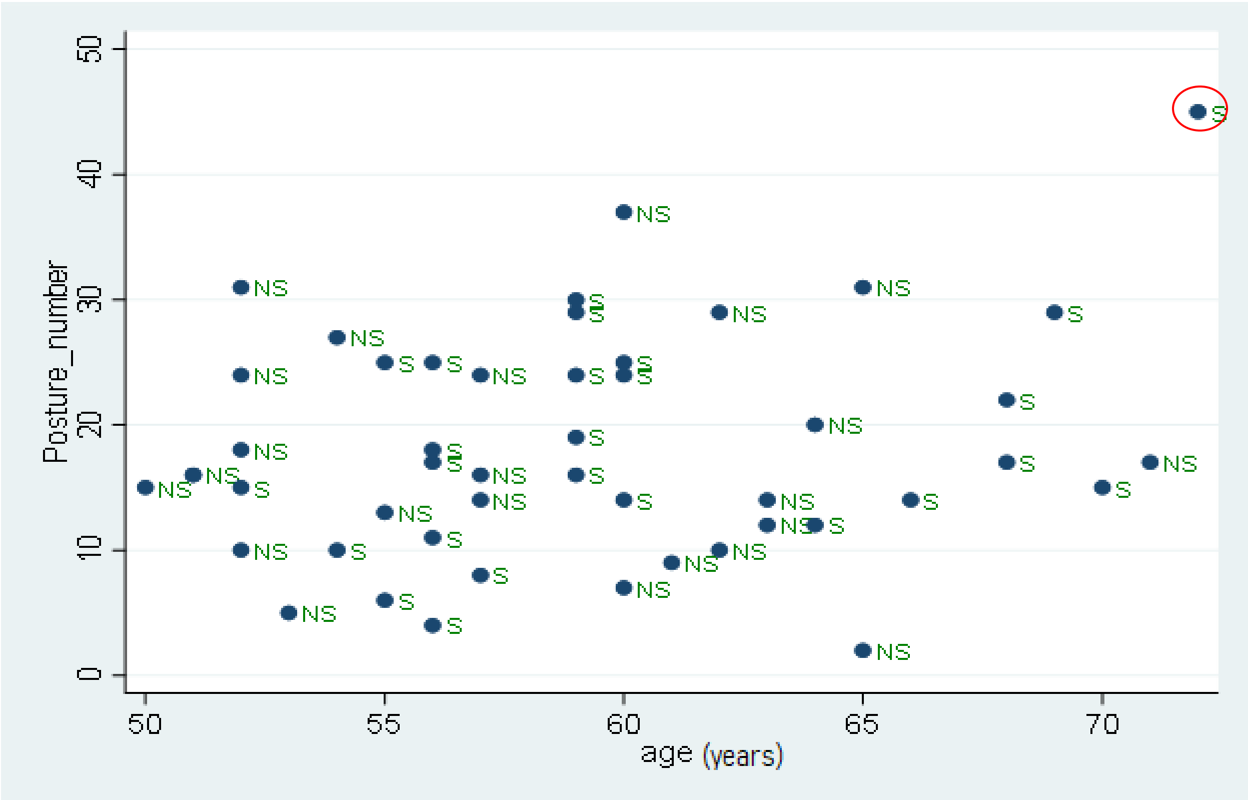

Figure 4-7 Scatter plot of Posture Number versus age for Non-surfers and Surfers

The Pearson correlation coefficient was also used to check for any correlation between Posture Number and activity years. For the NS group r = 0.0931 with p-value=0.665, while for the S group r = 0.1382 with p-value = 0.5099. There was thus no significant correlation between Posture Number and activity years in either of the NS or S groups. This meant that in this study, neither long-term surfing nor other activities affected postural development significantly.

4.11 Regression analysis approach for spinal angles

This section investigates whether there is a possible set of variables that could be significantly associated with the spinal angles and hence be used for prediction of the spinal angles. This can be done by formulating a linear regression model of the form $\hat{y} = b_0 + b_1 x_1 + b_2 x_2 + b_3 x_3 + b_4 x_4$. The symbols $b_0, \dots, b_4$ are the regression coefficients. The independent variables of interest are the Group (NS or S), BMI, Posture Number, and activity years. These variables play the role of the x-variables in the equation above and are entered in a linear regression model with the spinal angle as the dependent variable, (y). The variable, “Group” (NS or S), is a categorical variable with 2 categories and an indicator variable is required in order for the variable to be entered into the regression model. In this analysis Group has indicator variable value equal to 1 for NS and indicator value equal to zero for S.

4.11.1 C-angle (flex)

A linear regression model was fitted with C-angle (flex) as the dependent variable, i.e., the y-variable in the regression equation, and Group, BMI, Posture Number and activity years as independent variables. The results of the linear regression are presented in Table 4-9. In this regression model none of the variables were significant as all p-values were greater than 0.05. This means that none of the variables (Posture Number, Group, BMI or activity years) were significantly associated with C-angle (flex). This result suggests that when dealing with individuals presenting with altered sagittal alignment of the C-spine, the variables Group, BMI, Posture Number and activity years should not be considered over others such as pathology.

For the Group variable, the p-value = 0.369 which confirms the earlier result that there was no significant difference in the C-angle (flex) for the NS and S groups even when adjusting for Posture Number, BMI and activity years in a regression model. Thus, in this study the C-angle (flex) was similar for the NS and S groups, and this similarity was not affected by other variables such as activity years, BMI or Posture Number.

Table 4-9 Regression coefficients, t-value, p-value and 95% CI for parameters in regression model for C-angle (flex)

C-angle (flex)	Reg. Coef.	Std. Err.	t-value	p-value	[95% Conf.	Interval]
Posture-number	.1459	.2835	0.51	0.609	-.42540	.7173
Group	-5.3599	5.9055	-0.91	0.369	-17.2616	6.5417
BMI	.8321	.8098	1.03	0.310	-.7998	2.4641
Activity years	-.0709	.20598	-0.34	0.732	-.4861	.34420
constant	22.6191	24.7176	0.92	0.365	-27.1959	72.4341

4.11.2 T-angle (flex)

After fitting a linear regression model with T-angle (flex) as the dependent variable and the independent variables - Posture Number, Group, BMI and Activity years, it was found that the variables BMI and activity years were not significant and had high p-values, and were thus not included in the model. The model was refitted with only Posture Number and Group in the model.

Table 4-10 Regression coefficients, t-value, p-value and 95% CI for parameters in regression model for T-angle (flex)

T-angle (flex)	Reg. Coef.	Std. Err.	t-value	p-value	95% Conf.	Interval]
Posture-number	.35122	.1539	2.28	0.027	.04152	.66092
Group	2.1528	2.7251	0.79	0.434	-3.3325	7.6382
constant	36.4488	3.4811	10.47	0.000	29.4417	43.4558

The results for this regression model with Posture Number and Group as independent variables, are presented in Table 4-10 above.

Posture Number was significant with p-value=0.027. The Group variable was kept in the model to distinguish between the S group and the NS group, even though it was not significant (p-value=0.434). The regression coefficient associated with Posture Number, is 0.35. This means that a unit increase in Posture Number results in a 0.35º increase in T-angle (flex). For a more practical application, this will also mean that a 5-unit increase in Posture Number will result in a 5×0.35=1.75º increase in the T-spinal angle. This means that greater thoracic curvature would result in poorer posture. This result is consistent with the literature, as it suggests that there is indeed a correlation between the degree of thoracic kyphosis and sagittal posture.

The regression coefficient for Group was 2.15 which meant that for any given Posture Number, the NS group will have an average of 2.15 degrees greater T-angle (flex) than the S group. This suggests that even though the thoracic angle correlated with Posture Number subtle differences in the T-angle (flex) existed between the groups. The regression model can be formulated as follows:

Model: $\hat{y}$ =$36.45 + 0.35\ x_1$ + $2.15\ x_2$, where $\hat{y}$ represents the predicted T-angle (flex), x_1 represents Posture Number and x_2 represents the Group with $x_2 = 1$ for the NS group, and $x_2 = 0$ for the S group. The model representation for each group is then as follows:

For the S group (where $x_2 = 0$): $\hat{y}$ =$36.45 + 0.35\ x_1$ and for the NS group (where $x_2 = 1$): $\hat{y}$ =$36.45 + 0.35\ x_1$ + $2.15 = 38.6 + 0.35\ x_1$.

These two regression equations enable prediction of T-angle (flex) for the NS group and the S group. The regression lines have the same slope of 0.35.

