

**DEVELOPMENT AND EVALUATION OF A LOW COST, 3D  
IMAGING MOBILE SURFACE TOPOGRAPHY SYSTEM  
(MSTS) FOR MEASURING POSTURE AND BACK SHAPE IN  
CLINICAL SETTINGS**

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**Declaration**

I hereby declare that no material contained in this thesis has been submitted for any other academic award. Furthermore, that the research presented in this thesis is entirely the authors own work.



(Gok Kandasamy)

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## Abstract

**Introduction:** Spinal disorders encompass numerous clinical conditions of the spine that include spinal deformities, thoracic hyperkyphosis, increased or decreased lumbar lordosis and scoliosis amongst others. To enable the assessment and treatment of patients with spinal disorders, there is a need for appropriate valid and reliable, evidence-based objective tools. A further requirement for an objective measurement tool to be used within clinical practice is the need for it to be accepted by clinical practitioners.

**Aims:** The primary aim of this thesis was to evaluate the reliability and validity of the mobile surface topography system (MSTS) together with the assessment of the clinical acceptance of the tool by healthcare practitioners. The secondary aim was to conduct a randomised controlled trial (RCT) to evaluate the use of the MSTS to provide personalised educational biofeedback for the self-management of both acute and chronic low-back pain patients.

**Methods:** The current thesis consisted of four studies. (1) the evaluation of the intra- ( $n = 16$ ) and inter-rater reliability ( $n = 5$ ) of the MSTS for measuring posture and back shape variables (2) the appraisal of the validity ( $n = 25$ ) of the MSTS with reference to the gold standard 'Vicon' system (3) the exploration of the clinical acceptance ( $n = 23$ ) of the MSTS by clinical practitioners and (4) the evaluation of the effect of a personalised educational booklet for the management of patients with acute ( $n = 21$ ) and chronic ( $n = 19$ ) low-back pain (LBP) through a randomised control trial (RCT).

**Results:** The results of the current study suggest that the MSTS is reliable and valid to measure most of the three-dimensional posture and back shape variables in standing. This is the first study to quantify the MSTS in the measurement of standing posture. The results of the current study also detailed the magnitude of the postural and technical sources of error. Further, the clinical acceptance study confirmed the variables that contributed to the acceptance of the mobile-based MSTS; as well its application within clinical practice. Furthermore, the service users (patients with both acute and chronic LBP) of the personalised interactive educational booklet demonstrated greater improvement in the last majority of outcome measures (physical, behavioural and at work) as compared to the control group at the 4-week follow-up measurement.

**Conclusion:** The originality of this first comprehensive multifaceted study lies firstly in the development of a novel MSTS that is portable, low-cost and easy to use within current clinical practice. Secondly, in the confirmation of the reliability and validity of the tool. Thirdly, in the affirmation of the clinical acceptance of the tool by clinical practitioners and finally in the endorsement of the value of the output of the tool by patients for the self-management of their spinal disorders.

## **Dissemination of work**

### **In-proceeding and conference presentations**

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## List of Abbreviations

ADL	Activities of Daily Living
ANCOVA	Analysis of Covariance
ANOVA	Analysis of Variance
ASD	Adult Spinal Deformity
ASIS	Anterior Superior Iliac Spine
BI	Behavioural Intention
BSS	British Scoliosis Society
CBT	Cognitive Behavioural Therapy
CI	Confidence Interval
CL	Cervical Lordosis
CLBP	Chronic Low Back Pain
CT	Computed Tomography
DLT	Direct Linear Transformation Technique
DOI	Diffusion of Innovation
ECT	Expectation Confirmation Theory
EMG	Electromyography
FA	Fear Avoidance
FABQ	Fear Avoidance Belief Questionnaire
FABQ-pa	Fear Avoidance Belief Questionnaire Physical Activity
FABQ-W	Fear Avoidance Belief Questionnaire Work
FKA	Frontal Knee Angle
GDP	Gross Domestic Product
IBM	International Business Machines
ICC	Interclass Correlation Coefficient
IMU	Inertial Measurement Unit
IR	Infra Red
ISIS	Integrated Shape Imaging System

LBP	Low Back Pain
LL	Lower Limit
LL	Lumbar Lordosis
LOA	Limits of Agreement
LOG	Line of Gravity
LPT	Lateral Pelvic Tilt
MSK	Musculoskeletal
MSTS	Mobile Surface Topography System
NEBOT	Non-verbal Emotional Behaviour Observation Template
NHMRC	National Health and Medical Research Council
NICE	National Institute for Healthcare Excellence
NPRS	Numeric Pain Rating Scale
ODQ	Oswestry Disability Questionnaire
PA	Posterior Anterior
PALM	Palpation Meter
PC	Personal Computer
PDF	Portable Document Format
PE	Perceived Experience
PEOU	Perceived Ease of Use
PS	Perceived Satisfaction
PSIS	Posterior Superior Iliac Spine
PU	Perceived Usefulness
RCT	Randomised Control Trial
RGB	Red Green Blue
ROI	Region of Interest
ROM	Range of Motion
RT	Resistance to Technology
SAQ	Spinal Appearance Questionnaire

SD	Standard Deviation
SE	Shoulder Elevation
SEM	Standard Error Mean
SP	Scapular Prominence
SP	Scapular Prominence
SPANOVA	Split-plot Analysis of Variance
SPSS	Statistical Package for the Social Sciences
SRS	Scoliosis Research Society
STE	Standard Typical Error
TAM	Technology Acceptance Model
TK	Thoracic kyphosis
UL	Upper Limit
US	User Satisfaction
VAS	Visual Analogue Scale



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# **Chapter 1. Introduction**



## **1.1 Chapter Aim**

The aim of this chapter is to present the background and rationale to the programme of research undertaken by the author and presented within this thesis. The chapter starts with a brief description of the basic anatomy of the spine, spinal deformities and spinal pain. Studying the geometrical changes of human back shape and posture is of great importance for both the clinical as well as the scientific research field. Within this chapter, a rationale is also made for the need of the development of a novel simple-to-use mobile surface topography system (MSTS) for measuring whole body posture and back shape. Following this, a rationale is presented for the importance of the clinical acceptance of the MSTS for measuring back shape and posture within clinical practice. Subsequently, a rationale is also made on the applicability of using a MSTS to generate personalised educational material for patients with spinal pain. The rationale for the programme of research is outlined and research questions are posed; the aims of the current empirical research are then presented. The chapter concludes with the structure of the thesis.

## **1.2 Spinal Disorders**

Spinal disorders encompass numerous clinical conditions of the spine including spinal deformities, thoracic hyperkyphosis, increased or decreased lumbar lordosis and scoliosis amongst others. While some patients are clinically asymptomatic, others complain of severe pain with or without a functional disability. Adult spinal deformity (ASD) is one of the common clinical spinal disorders where the incidence of disease

increases with age. A study by Schwab et al. (2005) indicated that the prevalence rate in the elderly population was as high as 68% in individuals over 60 years of age. Furthermore, Watkins-Castillo and Andersson (2014) reported that the prevalence rate (which is the total number of patients present in a particular population at a given time) for the total number of health-care visits due to spinal disorders in the USA was 61% for females and 39% for males between the years 2008 and 2011. Conversely Alshami (2015) in a retrospective study reported the incidence rate (measure of the probability of occurrence of the clinical condition) to be 28.1%, (1669 out of 5929) of patients (all age groups) with spinal disorders over a three-year period (between 2011 and 2013). As reported by Alshami, the most common disorders affected the lumbar spine with an incidence of 53.1% followed by the cervical spine at 27.1%.

Spinal disorders pose a significant financial burden on both patients as well as the health-care system. Indrakanti et al. (2012), estimated that the direct (surgical and non-surgical management) and indirect (productivity, workday losses) costs for treating spinal disorders to be more than US \$100 billion per year. Carregaro et al. (2018) in Brazil reported the direct costs of managing spinal disorders to be as high as US\$ 71.4 million in 2016. Furthermore, Parker et al. (2017) estimates that the US health-care related spending for the management of spinal disorders is projected to grow 1.3 percentage faster than the gross domestic product (GDP) and as a result the projected health-care contribution to the overall GDP will rise by 20% by 2025.

Murray et al. (2012) further reported that within spinal disorders, musculoskeletal disease together with arthritis and back pain, are the second most common cause of

disability, with the largest overall health impact on the world population. Alshami (2015) stated that 75.3% of patients with back-pain reported pain in the lumbar region, whereas 35.8 % of patients reported pain in the cervical region between 2011 and 2013.

In 2009, the English National Institute for Health and Care Excellence (NICE) published the annual prevalence rate for low back pain (LBP) this ranged from 15% to 65%. In addition, they also reported that 70% to 84% of people experienced LBP at least once in their lifetime. As stated in NICE (2011), in the United Kingdom, around one-third of the adult population suffer from LBP every year. However, according to Wall and Wall (2006), 80%–90% of patients with LBP recover within four to six weeks; with the remaining 10% to 20% of people developing chronic low back pain (CLBP) and disability. Furthermore, Sinnott et al. (2017) reported that in the UK population, the prevalence rate of neck and back pain is growing 1.8 to 2.3 times faster than the incidence rate, suggesting the average duration of spinal pain care is increasing.

Along with the increase in the prevalence rate, the costs of spinal disorder management have also increased. Maniadakis and Gray (2000) in their review of UK cost-of-illness study reported that in 1998 the costs of managing LBP were estimated to be as high as £1632 million. Additionally, 35% of this cost were related to services provided by the private sector. The increase in the UK retail price over the past decade suggests that the current health-care costs are likely to be much higher than the costs in 1998 (Office for National statistics, 2011).

Spinal disorders can lead to a number of symptoms, including changes in spinal alignment, pain, decreased mobility, decreased strength, decreased quality of life, and increased morbidity (Murray et al., 2012). In order to assess and treat patients with spinal disorders, there is a need for appropriate valid and reliable objective tools to measure and monitor changes in posture and back shape.

Numerous authors (Rheault et al., 1989; Greenfield et al., 1995; Williams and McClay 2000; Iunes et al., 2009; Thigpen et al., 2010; Fortin et al., 2011; Souza et al., 2011; Furlanetto et al., 2012 and 2016) proposed a number of instruments and techniques to record both posture and back shape. This includes the use of simple tools like the flexi-rule and the scoliometer, together with various goniometers and inclinometers currently used within clinical practice as well as more complex tools like photogrammetry (Furlanetto et al., 2012) and Moiré topography (Zubovic et al., 2008). Due to the low cost and ease of availability, two-dimensional (2D) images (photography) are also currently being used within clinical examination.

Most of the equipment described above is either research laboratory-based, complex, unreliable, very expensive and very heavy to carry around or can only measure the back (Fortin et al., 2010). This suggests, that there is a need for a low cost, portable, reliable, simple to use, mobile back and body shape measurement system. This would allow for an extended assessment of the full back and body shape measurement in all planes within a clinical environment.