Figure 4-8 below, shows the relationship between the T-angle (flex) and Posture Number for the NS and S groups. The blue line represents the linear prediction equation for the NS group, while the red line represents the linear prediction equation for the S group. Both lines had the same slope with value 0.35 and hence the lines are parallel, but the intercepts are different as can be seen from the regression equations above. Because there was no significant Group effect, the blue and red lines are fairly close to each other and separated by a constant difference of 2.15 degrees. If there had been a significant Group effect then the lines would have been more separated from one another.

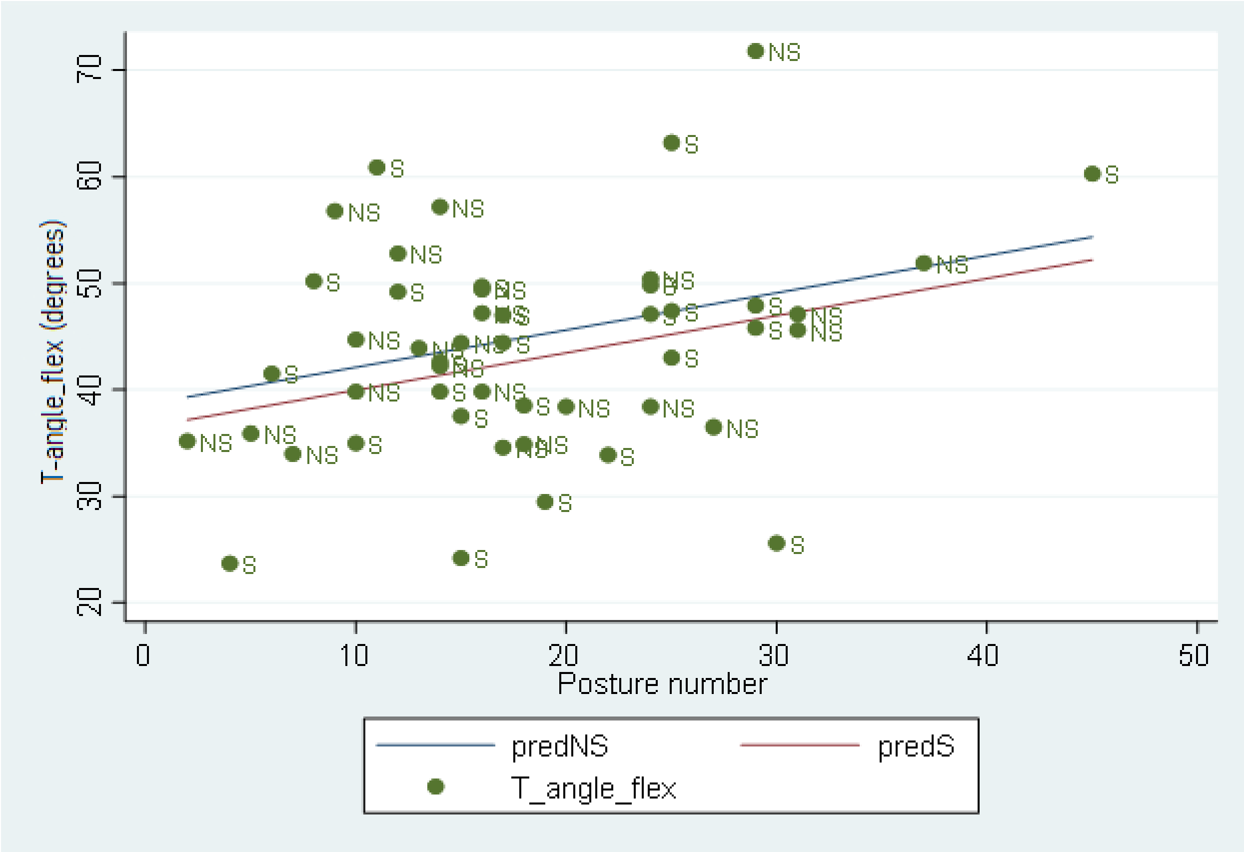

Figure 4-8 Scatter plot of T-angle (flex) versus Posture Number for NS and S groups with separate regression lines for NS and S

4.11.3 T-angle (Cobb)

The numerical values for T-angle (flex) and T-angle (Cobb) were numerically very similar and were highly correlated and thus the regression results are also very similar. The results for a linear regression model for T-angle (Cobb) with independent variables Posture Number, Group, BMI and activity years also showed that Posture Number was significant (p-value=0.026), while BMI and activity years were not significant. The results for the regression model with Group and Posture Number are given in Table 4-11 below.

Table 4-11 Regression coefficients, t-value, p-value and 95% CI for parameters for model for T-angle (Cobb)

T-angle (Cobb)	Reg. Coef.	Std. Err.	t-value	p-value	95% Conf.	Interval]
Posture-number	.30785	.13364	2.30	0.026	.03884	.5769
Group	2.0919	2.3671	0.88	0.381	-2.6727	6.8566
constant	37.8591	3.0237	12.52	0.000	31.7727	43.9456

As seen in Table 4-11 above, the regression coefficient associated with Posture Number is 0.31 which is positive and indicates that a unit increase in Posture Number results in a 0.31 degree increase in T-angle (Cobb). Like for the T-angle (flex) above, the difference between the T-angles (Cobb) of NS and S groups was not significant.

Although not significant in this study, these results may indicate subtle differences in the postural development of surfer and non-surfers.

4.11.4 L-angle (flex)

After fitting a linear regression model for L-angle (flex) with independent variables Posture Number, Group, BMI and activity years it was found that BMI was the variable with the highest association with L-angle (flex). The variables Posture Number and activity years were not significant in this model and had high p-values. Therefore, they were removed from the model. The results for the regression model with BMI and Group in the regression model are presented in Table 4-12 below.

BMI had a p-value=0.079 and although not statistically significant indicated that BMI was the leading variable in predicting L-angle (flex). The Group variable was kept in the model to distinguish between the S group and NS group even though it was not significant (p-value=0.240). The regression coefficient associated with BMI, is 0.65 which is positive and indicates that a unit increase in BMI results in a 0.65º increase in L-angle (flex). This will also mean that a 5-unit increase in BMI will result in a 5×0.65=3.25º increase in the L-angle (flex).

Table 4-12 Regression coefficients, t-value, p-value and 95% CI for parameters for model for L-angle (flex)

L -angle (flex)	Reg. Coef.	Std. Err.	t-value	p-value	95% Conf.	Interval]
Group	-2.8955	2.4337	-1.19	0.240	-7.7943	2.0033
BMI	.6470	.3601	1.80	0.079	-.0778	1.3718
constant	4.7842	9.1103	0.53	0.602	-13.5537	23.1222

The regression coefficient for Group was -2.90, which means that for any given BMI value, the NS group had an average of 2.90º lower L-angle (flex) than the S group. Although not significant, this result suggests that subtle differences may be present in the sagittal alignment of the L-spine between the NS and S groups.

4.11.5 L-angle (Cobb)

As above, the regression model for L-angle (Cobb) showed that BMI was the variable with the highest association with L-angle (Cobb), and that Posture Number and activity years were not significant.

Table 4-13 Parameter estimates, t-value, p-value and 95% CI for parameters for model for L-angle (Cobb)

L-angle (Cobb)	Reg. Coef.	Std. Err.	t-value	p-value	95% Conf.	Interval]
Group	-2.2294	1.8726	-1.19	0.240	-5.9988	1.5400
BMI	.4958	.27706	1.79	0.080	-.06191	1.0534
constant	13.4459	7.0099	1.92	0.061	-.66433	27.5562

The results for the regression model with BMI and Group in the regression model are presented in Table 4-13 above.

The regression coefficient associated with BMI, was 0.496. Thus, a unit increase in BMI results in a 0.496º increase in L-angle (Cobb), and a 5-unit increase in BMI will result in a 5×0.496=2.48º increase in the L-angle (Cobb). The regression coefficient for Group was -2.23, which means that for a given BMI, the NS group had an average of 2.23º lower L-angle (Cobb) than the S group. Thus, it seems that L-angle (flex) may increase with BMI.

The features of this section show that there was no clear set of variables amongst those measured in this study (Posture Number, Group, BMI and activity years), that were strongly associated with C-angle (flex). However, there is evidence that Posture Number could be a predictor of T-angle (flex and Cobb), as increasing Posture Number was associated with increasing T-angle values (flex and Cobb), suggesting that increased thoracic angles contribute to deteriorating posture. For L-angle (flex) and (Cobb) there seems to be an indication that BMI would be the best predictor suggesting that BMI may have some effect on sagittal spinal alignment and posture, but further investigation is needed.

This section highlights the usefulness of linear regression as a tool for prediction and its potential in future research on the topic of C, T, and L-angles in relation to BMI, Posture Number, age, years of activity and additionally possible gender and sport effects.

4.12 Summary

The age of participants in the NS and S groups were similar and minimised the confounding potential of the age effect on sagittal spinal alignment and posture. The primary activities practiced by participants in the NS group varied greatly. Despite more than 3 hours practicing their primary physical activities per week for more than 25 years, a large proportion of the total sample presented with BMI greater than 25kg/m^2. However, the mean BMI of the S group was in the normal range, while the mean BMI of the NS group was classified as overweight. Many years of surfing and the physiological demands of surfboard paddling could offer an explanation to this result. This could mean that surfing is a good activity to practise into later life to maintain cardiovascular fitness.

There was no evidence to suggest a significant difference in the mean values of the C, T, and L-angles (flex and Cobb) between the NS and S groups of this study. This suggests that the effect of long-term surfing (if any) on the selected sagittal spinal alignment parameters and posture was similar to that of other activities in this study.

There was no significant correlation of age or activity years with the C, T, or L-angles (flex and Cobb), in either of the NS or S groups. The lack of association between age and the spinal angles may be due to the age of the target population. Other research that has suggested this association included greater age ranges, and thus greater association could be observed. However, the T-angles (flex and Cobb) were consistent with thoracic curvature values in similar age groups of other studies.

In the S group, there was a positive correlation between age and Posture Number where $r = 0.4307$ and $p = 0.0316$. This suggests an association between postural deterioration and age, as Posture Number increased along with age. Though, this observation was only present in one of the groups (S group), it does agree with the available literature. Thus, despite surfing for many years the progression of posture with age was still notable.

In linear regression models with the C, T, and L angles (flex and Cobb), Posture Number proved to be significant in the regression model for T-angle (flex and Cobb). The result indicated that a one unit increase in Posture Number resulted in a 0.35 degree increase in T-angle (flex) and a 0.31 degree increase in T-angle (Cobb). This result suggests that increasing thoracic kyphosis is associated with the deterioration of sagittal posture, as has been suggested by the available literature.

The linear regression model showed that of all the independent variables, BMI had the highest association with L-angle (flex and Cobb). The regression coefficients showed that a one unit increase in BMI resulted in a 0.65 degree increase in L-angle (flex), and a 0.5 degree increase in L-angle (Cobb). Thus, BMI may have an effect on lumbar lordosis.

There was no significant Group effect in any of the regression models, however small differences were noted between the groups in the regression analyses of T-angle (flex and Cobb) with Posture Number, and L-angle (flex and Cobb) with BMI.

5 DISCUSSION

5.1 Introduction

This chapter discusses the results of the study as presented in chapter four. The discussion relates to the available literature concerning the effect of age and physical activity, specifically surfing, on sagittal spinal alignment and posture. This chapter draws a comparison between the results of this study and the findings of other similar studies in order to better understand postural development with age and how physical activity (specifically surfing) influences the aging process.

5.2 Age and anthropometric variables

In keeping with the aims of this study all participants were male and over the age of 50 years. Males, because a number of studies suggest sex differences in sagittal spinal alignment parameters, and because it is mainly males who practise surfing in South Africa (Hardacker *et al.* 1997; Asai *et al.* 2017; Katzman *et al.* 2017a; Yukawa *et al.* 2018; Yukawa *et al.* 2019; De Cock 2020). Even though the female surfing population is growing, finding enough female surfers in the eThekwini district, over the required age, would have proven problematic (De Cock 2020; Thompson 2020). Participants were divided into two groups according to their primary physical activity. Each participant was classified as either a surfer (S group) or non-surfer (NS group).

The distribution of age between the two groups was relatively similar with the NS group ranging from 50 to 71 years of age, with a mean age of 57.9 years, and the S group ranging from 52 to 72 years with a mean age of 60.2 years. The distribution of age was normal in both the NS and S groups, and no significant difference between the means of age was present between the NS and S groups (p=0.16). This simply confirmed that the NS and S groups were similar in terms of age. According to the available literature, the age group of this study sample is such that the age effects on sagittal spinal alignment and posture should be present. Systematic reviews by Roghani *et al.* (2017) and Pan *et al.* (2018b) stated that thoracic kyphosis is commonly affected by advancing age, and that increased thoracic kyphotic angles become more common by the age of fifty years.

Age also affects lumbar lordosis, though not to the same extent. Skaf *et al.* (2011), Dreischarf *et al.* (2014), and Yukawa *et al.* (2019) noted that lumbar lordosis tends to become less pronounced (flatten) with age, however, this is more prevalent after the age of 60 years. The similar ages of the NS and S groups ensure minimal confounding potential of the age effect on sagittal spinal alignment and posture of participants in this study.

Some studies have indicated that obesity contributes to deteriorating posture and sagittal spinal alignment parameters. As an example, when studying sagittal spinal and pelvic alignment regulated by pelvic incidence, Boulay *et al.* (2006) stated that BMI correlated strongly with lumbar lordosis. Jankowicz-Szymanska *et al.* (2019) suggested that increased BMI or obesity increased the risk of developing a hyper-lordotic curvature in the L-spine. However, that study was specific to children. Nevertheless, this study utilised height and weight of participants to calculate BMI.

Observation revealed no significant difference between the heights of the two groups (p=0.061), however, significant differences between the weight (p=0.00), and thus the BMI measurements (p=0.00), were present. The BMI of the S group ranged from 19.6 to 30.9kg/m^2, with a mean BMI of 24.9kg/m^2, while the BMI of the NS group ranged from 21.8 to 34.4kg/m^2, with a mean BMI of 27.6kg/m^2. These results suggest that long-term surfers in this study, on average, maintained a BMI within the normal range (18.5-25kg/m^2), while the NS group was generally classified as overweight (BMI 25-30kg/m^2). This could be due to the high physiological demand of surfboard paddling as suggested by a number of studies. Most recently dos Santos (2018) studied surf biomechanics and bioenergetics. Their results found that body composition parameters (including BMI) for all the surfers in their study across a range of performance levels and ages were all within the healthy zone according to the World Health Organization. Previous research has repeatedly produced this result. For example, by Meir *et al.* (1991) when studying heart rates and energy expenditure during recreational surfing. And also by Mendez-Villanueva and Bishop (2005) when studying physiological aspects of surfboard riding performance; and by LaLanne *et al.* (2017) when they characterised activity and cardiovascular response in recreational male surfers between 18 and 75; as well as a number of others (Everline 2007; Climstein *et al.* 2015; Furness 2015b).

5.3 Primary activity and occupation

The primary activity of the S group was surfing, while the primary activity of the NS group varied, as can be seen in Table 4-2. The primary activities practised by participants in the NS group included boxing/combat training, squash, swimming, walking/running, water polo, and windsurfing. However, the most frequently practised primary physical activities among the NS group members were cycling (20.84%), followed by gym training (12.5%), triathlon (12.5%), and paddling - surf ski or paddle ski (12.5%). This sample is similar to a study by Frank *et al.* (2009), who noted better control of force and posture in older surfers compared to that of physically active age-matched controls. Although the participants had all participated in surfing for more than forty years, there were, in this case, only 11 surfers and 11 non-surfers. Similarly, Furness *et al.* (2016) observed lower neutral thoracic kyphosis values in a group of thirty elite surfers versus previous age and gender matched controls. In the same way, other studies have compared posture between groups of physically active individuals. For example, Kruusamae *et al.* (2015), who compared the thoracic and lumbar curvatures of dance sport athletes to that of track and field athletes and found lower values of both curves in the dance sport athletes. The results of these previous studies indicate that comparison between the two groups in the current study may yield positive results.

Occupation varied widely within both the NS and S groups. Engineering and sales positions were the most common occupations in both groups, each contributing 16.3% to the total sample. Although past research has shown that occupation may contribute to postural change and conditions such as mechanical neck and low back pain, the occupations presented in this sample were too diverse to provide sound information.

5.3.1 Hours of activity per week

In this study sample, the hours spent practising primary activities were relatively similar between the two groups. However, the mean of the minimum hours per week was greater in the NS group (4.67hrs ± 1.55) than in the S group (3.28hrs ± 1.06). This result indicated that both groups participated in their chosen primary activities for at least 3 hours per week on average.

The smaller mean of the S group could be due to the inconsistent nature of ocean and weather conditions. When conditions are poor, (small waves, heavy wind, etc.) surfers generally stay in the water for shorter periods (Warshaw 2011; dos Santos 2018). However, when conditions permit, surfers will stay in the water for hours on end, and might do so for multiple days in a week (Warshaw 2011). In contrast, other activities are less dependent on environmental conditions.

The maximum number of hours per week was not significantly different between the two groups (NS=7.08 ± 2.34 and S=6.20 ± 1.98). These results suggest that both groups contained individuals of varying fitness levels, but that the level of activity was similar in both groups.