Furthermore, for any clinical tool to be useful within clinical practice, the instrument needs to be not only reliable and valid, but also needs to be accepted by clinical practitioners. Otherwise if clinicians do not accept the tool they will not use it. The current thesis appraises a novel tool 3D imaging Mobile Surface Topography System (MSTS) for the measurement of three-dimensional posture, back and body shape in patients with spinal disorders. This includes the evaluation of reliability and validity of the MSTS together with the assessment of the clinical acceptance of the tool by health-care practitioners. This thesis concludes with a randomised controlled study (RCT) using the MSTS to provide personalised educational biofeedback using the tool for the self-management of both acute and chronic low-back pain patients.

This chapter describes the anatomy of the spine both in normal subjects as well as patients with spinal disorders. This is followed by an introduction to a selection of range of tools currently available for the assessment of posture and back shape including their reliability and validity.

### **1.3 Spinal Anatomy**

Redmond et al. (2015) and Standring (2015) suggest that the understanding of spinal anatomy together with having an excellent knowledge of normal postures, curvatures and functions is crucial for the assessment of back and body shape and posture in patients with low back pain and spinal disorders. The human spine or vertebral column comprises of thirty-three individual bones called vertebrae. The vertebrae are stacked together, running from the base of the skull to the pelvis. In adult spines the

intervertebral discs separate the upper twenty-four vertebrae from each other, while the lower nine vertebrae are fused into a single sacral and coccyx segment (Cramer & Darby, 2014). Solomonow et al. (1999), Netter (2014) and Cramer and Darby (2014) detail that the main function of the spine together with the trunk ligaments and muscles is to support the weight of the head, upper extremity and limbs and to maintain an upright body posture.

Further, the seminal text 'Gray's anatomy' (Standring, 2015) describes the vertebral column as being divided into five distinct regions: cervical, thoracic, lumbar, sacrum and coccyx (see Figure 1.1). The cervical spine is normally described as a 'C' spine and has seven cervical vertebrae (C1 to C7). This section of the spine connects the head to the trunk, as C1 articulates with the occipital bone and C7 to the thorax. The thoracic vertebrae described as the 'T' spine, has twelve vertebrae (T1 to T12). In comparison to the lumbar and cervical spine, the thoracic spine is considered to be a quasi-rigid segment due to the articulation of the rib cage. The lumbar section of the spine comprising of five vertebrae has the critical responsibility of supporting the whole weight of the upper trunk (Netter, 2014; Cramer & Darby, 2014 and Standring, 2015). At the lower end of the spine, five bones that are fused together form the sacrum and caudally three to five bones are fused together to form the coccyx or tail bone (see Figure 1.1).

Cramer and Darby (2014) and Standring (2015) further documented that the size and shape of the vertebrae varies between regions, with the smallest vertebrae being found at the top of the cervical spine and the largest vertebrae at the bottom of the spine.

Together with the sacrum they provide the base for the large majority of the spinal ligaments and muscles. As explained by Standing (2015) and Rizzo (2015), the whole body is considered to be made up of three major planes and axes (frontal, sagittal and transverse) as described below in Figure 1.2.

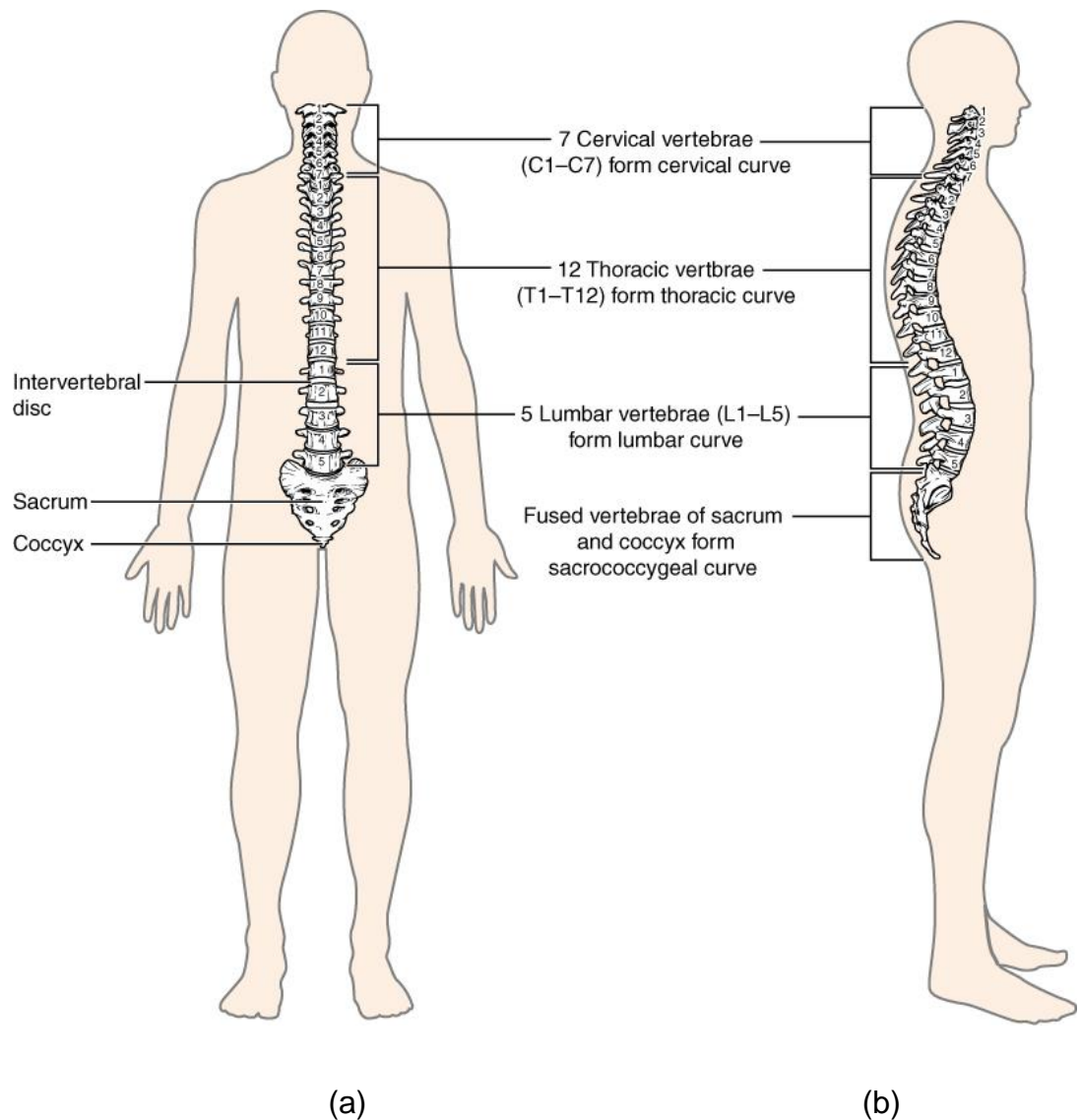


Figure 1.1 The front (a) and side (b) view of a normal human spinal column (source: Accessed at <http://oerpub.github.io/epubjs-demo-book/content/m46352.xhtml>).

### 1.3.1 Description of Anatomical Planes

Three principal anatomical planes transect the human body to describe the location of structures or the direction of movements as shown in Figure 1.2.

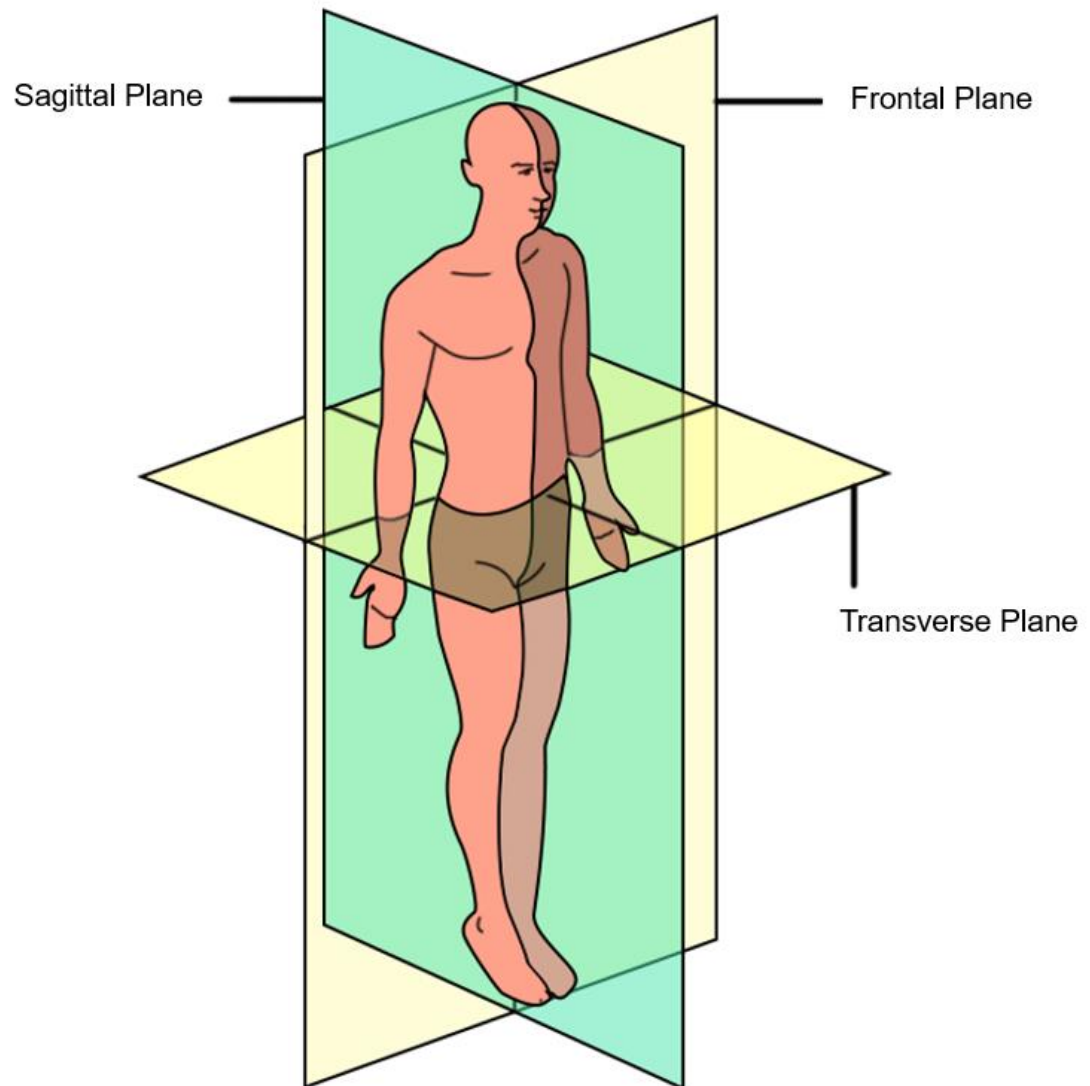


Figure 1.2 The definition of anatomical planes (source: Accessed at <https://bodytomy.com/sagittal-coronal-transverse-3anatomical-planes-of-human-motion>).



Furthermore, Cartwright and Pitney (2011), Behnke (2012) and Patel and Pinto (2014) describe the sagittal plane as dividing the body into left and right halves whilst the frontal (coronal) plane transects the body into front (anterior) and back (posterior) sections. The transverse plane also known as the horizontal plane divides the whole body into top (superior) and bottom (inferior) sections as seen above in figure 1.2.

### *1.3.2 Normal Curvatures of Spine*

Tveit et al. (1994), Wojtys et al. (2000), Kendall et al. (2005) and Magee (2014) describe the normal structure of the spine as consisting of different curves as seen in Figure 1.3. Whilst the spinal curvature has conventionally been considered to appear as a straight line when viewed from the coronal plane, Bettany-Saltikov et al's. (2017) study on 100 normal young adults reported a mean thoracic curvature value as being  $\pm 2.38$  degrees and a mean lumbar curve of  $\pm 1.65$  degrees in the frontal plane. Similarly, Milanesi et al. (2011) reported the right shoulder to be lower than the left in normal young adult right-handed people. The variation in the shoulder level indirectly indicates the change in alignment of the spine in the coronal plane.

Further the seminal textbook on posture by Kendall et al. (2005) describes the sagittal aspect of the spinal column as having four curves. The 'S' shaped curve is considered to have two posterior facing convexity curves (thoracic and sacral segments) called kyphosis or primary curvatures; and two anterior facing (convexity) curves in the cervical and lumbar segments called lordosis or secondary curvatures as seen below in Figure 1.3. Bettany-Saltikov et al. (2017) recorded a mean thoracic kyphosis of 29.37

$\pm 3.94$  degrees and a mean lumbar lordosis angle of  $-37.7$  degrees in young asymptomatic adults. These values are similar to the values provided by the Scoliosis Research Society (2017) who suggest that the normal range of thoracic kyphosis is between 20 and 40 degrees on X-ray measurement (Greendale et al., 2011; Bettany-Saltikov et al., 2017). Similarly, Betz (2003) described the normal range for lumbar lordosis on X-ray as between  $-20$  and  $-60$  degrees. Likewise, Stagnara et al. (1982) and Propst-Proctor and Bleck (1983) reported that the mean values of thoracic kyphosis in adults ranged between 30 to 50 degrees whilst the mean values for lumbar lordosis was calculated to be  $-55$  degrees. The variation in the reported angles may be attributed to different measurement approaches and different spinal curvature measurement instruments. For example, spinal curvature measurements based on radiographic methods are different from those based on surface topographic method. For example, the X-rays measure the curvature of spine through the bony elements whereas the surface topographic method uses the superficial aspect of body that includes bones, muscles, fat and skin.

### *1.3.3 Visible landmarks in the assessment of back and body shape and posture*

Kendall (2005) defines posture as the alignment of body parts in relationship to one another at any given point. Whereas the shape of the back or body describes the asymmetry between right and left sides (Berryman et al., 2008). Any change in the curvature of spine results in changes in the shape of the back, for example axial rotation of the thoracic spine results in asymmetric rib hump on the back (Berryman et al., 2008). Minguez et al. (2007), Patias et al. (2010) and Sribnoska et al. (2013)

suggest that the key features of the human body's back surface are easily visible to the 'knowledgeable' naked eyes and can easily be palpated. These include the C7 vertebra prominence, the sacral point, the acromial points, superior scapulae points, inferior scapulae points, and posterior superior iliac spine points – dimple points.

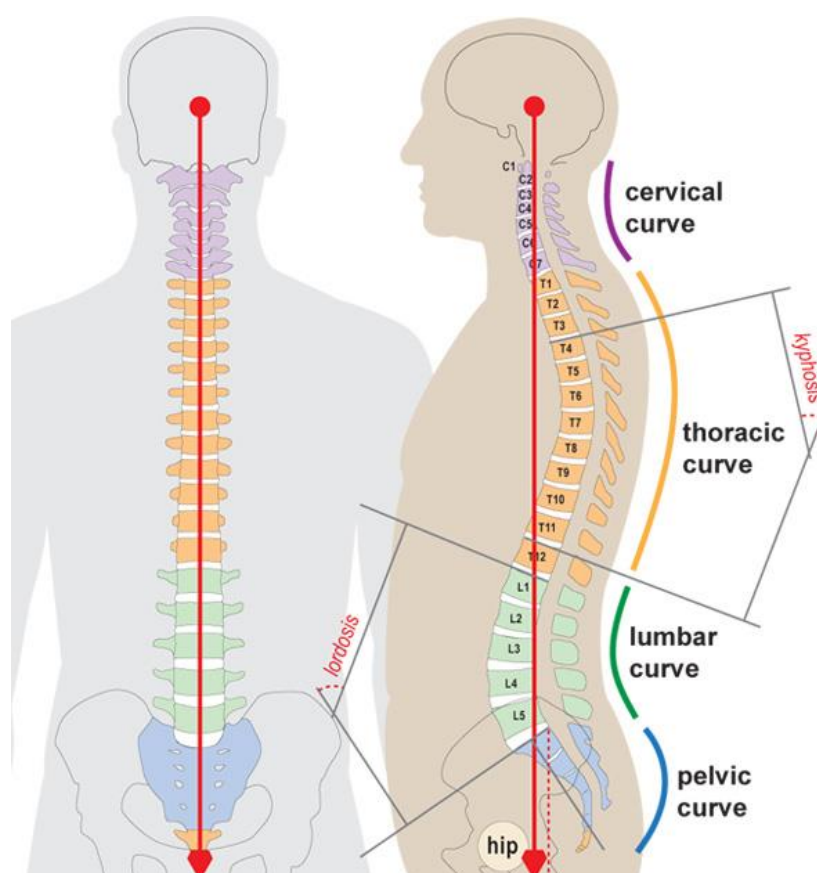


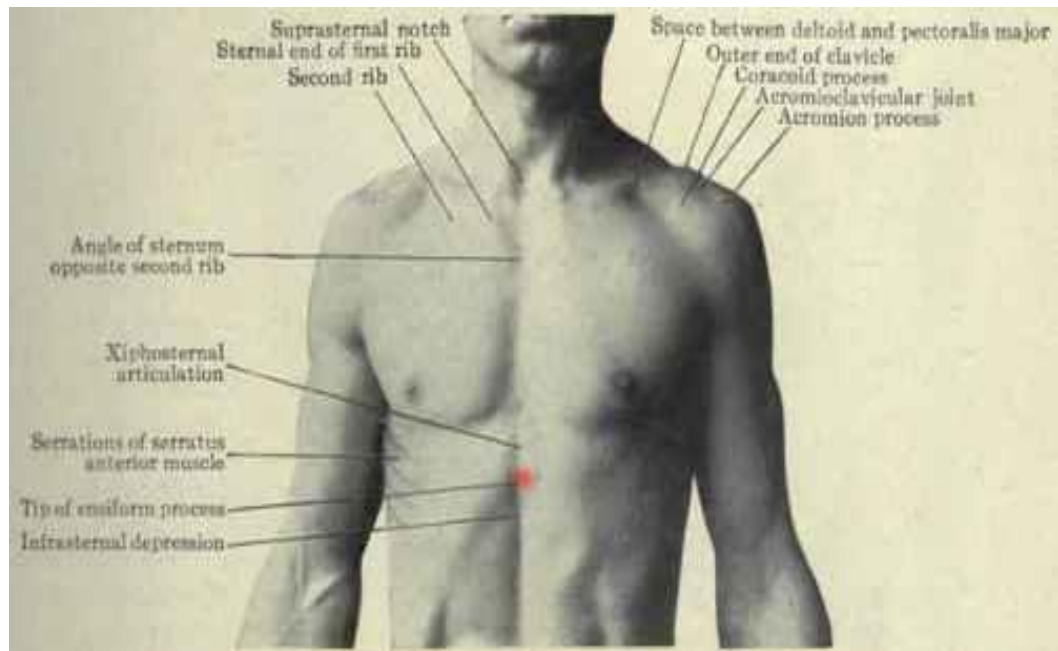
Figure 1.3. The normal curvatures of spine (source: [https://mayfieldclinic.com/Images/PE-scoliosis\\_Fig1.jpg](https://mayfieldclinic.com/Images/PE-scoliosis_Fig1.jpg)).

In addition to bony prominences, Lavaste et al. (1992) describes commonly visible muscle bulks in the human back region. The trapezius is a large, flat, triangular muscle that originates in the midline from the external occipital protuberance to the spinous process of T12 and inserts laterally onto the spine of the scapula. This is followed by

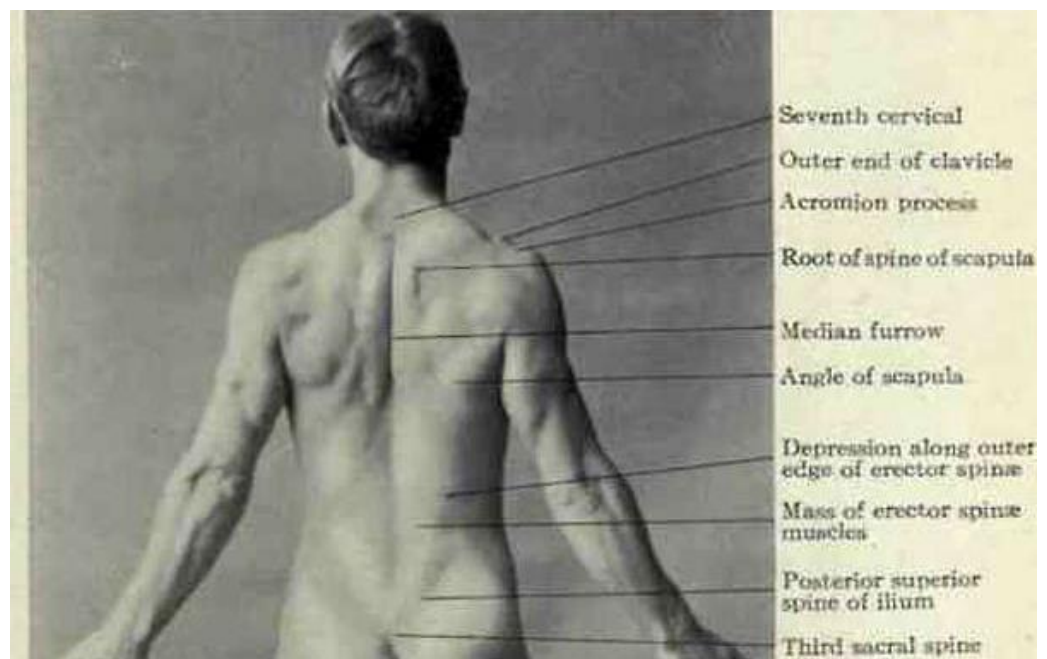
lattismus dorsi muscle, extending from iliac crest to posterior border of axilla. Drake et al. (2014) suggests the two longitudinal erector spinae muscle masses in the posterior part of back are responsible for the deepening of the median furrow (see Figure 1.4 (B)).