Some studies that looked at posture included much greater training loads than in this study. Kruusamae *et al.* (2015), for example, compared the thoracic and lumbar curvatures of dance sport athletes to track and field athletes. These athletes were involved in active training for an average of 8-12 hours per week. However, the minimum activity time per week in this study is in line with other studies that examined exercise and its relationship with sagittal spinal alignment and posture. For example, a study by Frank *et al.* (2009) that compared long-term surfers to non-surfers. They did not specify time, but indicated that participants had to have been surfing on a weekly basis for at least two years and doing so at least twice per week. While Greendale *et al.* (2009) found that three hours of yoga over 24 weeks was sufficient to reduce the kyphotic angle in hyperkyphotic adults over the age of 60,. Ostrowska, Rozek-Mroz and Giemza (2003) observed males between the ages of 61 and 83 years who participated in two one-hour long training sessions per week. Thus, when compared to these previous studies, the time spent per week by the participants in the present study should be sufficient to have some effect on sagittal spinal alignment and posture.

5.3.2 Years spent practising a primary physical activity (activity years)

In this study the number of activity years varied within each group, as well as between the NS and S groups. The mean number of years spent surfing (45.6 years) was significantly larger than the reported years spent practising the various activities in the NS group (32.0 years). The standard deviation for the NS group (15.32) was larger than that of the S group (8.37), which meant that there was a wider spread in the activity years in the NS group than in the S group.

The results outlined in this section revealed that, on average, the surfers in this study have been surfing for more years than the NS group have been participating in their respective primary activities. However, both groups have been taking part in their respective activities in the long-term. The surfer group specifically is comparable to two other studies that investigated long-term surfers. In both these studies, the surfer groups had been surfing for 40 years or more (Frank *et al.* 2009; Climstein *et al.* 2015). Frank *et al.* (2009) compared the surfers who had been surfing for at least 40 years to age-matched physically active individuals, and found better force and posture control in surfers. Whereas Climstein *et al.* (2015) compared surfers who had been surfing for at least 42 years to age-matched sedentary individuals and found that surfing is beneficial to bone health. Those results demonstrate that long-term surfing has benefits, not only when compared to sedentary individuals, but to physically active ones as well. The comparison drawn in this present study may reveal more benefits of surfing long-term.

All the participants in the S group had been surfing for more than 25 years. This might suggest that surfing is an activity that maintains participants' interest as an activity to keep doing into later life. However, this result may also indicate that surfing is a difficult activity to commence in later life. Thus, it can be encouraged and implemented in exercise programs for those who have surfed throughout adolescence and early to mid-adulthood, but it might be difficult to implement for those who have not. This suggestion is consistent with Climstein *et al.* (2015) who stated that surfing may be "an ideal physical activity for middle-aged aquatic enthusiasts."

5.4 Sagittal spinal alignment and posture

We highlight the fact that the C-angle (Cobb) was not included in the statistical analysis as the BiomechFlex software could not reliably estimate the C-angle (Cobb) for individuals with BMI>25 (classified as overweight). This is due to subcutaneous tissue accumulation over the C-spine, which might affect the measurement of the C-angle (flex) (de Oliveira *et al.* 2012; Raupp *et al.* 2017). Of the total sample (NS and

S groups) 59% presented in the overweight range (BMI 25-30), which significantly reduced the statistical power of the C-angle (Cobb), which was thus not included for analysis.

The resulting C, T, and L-spine angles (flex and Cobb) of both the NS and S groups all showed normal distribution patterns as all p-values were greater than 0.05. The independent samples t-test revealed no significant difference between the mean values of C-angle (flex p=0.6234), T-angle (flex p=0.5758 and Cobb p= 0.5518), or L-angle (flex p=0.6171 and Cobb p=0.6142) between the NS and S groups, as seen in Table 4-4. This similarity of mean values of the C, T, and L-spine angles (flex and Cobb) between the NS and S groups suggests that surfing does not influence sagittal spinal alignment more than other forms of physical activity that formed part of this study.

Posture was also included in this study as one of the parameters, where a low Posture Number represents better standing sagittal posture. The frequency distribution of the Posture Numbers of the NS and S groups were analysed using the WMW test, and proved to be similar (p=0.5348), with a large range of Posture Numbers within both NS and S groups (min=2, max=45). The similarity of the range and frequency distribution of the Posture Numbers between the NS and S groups (p=0.5348) shows that the deviation from ideal posture of the S groups was similar to that of the NS group. These results suggest that long-term surfing did not have a greater effect on sagittal spinal alignment and posture when compared to other forms of physical activity.

These results conflict with those from earlier studies. A study conducted by Furness *et al.* (2016) investigated thoracic mobility in the sagittal plane in an elite male surfing cohort. They observed that their cohort had lower neutral thoracic kyphosis values compared to previously published age and gender matched controls, and suggested that this was possibly due to the activity requirements of surfing i.e. paddling in a prone position. The preliminary investigation by Frank *et al.* (2009) suggested better control of force and posture in older surfers versus age matched physically active controls. Their study related more to functional parameters of posture control such as postural sway and proprioception, but showed benefit of long-term surfing in these parameters over general physical activity programmes. However, despite these suggestions and the cardiovascular benefits mentioned above, in this study long-term surfing was no more beneficial to sagittal spinal alignment and posture than other forms of physical activity. This conflict of results may be due to the differing age group from Furness *et al.* (2016), as they used elite level surfers in their study.

5.4.1 Sagittal spinal alignment and posture: correlation with age

In this study, age showed no significant correlation with the C-angle (flex r=0.1373), T-angles (flex r=0.0877 and Cobb r=0.0602) or L-angles (flex r=0.0831 and Cobb r=0.0847). This was true when measured for the total sample and for the NS and S groups separately. The lack of correlation between age and sagittal spinal alignment in this study could be due to the advanced age of the study sample. Previous research has noted that advancing age correlates with deterioration of sagittal spinal alignment and posture, especially when moving past the fourth-fifth decade of life, and that this is especially true for the thoracic kyphosis (Katzman *et al.* 2010; Asai *et al.* 2017; Roghani *et al.* 2017; Pan *et al.* 2018b). Thoracic kyphosis values over 40º are classified as hyperkyphotic, and this is a common problem encountered in individuals over the age of 50. This is termed age-related hyperkyphosis (Katzman *et al.* 2010; Asai *et al.* 2017; Roghani *et al.* 2017; Pan *et al.* 2018b). Previous research on this topic had larger sample sizes, and included a wider range of ages (Asai *et al.* 2017; Roghani *et al.* 2017). These high-quality studies revealed that thoracic kyphosis angles are often larger than 40º in adult males over 50.

Even though there is no accepted threshold to differentiate hyperkyphosis from normal kyphosis, 40º is often used to describe the upper 95 percentile of young adults. However older adults often pass this threshold (Roghani *et al.* 2017; Pan *et al.* 2018b). Although there was no correlation between increasing age and change in spinal angles in this study, the results are still in line with previous research. The T-angles measured in both NS (flex = 44º and Cobb = 45.3º) and S (flex = 43.1º and Cobb = 43.7º) groups were consistent with similar age groups in other studies (Katzman *et al.* 2010; Asai *et al.* 2017; Roghani *et al.* 2017). However, this research noted no significant association between age and L-angle (flex and Cobb). This is in contrast to previous literature, which has suggested that the lumbar lordosis angle decreases or flattens with increasing age (Skaf *et al.* 2011; Asai *et al.* 2017; Yukawa *et al.* 2018). Again, this may be due to the age group of the study sample, as a larger age group may have revealed greater association. Especially since this change becomes more prevalent only after the age of 60.

The results noted a positive correlation between age and Posture Number within the S group (r = 0.4307 and p-value = 0.0316). This result agrees with the literature, which suggests that posture generally deteriorates with advancing age. Results from Hasegawa *et al.* (2016) showed that whole body standing alignment gradually deteriorates with age, even in healthy subjects. However, the body compensates to preserve a horizontal gaze. Asai *et al.* (2017) found in their study that all the parameters of sagittal spinal alignment and posture that they measured were significantly associated with age, therefore, increasing age is a risk factor for spinal misalignment.