Three key studies (Duff & Draper [1987]; Bettany-Saltikov et al., [2002] and [2017]) in this area reported the normality and symmetry of back shape during standing. Bettany-Saltikov (2002) conducted a study evaluating normal back shape in young adults using the Integrated spinal imaging system (ISIS1). This is an optical computer system that is able to measure the 3D surface topography of the back. The authors were able to produce a representative scan for the interpretation of the back shape for all participants included in the study. This study found a mean thoracic kyphosis of 24.9 mm (median 24 mm, deciles: 6.8–47.2 mm). The thoracic kyphosis values found in this group of young adults are very similar to the children in Duff and Draper's (1987) study who reported a median value for thoracic kyphosis of 27.8 mm (17–40 mm). Carr et al. (1991) reported these values in degrees and therefore values were not directly comparable.

In this study the mean lumbar lordosis was 14.9 mm (median 14 mm). The lumbar lordosis values were found to be greater in Bettany-Saltikov's (2002) study that evaluated young adults compared to the Duff and Draper study (median 9 mm) that evaluated children. This suggests the possibility that lumbar lordosis may increase during growth from young adolescence to young adulthood. Carr et al. (1991), however, reported no significant differences in lumbar lordosis angles between



(A)



(B)

Figure 1.4 Surface landmarks of human body (A) front view and (B) back view (source: <http://fredhatt.com/blog/2010/06/20/exercising-perception/>; <http://languagelog.ldc.upenn.edu/nll/?p=3157>)

children and adults. It is possible that these changes may be due to variables such age, race and other population differences.

Bettany-Saltikov. et al. (2017) further suggest that identifying back shape, postural assessment, back surface features and major bony landmarks assist in the classification of back shape/posture types and provide normal ranges for different back surface parameters for the purpose of research, evidence-based practice and clinical decision making in practice.

#### *1.3.4 Optimal postural alignment*

Gangnet et al. (2003) states that good posture is considered to be an upright well-balanced skeletal alignment of all body segments in a 'normal' position. Further, Kendall et al. (2005) and Mock and Sweeting (2007) describe the ideal erect posture as when a line of gravity (LOG) passes through the midpoint of each segment of the body through the following points: a) ear lobe b) the mastoid process, c) bodies of cervical vertebrae, d) the tip of the shoulder joint, e) slightly posterior to the hip joint, f) just anterior to the centre of the knee joint, and g) a point just anterior to the ankle joint (see Figure 1.5).

In addition, Le Huec et al. (2011, p. S558) describe the ideal pelvic posture as “when the LOG passes slightly behind the femoral heads laterally, and frontally it runs through the middle of the sacrum at a point equidistant from the two femoral heads”. Zheng et al. (2010) and others (Gangnet et al., 2003; Jackson and McManus, 1994; Fegoun et al., 2005) not only reported different LOG measurement methods (optical,

radiographic, plumb line, photographic) but also demonstrated large variations in the values of LOG within asymptomatic volunteers. There are several potential reasons for the variability. This includes different starting or standing positions, changes in body position at different times (repeatability) and different methods of measurement using a diverse range of different instruments (Vrtovec et al., 2012).

In order to be balanced or in equilibrium, Bullock (1988) suggests that all forces acting on the body need to be equal to zero. As seen in figure 1.5, the balance of the physiological, biomechanical and muscle function maintains or realigns the body to an optimal position and produces stability (Gunther et al., 2004).

Changes in the anatomical structural positions due to abnormal internal or external forces results in numerous body segments moving out of alignment to compensate. Consistent prolonged application may then lead to changes in soft tissue length and its properties, resulting in a change in a person's posture (Kendall et al., 2005). Mock and Sweeting (2007) and Huec et al. (2011) detail that patients with excessive anterior pelvic tilt, present with tight hip flexors, weak gluteus medius, gluteus minimus and rectus abdominus muscle. As a consequence, this increased anterior pelvic tilt causes increased lumbar lordosis and slight knee flexion during standing. Furthermore, Smith et al. (1996) present supporting evidence that the altered posture can result in excessive tension in muscle groups, joint strain, ligamentous instability, cartilage damage, mechanical stresses of the myofacial region and can also be a contributing factor to arthritic changes.

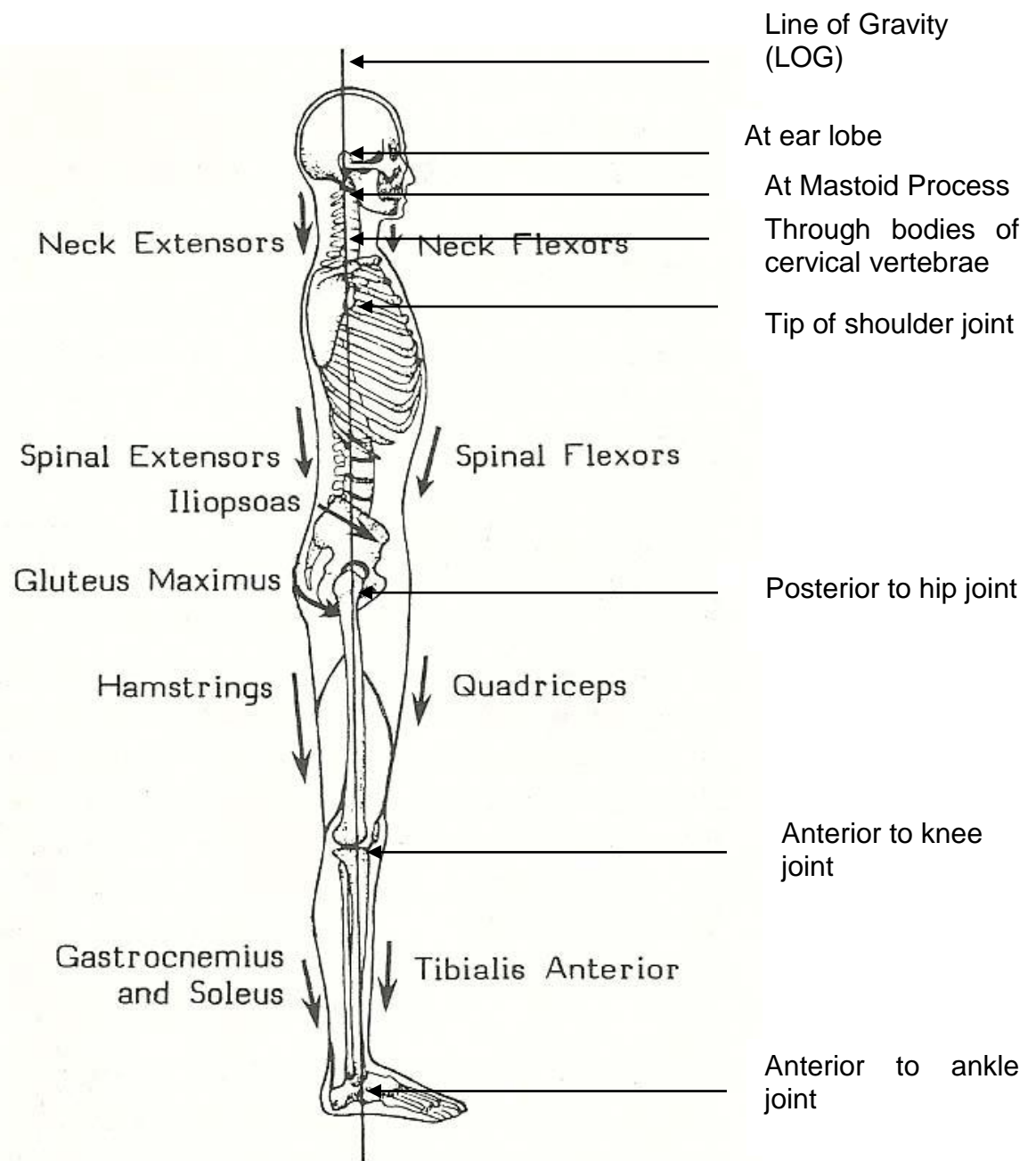


Figure 1.5 Lateral view of the reference line for erect standing posture with major antigravity muscles (source: [http://www.chiro.org/ACAPress/Body\\_Alignment.html](http://www.chiro.org/ACAPress/Body_Alignment.html))

Wong Wai (2007) suggests that postures can be categorized into both static and dynamic. Static posture is quasi-stationary, such as standing, sitting, and lying. Howorth (1946) describes dynamic postures as being succession positions of the body



during movements or activity (e.g. walking, bending forward, running). The analysis of a patient's optimal postural alignment, together with the understanding about the body and the capability of the musculoskeletal system to adjust to the external stressors, is essential in identifying and treating spinal disorders.

#### **1.4 Spinal Deformity**

Gunther et al. (2004) and Schwab et al. (2010) suggest that the identification of the optimal alignment of bone structures and joints is critical for the understanding of the efficient function of the musculoskeletal system. Similarly, any changes to the musculoskeletal system due to the ageing process or deformity of the spinal column can lead to the alteration in postural alignment (Lafage et al. 2009). A spinal deformity can affect all planes (e.g. coronal, sagittal, and transverse) (Good et al. 2011). Based on the plane in which the abnormality occurs, the spine deformity is generally categorized into three major groups: kyphosis, scoliosis, and kyphoscoliosis (Good et al. 2011) (see Figure 1.6).

Scoliosis and kyphosis were well known historically when postural asymmetries were witnessed (Choudhry, 2016). The terms 'kyphosis' and 'scoliosis' terms were introduced by Hippocrates (in ancient Greece) and Galen (Kostuik, 2015). Kyphosis is characterized by an exaggerated backward curvature in the sagittal plane of thorax region. This unnatural curving in the upper back, leads to a hunchback posture (Choudhry, 2016). Sagittal plane abnormalities are attributed to various causes: degeneration of the disks and/or vertebrae, developmental problems of the vertebrae,

osteoporosis in the elderly population, poor sitting or standing postures as well as Scheurman's disease (Ryan & Fried, 1997). Lafage et al. (2009) describe lordosis as an abnormal excessive lumbar sagittal plane curvature. This inward (ventral) curvature of lumbar spine is associated with poor posture, a congenital problem with the vertebrae, neuromuscular problems or hip problems.