5.4.2 Sagittal spinal alignment and posture: correlation with activity years

In this study, activity years showed no significant correlation with any of the C-angles (flex r=-0.0202), T-angles (flex r=0.0768 and Cobb r=0.0500, or L-angles (flex r=0.0842 and Cobb r=0.0851). This suggests that the primary physical activities practised by the participants in this study did not significantly alter the progression of sagittal spinal alignment. This is in line previous research by Ostrowska, Rozek-Mroz and Giemza (2003) who's results showed that, compared to students, despite being physically active elderly males developed postural changes characteristic of the aging process. These changes included increased lumbar-sacral segment inclination and increased upper thoracic segment inclination. However, other studies have suggested that focused exercise programmes or activities that place an inherent focus on spinal extensor strengthening, posture, and spinal alignment, such as yoga have beneficial effects on the development of conditions such as age-related hyperkyphosis (Greendale *et al.* 2009; Kado 2009; Bansal, Katzman and Giangregorio 2014; Katzman *et al.* 2017c).

There was no significant correlation between activity years and Posture Number within either group. For the NS group r = 0.0931 with p-value=0.665, while for the S group r = 0.1382 with p-value = 0.5099. This result suggests that the association between long-term physical activity (including surfing) and improved posture was negligible in this study sample. Although other studies have shown benefit of certain activities for sagittal spinal alignment and posture in individuals over 50. Examples include Greendale *et al.* (2009) which showed that yoga decreases age-related hyperkyphosis in men and women. Ball *et al.* (2009) demonstrated that spinal extension exercises prevent the natural progress of hyperkyphosis in women over 50. This would lead us to suggest that while surfing can be considered beneficial to cardiovascular health, bone health, proprioception and muscle force control, it may not be effective as a form of spinal extension exercise.

Due to the prolonged periods of spinal extension required, this research hypothesised that surfboard paddling might serve as a form of spinal extension exercise. However, the results in this section indicate that surfing is no more an effective form of spinal extension exercise than the other activities included in the study. Furthermore, despite long-term physical activity, age should remain an important factor when examining sagittal spinal alignment and posture. It may also be beneficial to include larger age ranges for comparison in future research.

5.4.3 Sagittal spinal alignment: association with BMI, Posture Number, and activity years

This study made use of linear regression models to investigate whether any variables included, other than age (Group (NS or S), BMI, Posture Number or activity years) were significantly associated with C, T, and L-spine angles (flex and Cobb). A significant association was present between the T-angle (flex and Cobb) and Posture Number in both the NS and S groups. This study also found BMI, though not statistically significant, to be the variable with the highest association with L-angle (flex and Cobb).

The association between T-angle (flex) and posture number was significant, (p=0.027) indicating that there was an association between posture and T-angle (flex and Cobb). The regression coefficient in this calculation was 0.35, which meant that a one-unit increase in Posture Number would result in a 0.35º increase in T-angle (flex). The regression coefficient was 2.15 for the group variable (NS or S), meaning the NS group had on average 2.15º greater T-angle (flex) than the S group for the same Posture Number. The association between T-angle (Cobb) and posture number was also significant (p=0.026). The regression coefficient in this calculation was 0.31, which meant that a one-unit increase in Posture Number would result in 0.31º increase in T-angle (Cobb). There was also a regression coefficient of 2.09 for the group variable, meaning the NS group had on average 2.09º higher T-angle (Cobb) than the S group for the same Posture Number.

The results of the regression analysis suggest two things.

1) A higher degree of thoracic kyphosis is indeed associated with poorer posture, as suggested in the literature. Katzman *et al.* (2010) and Roghani *et al.* (2017) both stated in their systematic reviews that hyperkyphosis can be associated with musculoskeletal alterations such as forward head posture, scapula protraction, reduced lumbar lordosis and decreased standing height. Which indicates that thoracic kyphosis is an important aspect of full body sagittal posture. Thus, healthcare practitioners should keep this association in mind when treating patients with postural abnormalities.
2) Subtle differences in postural adaptations or biomechanics that affect the T-angle existed between the NS and S groups. Future research can therefore focus on examining these subtle differences by determining how long-term surfing alters specific biomechanical and postural parameters, other than C, T, and L-angles.

BMI was the variable in this study that had the highest association with L-angle (flex and Cobb). Though this result was not statistically significant (p-value flex = 0.079; p-value Cobb = 0.08), it is near enough to warrant further investigation. Especially since previous research has suggested that sedentary life style and obesity might contribute negatively to sagittal spinal alignment and posture (Boulay *et al.* 2006). For example, Boulay *et al.* (2006) studied sagittal spinal and pelvic alignment regulated by pelvic incidence, and stated that BMI correlated strongly with lumbar lordosis. Jankowicz-Szymanska *et al.* (2019) suggested that the risk of developing a hyper-lordotic curvature in the L-spine was greater in individuals with higher BMI values, however, that study was specific to children. The results of a study by Araújo *et al.* (2014) showed that BMI classified as overweight contributed to the development of either hyper- or hypolordotic lumbar curvature, while BMI classified as obese was a risk factor for hypolordotic posture. The regression coefficient for L-angle associated with BMI was 0.65 for L-angle (flex), and 0.5 for L-angle (Cobb). Thus, a one-unit increase in BMI would result in a 0.65º increase in L-angle (flex), and a 0.5º increase in L-angle (Cobb).

The regression coefficient of the variable "Group", associated with L-angle was -2.90 (flex) and -2.23 (Cobb). This meant that for any given BMI the NS group had on average 2.90º lower L-angles (flex), and 2.23º lower L-angles (Cobb) than the S group. This further suggests that there are different postural adaptations that exist between the NS and S groups. Future research with bigger sample sizes can thus look at examining these subtle differences in postural adaptations and biomechanics.

5.5 Summary

In this study all participants were male and over the age of 50 years. The distribution of age among the two groups was relatively similar, the distribution of age was normal in both the NS and S groups, and no significant difference between the means of age was present between the NS and S groups (p=0.16). This simply confirms that the NS and S groups were similar in terms of age. According to the available literature, the age group of this study sample is such that the age effects on sagittal spinal alignment and posture should be present, including increased thoracic kyphotic angle, and possibly decreased lumbar lordotic angle.

The results of this study indicate that long-term surfers, on average, maintain a BMI within the normal range (18.5-25kg/m^2), while the NS group was generally classified as overweight (BMI 25-30kg/m^2). Numerous studies have produced this result and suggested that this could be due to the high physiological demand of surfboard paddling.

The primary physical activities practiced by participants in this study were diverse, however, all activities were being practised for at least three hours per week on average. The S group had a slightly lower mean minimum time spent surfing per week than the NS group spent on their primary activities. This could be due to the inconsistent nature of ocean and weather conditions. With poorer conditions, surfers will spend less time in the water. However, the S group presented significantly more years of practice of their primary activity (surfing – 45.6 years) than the NS group (32 years). All the participants in the S group had been surfing for more than 25 years, which may suggest that it can be encouraged and implemented in exercise programmes for older people who have surfed throughout adolescence and early to mid-adulthood. However, it might be difficult to implement for those who have not had this previous experience.

In this study, long-term surfing was no more beneficial to sagittal spinal alignment and posture than other forms of physical activity as both groups presented with similar C, T, and L-angles (flex and Cobb), as well as Posture Numbers.

In this study, age showed no significant correlation with C, T, or L-angles, due to the advanced age of the study sample. However, the results are still in line with previous research as the T-angles measured in both NS (flex = 44º and Cobb = 45.3º) and S (flex = 43.1º and Cobb = 43.7º) groups were consistent with similar age groups in other studies A larger age range of the study sample may have revealed greater association. Thus, future research on age and sagittal spinal alignment should include a larger age range in the study samples. However, the results of this study revealed a positive correlation between age and Posture Number in the S groups, which indicates that sagittal full body posture does deteriorate with advancing age, despite years of physical activity.

No association was present between activity years and sagittal spinal alignment and posture parameters in this study sample. This result suggests that the association between long-term physical activity (including surfing) and improved posture was negligible in men over 50 in this sample. Thus, despite long-term physical activity, age should remain an important factor when examining sagittal spinal alignment and posture.

Regression analysis revealed that a significant association was present between the T-angle (flex and Cobb) and Posture Number in both the NS and S groups. The regression analysis also found BMI, though not statistically significant, to be the variable with the highest association with L-angle (flex and Cobb). These results indicate that a higher degree of thoracic kyphosis is indeed associated with poorer posture, and that thoracic kyphosis is an important aspect of full body sagittal posture. Thus, healthcare practitioners should keep this association in mind when treating patients with postural abnormalities.

The results of the regression analysis also indicated that subtle differences in postural adaptations that affect the T and L-angles existed between the NS and S groups. Future research with bigger sample sizes can thus look at examining these subtle differences in postural adaptations and biomechanics by determining the sagittal spinal alignment and postural parameters that long-term surfing may affect.

6 CONCLUSION

Sagittal spinal alignment and posture deteriorate with age. However, physical activity, especially spinal extensor strengthening activities, may affect this process positively. Surfers paddle their boards in a prone position of spinal extension, which may be a form of spinal extension exercise and could thus be beneficial to postural development with age. This chapter draws conclusions concerning the sagittal spinal alignment and posture of long-term surfers (S group) and physically active non-surfers (NS group) over the age of 50.