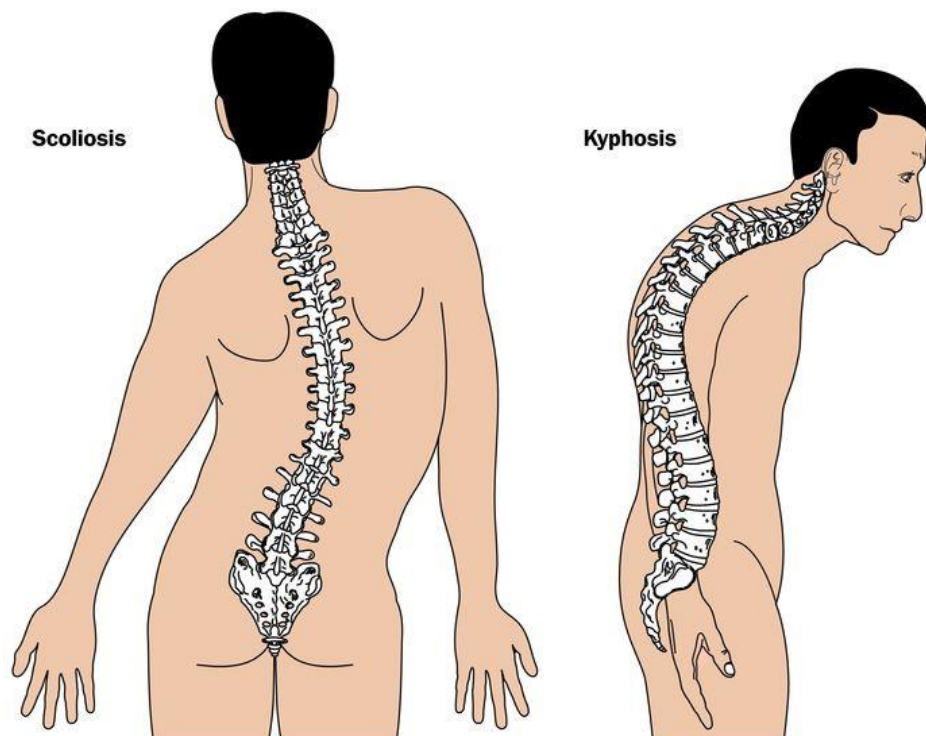


Figure 1.6 Illustration of various spinal deformities (source: <https://www.spineuniverse.com/conditions/kyphosis/scheuermanns-kyphosis-scheuermanns-disease>).

Morais et al. (1985, p. 1377) describe scoliosis as a “complex three-dimensional deformity, characterized by deformation (curvature) of the spine in the frontal plane”.

Whilst Stokes (1994, p.236) defines scoliosis as “the habitual lateral displacement of

the vertebral body line of the spine in the mid sagittal plane". However, the Scoliosis Research Society (SRS) radiographically define it as a "lateral curvature of spine greater than or equal to ten degrees of Cobb with vertebral rotation" (<http://www.srs.org/professionals/online-education-and-resources/glossary/revised-glossary-of-terms>). British Scoliosis Society (BSS), also refers to scoliosis as a "complex 3D deformity, accompanied by the rotation of the vertebra around its axis" (<http://www.britscoliosissoc.org.uk/patient-information/bss-documents>).

Rolton et al. (2014) state that the onset of scoliosis is associated with kyphosis, which further develops into a deformity called kyphoscoliosis. Calvert et al. (1989) describe kyphoscoliosis as a collapse of apical dystrophic vertebrae as a result of flexion forces in the scoliotic spine. Furthermore, Dickson (1999) clinically refers to "kyphoscoliosis" as a combination of an outward curvature (kyphosis) and lateral curvature (scoliosis) of the spine. This deformity is mostly associate with the extrapulmonary restriction of the lungs and generally gives rise to impairment of pulmonary functions. The condition may be primary (idiopathic) or secondary to neuromuscular disease, spondylitis or Marfan syndrome.

## **1.5 Spinal Pain**

Spinal pain is an extremely common musculoskeletal symptom caused by a multitude of diverse contributing factors. Glassman et. al. (2005) suggests that the main causes that contribute to spinal pain in adult age group are spinal deformity (for example,

scoliosis, increased thoracic kyphosis or lumbar lordosis as well as marked asymmetries between the right and left sides of the back).

Davies et. al. (2006) explain that any significant asymmetries in back posture/deformity may lead to abnormal stresses and loading on the spinal musculoskeletal structures. Hence, the shape of the spine or whole back is a key aspect for the clinical assessment of various spinal disorders. Spinal back shape (e.g. asymmetry of the back surface) assessment helps in identifying a variety of diseases (Stokes et al., 1988). Grivas et al. (2009) suggest that back shape assessment helps to identify the early signs of any disease prior to its occurrence, such as Scheuermann's disease. An additional advantage of measuring the shape of the spine as well as the whole back as a baseline outcome measure is that it helps to objectively quantify the effect of treatment together with the patient prognosis and recovery rate.

### **1.6 Tools used in measuring postural variables**

In order to assess and treat spinal patients, there is a need for the appropriate valid and reliable objective tools to measure and monitor changes in posture and back shape (Kotwicki et al., 2007; Berryman et al., 2008; Fortin et al., 2010; Betsch et al., 2013). Furian et al. (2013) have proposed various techniques to record the shape of the back (spine). This includes instruments ranging from the simple Flexi-rule to the much more complex three-dimensional radiographic method. Due to the cost effectiveness and ease of availability, two-dimensional (2D) images are also currently being used in clinical practice in order to treat any patient with a spinal disorder. Since

numerous back shape or posture variables of spinal deformity such as the sagittal and coronal curvatures are detectable through 2D images, photogrammetric methods have been used extensively in the evaluation of back shape and spinal curvature (Vrtovec, Pernuš et al., 2009; Stolinski et al., 2014).

The scoliometer (Bunnell, 2005), flexi-ruler and spinal rotation meter (Prujjs et al., 1995) are all examples of tactile methods for the measurement of posture and back shape. However, examples of non-tactile methods include Moiré' topography (Adair, 1977; Grivas et al., 1997) and structured light techniques (Turner-Smith et al., 1988). Non-tactile methods have the advantage of having minimal interference with the subject, thereby reducing operator error. The advantages and disadvantages of every method of posture screening are extensively discussed in the subsequent literature review chapter (Chapter 2, section 2.7).

### **1.7 Clinical Acceptance**

Ventola (2014) identifies that technological innovation is critical to all health-care professionals for improving the quality of clinical practice. The opportunities these technologies can offer to clinicians can occur by enhancing their decision-making skills and thereby improve patient outcomes (Califf et al., 2016). Although there are numerous tools/methods available for the assessment of posture and back shape, most systems are not utilised to their full potential as they are heavy, complex and expensive for regular clinical use. Nilsen et al. (2015) suggest that a major factor for

the clinician's adaptation to use the innovation of technology within their clinical practice is their acceptance of the technology.

As reported by Marangunic and Granic (2015), research into the acceptance of technology is important and considerable progress has been made since the 1970s. In accordance with Venkatesh and Davis (2000), Venkatesh et al. (2003), Venkatesh and Bala (2008) and Venkatesh et al. (2012), it is generally agreed that user acceptance is the fundamental issue determining the success or failure of any tool or system. The main theory used to explain acceptance is through the Technology Acceptance Model (TAM). The model suggests that when users are presented with a new technology, a number of factors (perceived usefulness and perceived ease of use) influence their decision about how and when they will use it. Similarly, Succi et al. (1999) suggested extending the TAM to take into account a new dimension of perceived usefulness, that of professional status such as in the clinical environment for health-care professionals.

To understand the challenges and obstacles faced by health-care professionals there is a need to understand the acceptance of technology within clinical practice. Chapter 5 aims to understand clinicians' perceptions together with their intention to use the novel MSTS for measuring posture and back shape. A study by Kuru and Erbuğ (2013) reported that clinical acceptance, perceived usefulness and perceived ease-of-use are fundamental determinants of an individual's behavioural intention to use a novel device. They also discovered the importance of other factors, such as perceived satisfaction and perceived positive experience together with their aesthetic attributes

might also influence the decision to use technology within clinical practice. The term aesthetic refers to the exterior design characteristics together with their ease of use.

The current clinical acceptance study is based on Brown et al's. (2014) technology acceptance model (TAM). Brown et al. (2014) suggest that the expectation confirmation is a strong predictor of perceived satisfaction and perceived usefulness; positive expectation disagreement is a predictor of 'level of use' and predictor of 'perceived usefulness'. It is a widely used model used by researchers and practitioners to understand and explain users' acceptance of technology based on their perceived usefulness and ease of use. It is important to note that the purpose of this study was not to prove or disprove the technology acceptance model, but rather to identify factors that are correlated with the behavioural intention of clinical practitioners' using the MSTs in clinical use.

### **1.8 Personalised Patient-Centred Care in the Management of Low Back Pain (LBP)**

The author postulates that the latest advancement in mobile technology, together with its capability for capturing and viewing three-dimensional data with accuracy and ease, can act as powerful persuaders in improving the quality of health-care practice. For the implementation of any new health technology to be successful, meeting the demands of users and other beneficiaries is equally important. The following section highlights the importance and usefulness of the latest mobile technology for beneficiaries. In the current thesis, the beneficiaries were patients with low back pain.

The latest systematic review by Sawesi et al. (2016) found that using the latest technology platforms in health-care management not only increases patient engagement, but also results in positive behavioral outcomes. In support of this numerous studies (Von Korff et al., 1998; Smeets et al., 2006; Van Tulder et al., 2006; Furlan et al., 2009) have indicated that the active participation of patients is important in the management of low back pain (LBP). Any intervention involving poor patient engagement is more likely to lead to poor outcomes in their clinical care (Sundararajan et al., 2004; Sen et al., 2005). Previous studies (Verbeek et al., 2004; Snelgrove et al., 2009) on the management of LBP have reported high levels of patient dissatisfaction due to poor patient engagement. In relation to the cost of care, a recent study by Hibbard and Greene (2013), found that healthcare costs were as much as 21% higher for patients with low patient engagement measured scores (a scale designed to measure one's knowledge, skills, and confidence in managing their own health needs). Patient engagement has always aimed at improving three key things: patient experience, satisfaction and outcome measures.

In order to address patients' dissatisfaction and improve engagement, Koes et al. (2006), Montori et al. (2013) and Constand et al. (2014) advise healthcare practitioners to adopt a patient-centred model of care. Similarly, Burton et al. (2002) proposed a method of engagement through a standard educational booklet which aimed to provide advice on the pain coping mechanism, staying active at work or an early return to work in LBP patients. Along with booklets, information provided through the generalised leaflets in the primary care centres helps to improve patient beliefs on LBP (Henrotin



et al., 2006; NØst et al., 2018). As booklet are easy to deliver and inexpensive it has become common practice to provide them to patients for the self-care management of LBP (Coudeyre et al., 2006; Henrotin et al., 2006; Liddle et al., 2007).”.