6.1 Key findings

- The mean BMI of the S group was 24.9kg/m² (normal), which was significantly lower than the 27.6kg/m² mean of the NS group (overweight).
- Both groups practised their primary activities for more than three hours per week, on average (S group - 3.28hrs and NS groups - 4.67hrs), and up to a maximum average of 6.20 (S group) - 7.08 hours (NS group) of practise per week.
- On average, the S group (45.6 years) had been practising surfing for significantly more years than the NS group (32 years) had been practising their respective primary activities.
- There were no significant differences between the S and NS groups in terms of C-angle (flex p=0.6234), T-angle (flex p=0.5758 and Cobb p= 0.5518), L-angle (flex p=0.6171 and Cobb p=0.6142), or Posture Number (p=0.5348).
- There were no significant correlations between age and C-angle (flex r=0.1373), T-angles (flex r=0.0877 and Cobb r=0.0602) or L-angles (flex r=0.0831 and Cobb r=0.0847). However, the mean T-angles (flex and Cobb) obtained from both NS and S groups were greater than 40º, which is classified as hyperkyphotic.
- There was a positive correlation between age and Posture Number in the S group (r = 0.4307 and p-value = 0.0316), but not the NS group.
- There were no significant correlations between activity years and C-angle (flex r=-0.0202), T-angles (flex r=0.0768 and Cobb r=0.0500), L-angles (flex

r=0.0842 and Cobb r=0.0851), or Posture Number (S group r=0.1382 and NS group r=0.0931).

- There was a significant association between Posture Number and T-angle (flex p=0.027 and Cobb p=0.026). A one-unit increase in Posture Number would result in a 0.35º increase in T-angle (flex) in both groups. The NS group had a 2.15º (flex) and 2.09º (Cobb) greater T-angles for any given posture Number.
- Though not significant, BMI was the variable with the highest association with L-angle (flex p=0.079 and Cobb p=0.08). A one-unit increase in BMI would result in a 0.65º increase in L-angle (flex), and a 0.5º increase in L-angle (Cobb). The NS group had an average of 2.9º (flex), and 2.23º (Cobb) lower L-angles than the S group for any given BMI.

6.2 Strengths

- To our knowledge, this is the first study to investigate sagittal spinal alignment and posture in long-term surfers.
- This study adds information to the available literature regarding the effect of age and physical activity – specifically surfing, on sagittal spinal alignment and posture in aging individuals.
- This study made use of separate measures to measure sagittal spinal alignment and posture, and thus provides useful information regarding the association between sagittal spinal alignment and full body sagittal posture.
- Useful information was presented regarding the correlation of other factors such as regularity of practice (hours per week), years of physical activity, and BMI with Sagittal spinal alignment and posture.
- This study has revealed that more research is needed surrounding the postural and biomechanical differences between surfers and non-surfers, especially in those over the age of fifty years.

6.3 Limitations

- The study sample was limited to individuals within the eThekwini district; thus, the results may not apply to surfers everywhere.

- The data collection period was interrupted by the Covid-19 pandemic and the resulting lockdown. The study sample also consisted of higher risk individuals, which significantly prolonged the data collection process.
- Participants may have made errors in the reporting of practise time per week, activity years, injuries, etc. As the researcher cannot determine whether incorrect information has been provided by the participants, all information was included in the results and could affect the accuracy of the results overall.
- This study could not produce Cobb angles for the C-angles, as BMI greater than 25 makes the estimation unreliable. Inclusion would thus compromise statistical power.
- This study only included male participants, thus generalisation to the female population may not be reliable.
- The study only included individuals over 50, which diminishes the correlation between age and sagittal spinal alignment and posture.

6.4 Recommendations

- Larger sample sizes may achieve results that can be generalised to the greater surfing population.
- Future studies could widen the age range to include younger individuals in order to clarify the age effect on sagittal spinal alignment and posture.
- Similar studies should be conducted for female surfers.
- Future studies could include secondary activities and occupation of participants in their data analysis.
- More sagittal spinal alignment parameters should be included, e.g., sagittal vertical angle and lumbar-pelvic incidence to include the pelvis in the investigation.

6.5 Conclusion

Deterioration of sagittal spinal alignment and posture with age is a common phenomenon, especially after the age of fifty. However, certain physical activities or exercise programmes may modify these changes. The results of this study show that long-term surfing is beneficial to the aging individual in terms of body composition. However, it is no more effective at modifying the effect of age on sagittal spinal alignment and posture than other forms of physical activity included in this study. Nevertheless, slight differences between the NS and S groups were present, which may indicate that the biomechanical or even postural effects/adaptations of long-term surfing differ from those of other activities. These subtle differences indicate the need for further research in the area. Exercise programmes for the aging individual may include surfing/surfboard paddling for cardiovascular fitness, but programmes with specific focus on postural correction is still recommended to combat age-related sagittal spinal alignment and postural change.

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Appendix A – Full Institutional Research Ethics Committee approval letter

DUT
DURBAN UNIVERSITY OF TECHNOLOGY

Institutional Research Ethics Committee
Research and Postgraduate Support Directorate
2nd Floor, Berwyn Court
Gate 1, Steve Biko Campus
Durban University of Technology

P O Box 1334, Durban, South Africa, 4001

Tel: 031 373 2375
Email: lavishad@dut.ac.za
http://www.dut.ac.za/research/institutional_research_ethics

www.dut.ac.za

22 October 2019

Mr A Mudge
P.O. Box 11396
Klein Windhoek
Windhoek
Namibia

Dear Mr Mudge

Sagittal spinal alignment in long-term surfers of EThekwini
Ethical Clearance number: IREC 090/19

The Institutional Research Ethics Committee acknowledges receipt of your gatekeeper permission letters.

Please note that FULL APPROVAL is granted to your research proposal. You may proceed with data collection.

Any adverse events [serious or minor] which occur in connection with this study and/or which may alter its ethical consideration must be reported to the IREC according to the IREC Standard Operating Procedures (SOP's).

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

Yours Sincerely

Professor J K Adam
Chairperson: IREC

Appendix B – Amendment to existing proposal approval letter

DUT DURBAN UNIVERSITY OF TECHNOLOGY
INSTITUTIONAL RESEARCH ETHICS COMMITTEE

Institutional Research Ethics Committee
Research and Postgraduate Support Directorate
2nd Floor, Berwyn Court
Gate 1, Steve Biko Campus
Durban University of Technology

P O Box 1334, Durban, South Africa, 4001

Tel: 031 373 2375
Email: lavishad@dut.ac.za
http://www.dut.ac.za/research/institutional_research_ethics

www.dut.ac.za

15 June 2020

Mr A Mudge
P.O. Box 11396
Klein Windhoek
Windhoek
Namibia

Dear Mr Mudge

Application for Amendment of Approved Research Proposal

Sagittal spinal alignment in long-term surfers of EThekwini

I am pleased to inform you that your application to change your research site has been approved.

Yours Sincerely

Professor J K Adam
Chairperson: IREC

Appendix C – Poster and flyer

Attention: Senior Surfers (50yrs+)

Have you been surfing for 20 years or more? We want to check the curves in your back, and compare them to non-surfers.

(A research study at the Durban University of Technology)

Participation will include:

- **medical history**
- **postural examination**
- **photographic documentation & analysis – front and side view**
- **spinal curvature measurement with a flexible ruler**

Participation will be anonymous.

The whole thing shouldn't take more than an hour.

If you are interested in participation or have any questions regarding the project please contact Alex

076 496 5394

alexmudge53@hotmail.com

Appendix D – Letter of information and consent

LETTER OF INFORMATION

Title of the Research Study: Sagittal Spinal Alignment in Long-Term Surfers

Principal Investigator/s/researcher: Alexander Mudge (BTech: Chiropractic, BA Sport Science)

Co-Investigator/s/supervisor/s: Prof. J.D. Pillay (PhD: Physiology)

Brief Introduction and Purpose of the Study:

I (Alexander Mudge – Intern Chiropractor) am conducting research on the posture of older surfers (50+ years) who have been surfing for more than 20 years, in order to determine whether postural changes which have occurred with age are consistent between surfers and non-surfers. Postural change is a normal part of aging, which may be affected by physical activity. However, it is still unclear whether surfing is positively or negatively associated with age related postural change. Two groups of participants will be included, i.e. surfers and non-surfers. This form serves to provide information on - and invite you to participate in this research.