However, little is known on the effectiveness of self-care management through personalised educational booklet in LBP patients. There is a relative dearth of studies and a complete lack of evidence in existing studies on the efficacy of personalised education in improving patients’ psychosocial variables in LBP. Despite a comprehensive search, to the author’s knowledge there is no previous study has investigated the effectiveness of standard educational booklet to personalised educational booklet containing 3D interactive material. Therefore, one of the purposes of the research presented in the current thesis was to explore the use of the MSTS in providing personalised educational booklet for self-management of both acute and chronic LBP patients. This is detailed in Chapter 6 of the current thesis.

## **1.9 Objectives**

The main goal of the current study was to develop a low-cost, portable, easy-to-use, posture and back-shape measurement system capable of measuring posture variables in standing. The current study includes the following stages: firstly, the development of a novel approach to using a 3D imaging mobile surface topography system (MSTS) along with freeware measurement software for measuring posture variables; secondly, the evaluation of the reliability and validity of the MSTS for measuring posture variables; thirdly, the evaluation of the clinical acceptance of the MSTS by clinicians;

and fourthly a randomised control design study to evaluate the use of the MSTS for providing personalised educational biofeedback for the self-management of both acute and chronic low-back pain patients.

### **1.10 Outline of the thesis**

The current thesis consists of an introductory chapter together with seven further chapters. A brief description for each chapter is provided below.

Chapter 1 introduces the thesis, reviews the normal features of the vertebral column, and spinal deformity together with the alignment of optimal standing posture. This chapter includes the summary, the background and rationale of the study together with the outline of the thesis as a whole.

Chapter 2 reviews the literatures on different postural deviations of the spine, together with different methods and technologies used for the measurement of posture/back shape measurements.

Chapter 3 introduces the novel mobile surface topography system (MSTS) system and discusses the results of the intra and inter-rater reliability study for the measurement of different posture and back shape variables.

Chapter 4 demonstrates the method of using the MSTS for the measurement of posture variables. Within this chapter, the results of the validation study, for measuring posture variables using the MSTS is discussed.

Chapter 5 evaluates the clinical acceptance of the MSTS tool within clinical practice.

Chapter 6 demonstrates and evaluates the method of using the MSTS together with its output in providing personalised educational biofeedback for patient self-management for both acute and chronic low back pain patients.

Chapter 7 Provides the overall discussion and draws together the findings from all the research studies in terms of the objectives raised within the first chapter. It also attempts to provide useful insights about the clinical implications of using the MSTS in the measurement of posture and back shape. Additionally, this chapter points out the limitations and implications of future research studies on the MSTS. Finally, this chapter concludes by presenting ideas for further development of the MSTS to improve the knowledge generated in this thesis.

Please see Figure 1.7 for the flow chart of the whole thesis.

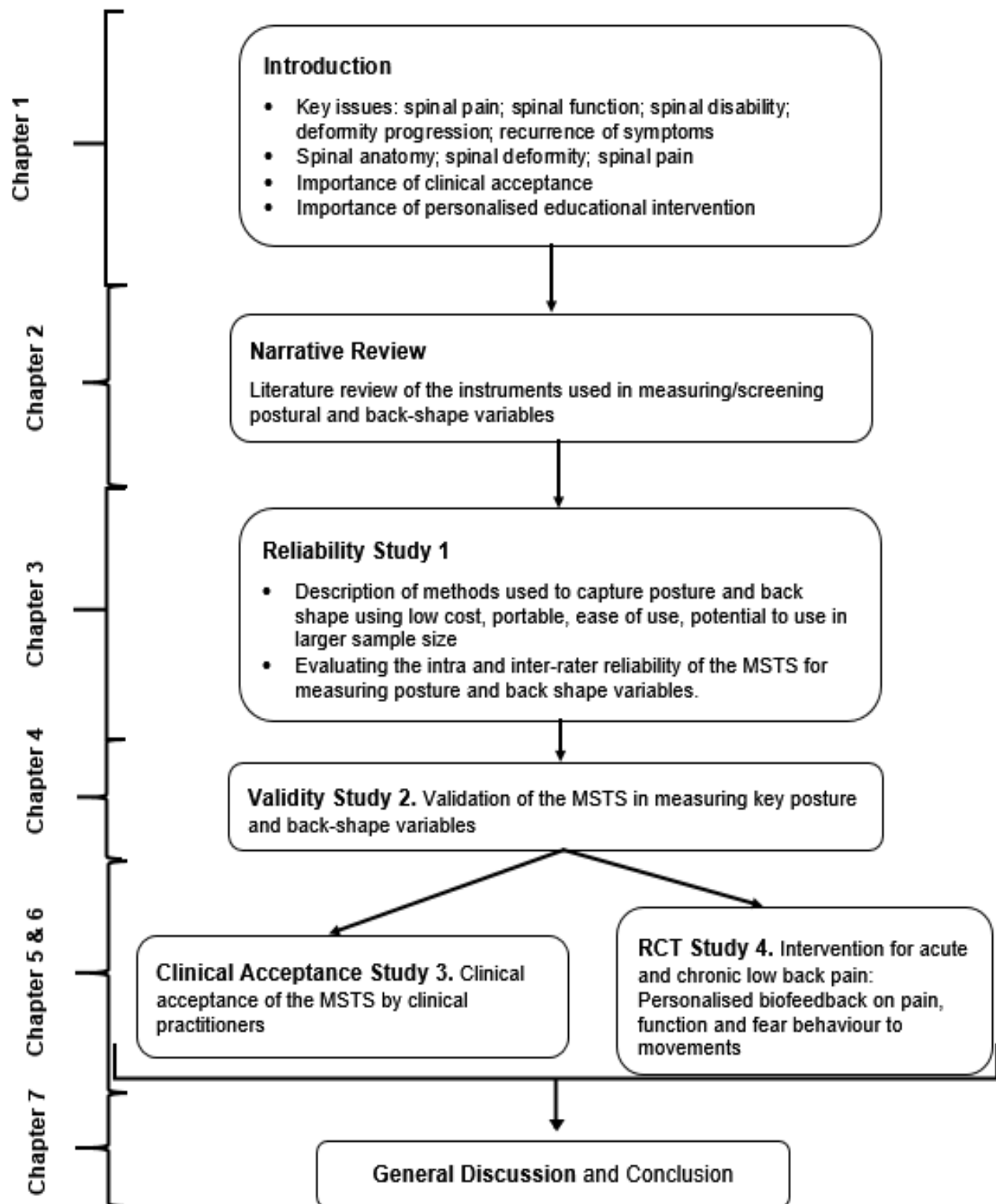


Figure 1.7 Flow chart for the structure of the current thesis.

# **Chapter 2. Posture and Back Shape Measurement Tools: A Narrative Literature Review**

## **2.1 Chapter Aim**

The primary aim of this chapter is to give an overview of different tactile and non-tactile measurement systems that have been developed for the measurement of posture and whole-body analysis. Various two and three-dimensional posture measurement systems and imaging modalities have been proposed over the past few decades. In this chapter, the underlying measurement techniques, their application and advantages together with the limitations and methods of each system are presented and critiqued. The current chapter also discusses the recent advances in mobile technology for the fast and accurate acquisition of three-dimensional posture and back shape. Finally, this chapter presents the novel mobile surface topography system (MSTS), together with its working principle and mechanism for data acquisition and processing.

## **2.2 Background**

As described in the previous chapter, the term ‘spinal deformity’ indicates the abnormal alignment or shape of the vertebral column and rib cage. Schwab et al. (2005) identifies the most common spinal deformities found in the population are scoliosis, lumbar lordoscoliosis, pelvic obliquity and either increased or decreased lumbar lordosis, with a high prevalence rate of 68%. These spinal deformities are often linked to a range of different types of pain, physical dysfunction and psychosocial wellbeing (Fallstrom et al., 1986; Burt and Punnett, 1999; Danielsson et al., 2001; Tyson, 2003). The clinical assessment of these spinal deformities often involves the assessment of posture and

back shape together with the associated mobility of the spine, pelvis and rib-cage. Currently, there is a wide range of posture and back shape assessment tools available for clinical use. The choice varies from conventional approach to advanced structured light methods. The advanced methods like ultrasound (Cheung et al., 2015), 3D radiography (Cheriet et al., 2007) and inertial sensor (Fathi and Curran, 2017) are not easily accessible for most clinicians, as they were either expensive, required specialist training or were complex or difficult to use. Thus, simple conventional methods like photography (Fortin et al., 2011) and the plumb line (Williams and McClay, 2000) are still used within clinical practice.

A comprehensive literature review was undertaken firstly to search and retrieve research papers related to the tools and scientific methods for assessing posture and back shape and secondly to critique which methods were best for assessing posture and back shape with regards to their cost, safety, reliability, validity, ease of use and duration. The primary research question for the current narrative review was ‘what are the different types of tactile and non-tactile measurement systems, for the measurement of posture and whole-body analysis in adults with spinal disorders?’ and the secondary research question is to critically evaluating the methods in terms of cost, safety, reliability and validity of the tool.

## **2.3 Methods**

### *2.3.1 Search strategy*

A comprehensive literature search was performed in the following databases (PubMed, EMBASE, Scopus, CINAHL, Medline, Science Direct) for articles on posture and back shape from 1980 to 2017. The search keywords were 'posture', 'back shape', 'spinal mobility', 'postural assessment', 'back surface measurement', 'postural alignment', 'posture' and 'reproducibility', 'posture' and 'reliability', 'posture' and 'accuracy', 'posture' and 'validity', 'posture' and 'spinal pain', 'posture' and 'low back pain'. The author also combined each human body segment with 'posture' as keywords, 'head posture', 'neck posture', 'cervical posture', 'thoracic posture', 'trunk posture', 'lumbar posture', 'shoulder posture', 'arm posture', 'upper limb posture' and 'lower limb posture'. In addition, the author searched for related articles from references cited in the articles identified from the original search. The search was limited to articles only written in English. No wildcards were used in this study.

### *2.3.2 Criteria for inclusion and exclusion*

All articles that assessed posture and back shape were considered in order to identify all possible methods for the evaluation of posture. Reviews of postural assessment and articles that discussed posture in some manner that could help the discussion were also included. Letters to the editor and conference proceedings were excluded.



## **2.4 Data collection and analysis**

The titles, keywords and abstracts of all research articles identified during the search were read to confirm whether they satisfied the inclusion criteria. Full text copies of all articles that met the inclusion criteria were obtained for analysis and data extraction. Preference was given to recent reviews on posture and back shape assessment and research papers on new or unusual forms of postural evaluation. Older articles with the same information contained in newer ones were excluded.

## **2.5 Results and Discussion**

The author identified 66 articles representing 15 principal instruments that are currently used to assess posture and back shape (please refer to the below PRISMA diagram Figure 2.1). These included tactile, non-tactile, two-dimensional as well as three-dimensional methods. Tactile measurement methods are defined as methods used to measure posture or back shape through contact for example the Flexiruler and Goniometry. Whereas non-tactile measurement method measure posture and back shape without any direct contact to the skin by the operator for example X-rays and photogrammetric methods. The literature primarily documented the reliability and validity of each postural measurement tool in normal individuals with few including patients with spinal deformities. Each method is described and critiqued below.

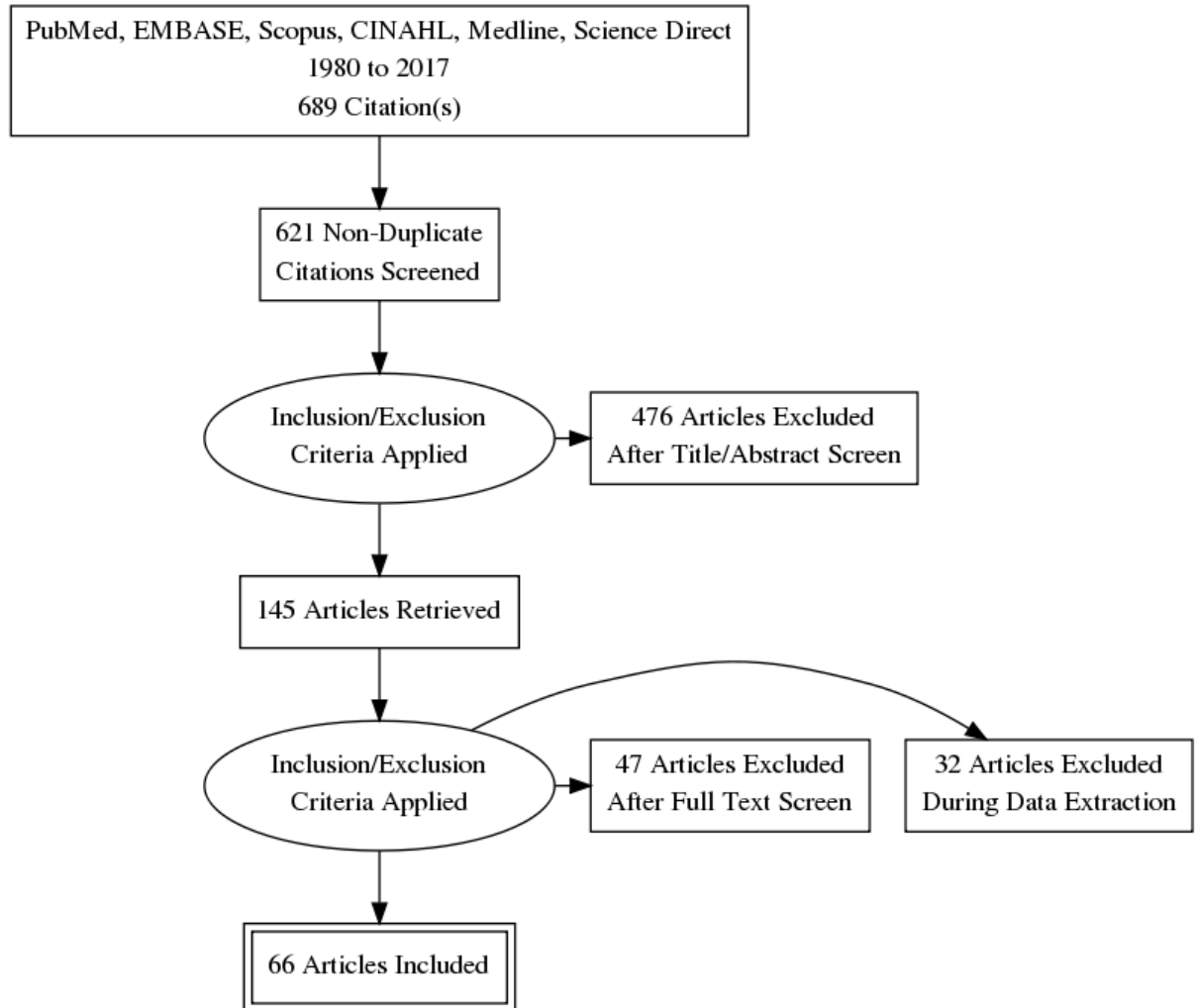


Figure 2.1 PRISMA flow diagram of literature search and selection process

### 2.5.1 Two-Dimensional Analysis of Posture and Back Shape

#### 2.5.1.1 Tactile methods of measurement

##### 2.5.1.1.1 Flexiruler

The flexiruler is currently used for numerous clinical and research purposes due to its low cost and simplicity of use. The flexiruler for the evaluation of posture is common for clinical and research purposes (Elabd et al., 2017; Raupp et al., 2017). This

objective method of postural measurement requires the manual placement of the flexiruler onto the contours or curvatures of the spine followed by the tracing and calculation of these angles onto paper (see Figure 2.1A A and B).

Greenfield et al. (1995) used a flexiruler to measure the mid-thoracic curvature, while Reheault et al. (1989) observed the inter-rater reliability of the flexiruler for measuring cervical lordosis in two different positions (neutral and fully flexed) in 20 healthy subjects. In both studies, the flexiruler was placed on the curvature of the spine, with its tip at the most proximal part of the curvature and the other end at distal end.

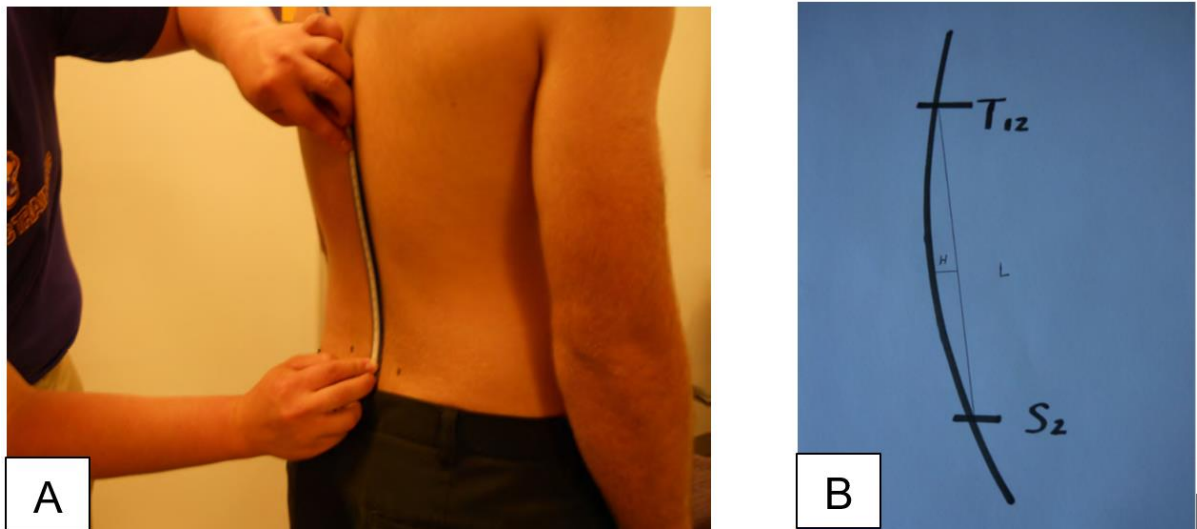


Figure 2.1A An example of the flexiruler method A) data collection and B) measurement of lumbar lordosis based on the captured data (Hecimovich & Stomski, 2016).

Following the measurement in the spine, the flexiruler was placed on a paper, to trace its curve. Greenfield et al. (1995) reported good to moderate Pearson correlation for intrarater ( $r = 0.90$ ) and interrater reliability ( $r = 0.70$ ). Furthermore Rehaul et al. (1989)

reported no significant difference between raters ( $t = 1.24$ ;  $p > 0.05$ ) at the two different positions of the cervical spine. The results of both Greenfield et al. and Rehault et al. studies suggest that the flexible ruler is a reliable measuring tool between raters for measuring sagittal plane curvature.

Concerning validity, many researchers have also demonstrated a high correlation between radiographic and surface measurements for measuring the lumbar spine curvature (Willner, 1981; Portek et al., 1983; Burton. 1986; Bryan et al., 1990;). For example, Hart and Rose (1986) compared the angles of the curve taken with a flexible ruler to the angle obtained by the standard roentgenographic technique and found good validity with the Pearson product moment correlation of + 0.87. Burton (1987) further substantiated the result by reporting a correlation of + 0.87 for the validity of the flexible ruler in comparison to the radiographic method for measuring lumbar lordosis. Even though the above studies demonstrated good validity, the main limitation was that the results were based on a very low sample size ( $n = 8$ ). In addition, the measurement of postural variables through flexiruler is always two-dimensional. Measurement of spinal curvature not necessary it should be always two-dimensional, there is a possibility of deviation of curvature more than one plane. In this scenario, the obtained spinal curvature angle might not represent the real degree.

It is important to note that most of the above studies reported their results based on the data collected from young normal healthy participants. Although the use of the flexible ruler is important for this population, there is a possibility that the flexible ruler may be more difficult to use for patients with pain, disease, or postural deformity. The

positions that were used in the normal population may be unattainable for patients with a known pathology, as most of the spinal deformities were bi- or tri-planar. Therefore, it is likely that the validity and the inter-rater reliability coefficients may be lower for patients with different spinal disorders and deformities.

Other limitations of this method of postural assessment are the following. Firstly, it is difficult for patients to maintain in one position during data collection. Secondly, the literature reports only one measurement plane (sagittal). It is difficult to measure both the frontal and the transverse plane posture variables. Third, this method of postural assessment has a high possibility of manual error during data collection and angle measurement (Wu et al., 2014).

#### *2.5.1.1.2 Goniometry*

In clinical practice, goniometers are commonly used to measure joint range of motion (ROM) (Hogeweg et al., 1994). Sacco et al. (2007) reported the use of a goniometer for the assessment of a number of posture variables. This method of direct body measurement used a goniometer to quantify posture variables with a value from zero to 360 degrees. The results of their study show moderate correlation ( $r = 0.47$ ) to measure tibiotarsal angle, knee flexion/extension angle, quadriceps angle as well as the sub-talar angle in relation to photogrammetry.

Conversely, Harrison et al. (1996) reported poor interrater reliability when using manual goniometry for the measurement of sagittal postural angles in neck inclination angle (craniovertebral angle) and cranial rotation (sagittal head tilt) (see Figure 2.2).

The ICC measures were found to be  $r = 0.68$  and  $r = 0.34$  for the cervical rotation angle and neck inclination angle, respectively. The authors attribute the poor results to the difficulty in maintaining the arm of the goniometer parallel with the horizontal axis.

Fortin et al. (2011, p381-382) suggests that for the measurement of reliability the main limitation for this type of individual measurement of postural variables is the lengthy evaluation process involved for both the therapist and the patient. The author states that “this approach may be appropriate for the assessment of one body segment or a variable, but not for the whole body or posture.”