Outline of the Procedures: Due to the global Covid-19 pandemic and the fact that the target population for this study is considered high-risk for infection, as well as the limited travel regulations set out by the Covid-19 pandemic national governmental response (DoH:SA 2020;

World Health Organization 2020) participants will not need to report to the DUT Chiropractic day clinic to complete the information and consent form before participation can begin. Participants may choose to have the researcher meet them at a location more convenient to them for completion of the information and consent form, to minimize the risk of Covid-19 transmission. Once informed consent has been obtained, the participant will complete a brief information/medical history sheet, after which a postural examination will be conducted by the researcher. These are completed in order to determine eligibility to the study. Once considered eligible the participants' spinal curvatures (cervical, thoracic and lumbar) will be measured with a FlexiCurve ruler, and photographic documentation will take place in a front and side views (face will be blurred to maintain anonymity). The full procedure should take no more than 1 hour. No treatment will be provided in this session.

To be part of this study you must:

Be male and over the age of 50.

Have been surfing, or physically active (purposeful surfing/exercise) for at least 3 hours per week for at least 3 years.

Give informed consent in writing to participate in the research.

You will not be eligible to take part in this study if any of the following are present:

Known structural spinal anomalies (e.g. structural scoliosis or block vertebrae, congenital or acquired)

Obvious deformities as determined by postural examination

Spinal surgery or injury (e.g. intervertebral disk replacement/spinal fusion)

Chronic respiratory conditions (e.g. chronic bronchitis/emphysema)

Risks or Discomforts to the Participant: No risk has been identified within this study

Benefits: You will receive a postural examination, a report of which will be sent to you via email.

Reason/s why the Participant May Be Withdrawn from the Study: Your participation in this research is entirely voluntary. It is your choice whether to participate or not. Whether you choose to participate or not, all the services you receive at this clinic will continue and nothing will change. If you choose not to participate in this research project, you will be offered the treatment that is routinely offered in this clinic, at regular rates. You may change your mind later and stop participating even if you agreed earlier.

You may also be withdrawn from the study if you become non-compliant, ill, or injured in the research process.

Remuneration: There is no monetary remuneration for participating in the study.

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

Confidentiality: All personal details and relevant information gathered through the research process will only be accessible by me and my supervisor. Once all the relevant data has been gathered and analyzed, it will be disposed of in a professional manner, not being made available to the general public. Your name will not appear in my dissertation or any research article. Your name is not included on the information sheet or data which is captured, only on this form.

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). If any research related injuries or adverse effects occur during the period of this study, these will be reported to the Institutional Research Ethics Committee.

Persons to Contact in the Event of Any Problems or Queries:

Please contact the researcher (Alexander Mudge – 076 496 5394 – alexmudge53@hotmail.com), my supervisor (Prof. J.D. Pillay – 031 373 2398 - pillayjd@dut.ac.za) or the Institutional Research Ethics Administrator on 031 373 2375. Complaints can be reported to the DVC: Research, Innovation and Engagement Prof S Moyo on 031 373 2577 or moyos@dut.ac.za.

CONSENT

Statement of Agreement to Participate in the Research Study:

- I hereby confirm that I have been informed by the researcher, Alexander Mudge, about the nature, conduct, benefits and risks of this study - Research Ethics Clearance Number: ____,
- I have also received, read and understood the above written information (Participant Letter of Information) regarding the study.
- I am aware that the results of the study, including personal details regarding my sex, age, date of birth, initials and diagnosis will be anonymously processed into a study report.
- In view of the requirements of research, I agree that the data collected during this study can be processed in a computerised system by the researcher.
- I may, at any stage, without prejudice, withdraw my consent and participation in the study.
- I have had sufficient opportunity to ask questions and (of my own free will) declare myself prepared to participate in the study.

- I understand that significant new findings developed during the course of this research which may relate to my participation will be made available to me.

____________________ __________ ______ _______________

Full Name of Participant Date Time Signature / Right

Thumbprint

I, ___ (name of researcher) herewith confirm that the above participant has been fully informed about the nature, conduct and risks of the above study.

Full Name of Researcher Date Signature

Full Name of Witness (If applicable) Date Signature

Full Name of Legal Guardian (If applicable) Date Signature

Appendix D – Letter of information and consent (isiZulu)

INCWADI YOLWAZI

Isihloko Sesifundo Sokucwaninga:

Ukuqondanisa komgogodla kwe-sagittal kubantu abasefayo (surfers) isikhathi eside.

Umphenyi oyinhloko/ abacwaningi:

Umnuzana uAlexander Mudge (onesiqu kwi-Btech: Chiropractic ne-BA kwi- Sport Science).

Unphenyi/abahloli/abaphathi: UProf. J. D Pillay (PhD: Physiology)

Isingeniso esifushane nenhloso yocwaningo:

Mina (Alexander Mudge-Intern yesechiropractor) ngenza ucwaningo ngokuma komgogodla kwabantu abakhulile abasefayo (surfers) (abaneminyaka esukela kwamashumi emihlanu nangaphezulu (50+)) ababelokhu besebenzisa amagagasi (surfing) iminyaka engaphezulu kweminyaka emithathu, ukuze kutholakale ukuthi ngabe izinguquko zomgogodla ezenzekile ngobudala ziyafana yini phakathi kulaba abasebenza ngamagagasi (surfers) nalaba abangasebenzi ngamagagasi (non-surfers).Ukuguquka kwasemuva kuyingxenye evamile yokuguga, engathinteka ngokusebenza komzimba. Kodwa-ke akucaci ukuthi ukusebenzisa amagagasi (surfing) kuhlotshaniswa kahle/kabi noma kuhambelana noguquko oluhlobene nobudala. Kuzohlanganisa amaqembu amabili okuzoba abasebenzisa amagagasi (surfers) nabangasebenzisi amagagasi (non-surfers).Leli fomu lisebenza ukunika imininingwane futhi liku mema ukuthi ubambe iqhaza kulolu cwaningo.

Uhlaka lwezinqubo zocwaningo: Ababambe iqhaza kuzodingeka babike emtholampilo wosuku lwe-DUT Chiropractic ukuze bagcwalise ifomu lolwazi Kanye nemvume ngaphambi kokubamba iqhaza. Uma imvume isitholiwe, umhlanganyeli uzogcwalisa imininingwane emfushane/iphepha lomlando wezokwelapha, emva kwalokho ukuhlolwa kwasemuva kuzokwenziwa ngumcwaningi. Lokhu kugcwaliswa ukuze kutholakale ukufaneleka esifundweni. Uma sekubhekwa njengabafanele abangabambiqhaza, umgogodla wababambi qhaza (kungaba umgogodla we-cervical, thoracic noma owe-lumbar) uzokalwa kusetshenziswa okokudwebela (ruler) ekuthiwa iflexicurve ruler, futhi imibhalo enezithombe izokwenzeka ekubukeni kwangaphambi nangasohlangothini (ubuso buzofiphazwa ukuze kugcinwe ukungaziwa). Inqubo ephelele akufanele ithathe amahora angaphezu kwamabili noma amathathu. Akukho ukwelashwa okuzonikezwa kulesi sikhathi.

Ukuze ube yingxenye yalolu cwaningo kumele:

Yiba ngowesilisa nangaphezulu kweminyaka engamashumi amahlanu (50+)

Ubelokhu usebenzisa amagagasi (surfing) noma usebenza ngokomzimba (ukusebenza ngamagagasi ngenhloso/uzivocavoca) okungenani lamahora amathathu (3) ngeviki okungenani leminyaka emithathu.

Unikeze imvume enolwazi ngokubhala ukuze uhlanganyele ocwaningweni.

Ngeke ukwazi ukubamba iqhaza kulolu cwaningo uma ngabe kukhona okulandelayo:

Ukungami kahle kwesakhiwo somgogodla okwaziwayo (isibonelo: ukugwegwa komgogodla eceleni/iscoliosis noma i-block vertebrae, icongenital noma okutholiwe).

Ukukhubazeka okubonakalayo njengoba kunqunywa ukuhlolwa kwasemuva.

Ukuhlinzwa komgogodla noma ukulimala (isibonelo. Ukubuyiselwa kwedisk ye intervertebral/ ukuhlanganiswa komgogodla).

Izimo zokuphefumula ezingalapheki (isibonelo. Isifo sofuba/ i-emphysema).

Ubungozi kubambi qhaza: Akukho bungozi obukhonjwe kulolu cwaningo.

Izinzuzo: Uzothola ukuhlolwa kokuma komgogodla wakho, umbiko wawo ozothunyelwa kuwe nge-imeyili. Uzokwazi ukuthola amavawusha e-Chiropractic Day Clinic uma kwenzeka uzwa ubuhlungu kwintamo, ubuhlungu emuva, ubuhlungu behlombe, ubuhlungu bedolo noma yibuphi ubuhlungu wamalunga omzimba-kumele isetshenziswe kungakapheli iminyaka emithathu yokubonisana kwakho kokuqala e-Chiropractic Day Clinic.

Isizathu/Izizathu zokuthi kungani umhlanganyeli angahoxiswa esifundweni:

Ukubamba iqhaza kwakho kulolu cwaningo kungokuzithandela ngokuphelele. Kungukhetho lwakho ukuthi ubambe iqhaza noma cha. Noma ngabe uyakhetha ukubamba iqhaza noma cha, zonke izinsizakalo ozozithola kulo mtholampilo zizoqhubeka futhi akukho okuzoshintsha.Uma ukhetha ukungabandakanyi kule projethi yocwaningo, uzonikezwa ukwelashwa okuhlinzekwa njalo kulo mtholampilo, ngamanani ajwayelekile. Ungashintsha umqondo wakho kamuva futhi uyeke ukubamba iqhaza noma ngabe wavuma ngaphambili. Ungahoxiswa futhi ocwaningweni uma ungahambisani, ugula, noma ulimala kwinqubo yocwaningo.

Umkomelo/Umholo: Akukho mholo wemali yokubamba iqhaza ocwaningweni. Kodwa-ke. Uzokwamukela ivawusha lomtholampilo we-Chiropractic Day Clinic uma kwenzeka uzwa ubuhlungu kwintamo, ubuhlungu emuva, ubuhlungu behlombe, ubuhlungu bedolo noma yibuphi ubuhlungu wamalunga omzimba-kumele isetshenziswe kungakapheli iminyaka emithathu yokubonisana kwakho kokuqala e-

Chiropractic Day Clinic. Isaphulelo kumele silethwe kubasebenzi abamukelayo lapho uza e-Chiropractic Day Clinic ukuthola ukwelashwa kwakho mahhala.

Inani elikhokhwa umbambiqhaza wocwaningo:

Ngeke udinge ukukhokhela ukubonwa emtholampilo noma ukokwenza i-x-ray uma ubambe iqhaza kulolucwaningo. Ngeshwa, ngenxa yezinkinga zezezimali, asikwazi ukukhokhela izindleko zakho zokuhamba ukuya eChiropractic Day Clinic mase uzela iaphoyimenti yakho.

Imfihlo: Yonke imininingwane yomuntu kanye nemininingwane efanele eqoqwe ngenqubo yocwaningo izotholakala kuphela kimi nabaphathi bami. Lapho yonke imininingwane efanele isiqoqiwe futhi ihlaziyiwe, izosetshenziswa ngendlela efanelekile, ngeke ikhishwe emphakathini jikelele. Igama lakho alizovela kwi-dissertation yami noma kunoma iyiphi i-athikili yocwaningo. Izilinganiso nezithombe zingasetshenziselwa izinjongo zokufundisa kepha imininingwane yakho ngeke ibe khona.

Ukulimala okuhlobene nocwaningo: Ngeke unxephezelwe uma kwenzeka ube nokulimala okuhlobene nocwaningo noma ukusabela okubi (alikho ithuba lokuthi kungenzeka ukuthi ulimala noma ube nokubi lapho usabambe iqhaza kulolu cwaningo). Uma kunokulimala okuhlobene nocwaningo noma imiphumele emibi ivela phakathi kwesikhathi socwaningo, lokhu kuzobikwa ekomitini lezimilo zokuziphatha lezikhungo (Institutional Research Ethics Committee).

<u>Abantu ongaxhumana nabo uma unenkinga noma unemibuzo:</u>

Sicela uthinte umnini womcwaningi (uMnuzana Alexander Mudge ku-0764965394-alexmudge53@hotmail.com), umphathi wami (u-Prof .J.D. Pillay ku-0313732398-

pillayjd@dut.ac.za) noma umlawuli wezimiso zokuhle kwezocwaningo weSikhungo kule nombolo 031 373 2375. Izinkonondo zingadluliselwa futhi kumphathi/umqondisi: Wezocwaningo nesisekelo semfundo ephakeme, Solwazi S. Moyo kule nombolo 031 373 2577 noma moyos@dut.ac.za.

Okujwayelekile:

Ababambe iqhaza kumele baqinisekiswe ukuthi ukubamba iqhaza kungokuzithandela futhi isibalo sababambiqhaza okufanele bafakwe kufanele sivezwe. Ikhophi yencwadi yolwazi kufanele inikezwe ababambiqhaza. Incwadi yolwazi Kanye nefomu lokuvuma kumele lihunyushwe futhi linikezwe ngolimi olukhulunywa phambili lwabantu abacwaningayo .isibonelo. IsiZulu.

ISIVUMELWANO

Isivumelwano sokuhlanganyela kucwaningo:

Ngiyaqinisekisa ukuthi nginikiwe ulwazi umcwaningi, uAlexander Mudge, ngemvelaphi, ukuziphatha, inzuzo, nobunzima bocwaningo - Inombolo yemigoma yocwaningo: ___________.

Ngiyitholile incwadi yolwazi, ngayifunda ngazengaqondisisa ngokuzimbandakanyeka kulolucwaningo.

Kusobala kimi ukuthi imiphumela yalolu cwaningo ihlangene nezimfihlo zami maqondana nobulili, iminyaka, usuku lokuzalwa. Amagama ami kumbe nokuxilongwa kwami kuzoba imfihlo kulolucwaningo.

Umangibheka izidingo zocwaningo ngiyavuma ukuthi yonke iminininingwane eqoqeke ngesikhathi kucwaningwa, kungenzeka igcinwe kwisikhahlamezi somcwaningi.

Kungenzeka noma kunini ngaphandle kwesivumelwano ngihoxe ekuzibandakanyeni kocwaningo.

Sengibenesikhathi esanele ukubuza (nginga phoqiwe) ukuzilungiselela ngizabandakanye nocwaningo.

Ngiyaqonda ukuthi lonke ulwazi olwanele olutholakale ngokuzimba ndakanya kwami kulolucwaningo ngiyokwaziswa ngalo.

____________ ___________ ________ ______________

Igama lobambiqhaza Usuku Isikhathi Sayina/isiqxivizo sesithupha sokudla

Mina mcwaningi ___uAlex Mudge___(igama lomcwaningo) ngiyaqininisekisa ukuthi lombandakanyi ongenhla uchazelwe ngokuphelele ngemvelaphi, nangezimiso zocwaningo.

______________________ ________________ ________________

Igama eliphelele lomcwaningi Usuku Sayina

______________________ ________________ ________________

Igama eliphelele lofakazi Usuku Sayina

______________________ ________________ ________________

Appendix E – Case history

DUT DURBAN UNIVERSITY OF TECHNOLOGY — DEPARTMENT OF CHIROPRACTIC

CHIROPRACTIC DAY CLINIC
CASE HISTORY

Patient: ____________________ Date: ________

File #: ________ Age: ________

Gender: ________ Occupation: ____________________

Student: ____________________ Signature ____________________

FOR CLINICIANS USE ONLY:
Initial visit
Clinician: Signature:

Case History:

Examination:
Previous: Current:

X-Ray Studies:
Previous: Current:

Clinical Path. lab:
Previous: Current:

CASE STATUS:

PTT: Signature: Date:

CONDITIONAL:
Reason for Conditional:

Signature: Date:

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

Case Summary signed off: Date:

Student's Case History:

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1. **Source of History:**

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

3. **Present Illness:**

	Complaint I (principle complaint)	**Complaint 2 (additional or secondary complaint)**
Location		
Onset : Initial:		
Recent:		
Cause:		
Duration		
Frequency		
Pain (Character)		
Progression		
Aggravating Factors		
Relieving Factors		
Associated S & S		
Previous Occurrences		
Past Treatment		
Outcome:		

4. **Other Complaints:**

5. **Past Medical History:**

General Health Status

Childhood Illnesses

Adult Illnesses

Psychiatric Illnesses

Accidents/Injuries

Surgery

Hospitalizations

6. Current health status and life-style:

Allergies

Immunizations

Screening Tests incl. x-rays

Environmental Hazards (Home, School, Work)

Exercise and Leisure

Sleep Patterns

Diet

Current Medication
Analgesics/week:
Other (please list):

Tobacco
Alcohol
Social Drugs

7. Immediate Family Medical History:

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

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

8. Psychosocial history:

Home Situation and daily life
Important experiences
Religious Beliefs

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

General

Skin

Head

Eyes

Ears

Nose/Sinuses

Mouth/Throat

Neck

Breasts

Respiratory

Cardiac

Gastro-intestinal

Urinary

Genital

Vascular

Musculoskeletal

Neurologic

Haematological

Endocrine

Psychiatric