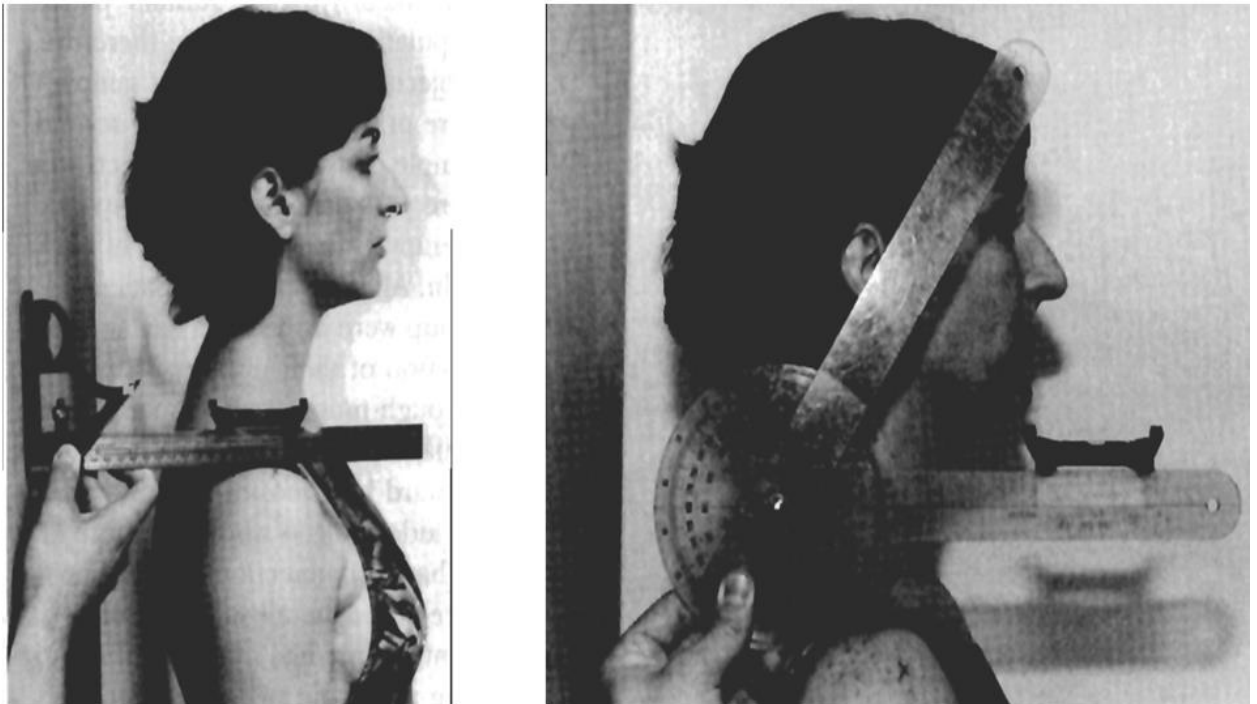


Figure 2.2 Measurement of shoulder and neck inclination angle using goniometer (reproduced from Harrison et al., 1996).

### *2.5.1.2 Non-tactile methods of measurement*

#### *2.5.1.2.1 Visual Observation Method*

Visual observation methods are still the most common method used within clinical practice for the measurement of posture (Iunes et al., 2009). Visual postural evaluation methods require the observation of the patient from front, back as well as both side views. Schwertner et al. (2016) and Watson et al. (2000) suggest that any visible deviations or asymmetries of posture are being analysed by the therapist using a predetermined guide as the ideal alignment of back posture. For example, the ideal sagittal alignment of the upper trunk is defined as “the gravitational line that passes through the external acoustic meatus, the bodies of the cervical vertebrae and the tip of the shoulder” (as discussed in Chapter 1, Section 1.3.4).

Iunes et al. (2009) compared the interobserver agreement between visual postural assessment and the photogrammetry method. In their study, three experienced physical therapists visually evaluated postural symmetries and asymmetries of twenty-one healthy adult volunteers. The agreement between the raters on each postural assessment variable was determined using Cramer’s V coefficient, with the significance level set at 5%. The results indicated a poor interrater agreement ( $p = 0.00$ ) for the visual observation method in comparison to photogrammetry. This suggests that it is difficult to evaluate postural variables using visual observation method.

The main advantage of this method is that it does not require any equipment or specialised space. On the other hand, the biggest limitations of this method are (1) its

inability to quantify the observed data (i.e. non-evidence-based and (2) its difficulty in detecting and recording any minor postural alterations (Nichele et al., 2001; Singla et al., 2014).

#### *2.5.1.2.2 Plumbline method*

The two-dimensional evaluation of posture, using a plumbline is very common, due to its low cost and simplicity (Hickey, 2000; Yip et al., 2008; Perry et al., 2008). Kendall et al. (2006), postulated guidelines to evaluate posture in accordance with the alignment of the ideal plumb line for the measurement of sagittal and the frontal planes. Kendall et al. states that the ideal alignment of sagittal plane posture is when the plumb line should intersect the ear lobe, then run to the shoulder joint, then through the greater trochanter of the hip, just in front of the knee joint and finally slightly in front of the lateral malleolus of the ankle before it reaches the floor. William and McClay (2000) reported the plumbline method to have a good intra-rater reliability for measuring postural variables with an average ICC of 0.80 in both 10% and 90% of body weight bearing scenarios in standing. The standard error of the mean (SEMs) reported was between 2 and 5 mm for the lowerlimb indices and from 5 to 10 mm for patients with a trunk list or lateral shift. List is defined as “the lateral displacement, in millimetres, of a surface marking of the spinous processes of T12 from that of S1” (McKenzie and May, 2003, p214).

Hickey et al. (2000), evaluated the reliability of using the plumbline to measure resting head posture in a large sample size of 122 healthy volunteers (80 women and 42 men, ages 18 to 60 years). In this study, all participants were screened for cranial, cervical,



and/or upper thoracic dysfunction. The results of this study demonstrated the plumbline method to have high intra-rater reliability with ICCs ranging from 0.83 to 0.84 for the measurement of resting head posture. Although the plumbline method has been reported to have good intra-rater reliability and is a useful and easy to use instrument for measuring posture, its limitations are its difficulty to minimize movement error or postural sway (Perry et al., 2008; Fortin et al., 2011). Additionally, this plumbline method only measures in one plane.

#### *2.5.1.2.3 Radiography*

McCloskey et al. (1993), Glassman et al. (2005), Wang and Mummaneni (2010) and Schwab et al. (2010) considers the radiographic method of spinal screening to be the traditional and “gold standard” method for the assessment and screening of patients with spinal deformity. Furthermore, Schwab et al. (2002) suggests radiography is an essential tool for the accurate diagnoses of spinal abnormalities/deformities and accurately reveals the degree and severity of the problem.

In this method, an X-ray image is captured when a beam of X-ray light is passed through the spine and the amount of radiation emerging on the other side is recorded. Since the bones of the spine absorb the radiation and soft tissues allow it to pass through, a clear image of the spine is captured. McVey et al. (2003) suggest that the captured radiographic image provides essential information on spinal bone structure, which can be used to analyse individual vertebrae and the overall contour of the spine.

In addition to the assessment of spinal curvature and X-rays are also used to record as well as monitor the progression of spinal deformities and dysfunction (McCloskey et al., 1993; O'Neill et al., 1996; Rea et al., 1998). Therefore, in adolescent patients it is performed every few months in order to detect any changes in the progression of spinal deformity.

The main drawback of the radiographic method of spinal assessment is associated with the increased radiation of the carcinogenic factor (Knott et al., 2014; Zhang et al., 2015). Doody et al. (2000) in their retrospective cohort study estimated the carcinogenic risk and the patterns in breast cancer mortality among female patients with scoliosis. This study included a large sample size (5,573 female patients with scoliosis, or abnormal curves). The results suggested that due to the high exposure to cumulative x-ray radiation of 10.8 cGy (from childhood to adolescence), breast cancer risk increased by 70%. Similarly, Beir (1990) in his review, reported that the exposure to radiation during periods of rapid growth, potentially amplified the deleterious biological effects.

Due to its high cost and risk of exposure towards harmful radiation, studies by van Niekerk et al. (2008) and Kilinc et al. (2009), recommended using alternative non-invasive methods for the assessment and screening of postural variables. In the next section, photogrammetry tools, together with methods to analyze postural variables are discussed. As stated by Furlanetto et al. (2016), the simplicity and convenience, has made photogrammetry method very popular among clinical practitioners.

#### *2.5.1.2.4 Photogrammetric method*

In the last two decades, the photogrammetric method of postural evaluation and its applicability has been widely reported in the literature (Fortin et al., 2011; Furlanetto et al., 2016; Sutkowski et al., 2017; D'Amico et al., 2017; Andrade et al., 2017). Low-cost, quantitative evaluation together with its use in reducing the exposure to radiation, makes this method much more feasible for healthcare practitioners to use within their clinical practice. Following are a number of research studies that have assessed the reliability, the validity and its application in different scenarios:

Souza et al. (2011), Fortin et al. (2011) and Furlanetto et al. (2012; 2016) have all proposed a number of diverse photographic methods for evaluating postural variables and conducting postural diagnosis. While standing in their normal anatomical position, photographs were taken in the sagittal and the frontal plane using a digital camera. The captured data were uploaded into the two-dimensional analysis software to calculate postural angles. Angles were then drawn between the markers by drawing horizontal and/or vertical lines (please see figure 2.3). With the use of this method, the sagittal and frontal plane postural variables for example head/ shoulder posture, cervical lordosis, thoracic kyphosis, lumbar lordosis, lower limb posture and pelvic tilt were measured. The type of software used to analyse the postural variable varied from study to study.

Several authors (Sacco et al., 2007; Iunes et al., 2009; Santos et al., 2009; Thigpen et al., 2010) have reported the use of photographic methods for the quantification together with the reliability of measuring postural variables. Santos et al. (2009)

reported good to excellent inter-rater reliability (interclass correlation coefficient [ICC] values were between 0.84 and 0.99) for the photographic measurement of 33 postural variables in standing in 122 normal healthy children aged 7 to 10 years.

However, Souza et al. (2011) in their study on measuring 20 postural variables found mixed results. The ICC values for inter and intra-rater reliabilities for trunk and hip angle were found out to be 0.62 ( $p$  value was 0.12) and 0.56 ( $p$  value was 0.43) respectively. The level of reliability of these two angles was thus classified as not acceptable. The ICC values for lower leg postural variables (bilateral hind foot angle) ranged from 0.74 to 0.86 ( $p < 0.05$ ). This level of reliability was classified as good and acceptable. The interrater reliability for rest of the sixteen posture angles reported excellent ICC values (greater than 0.90). Except trunk and hip angle, the rest of the sixteen variables yielded non-repeatable intra-rater values. The authors of this study concluded that frontal-view postural variables, such as alignment of head, trunk and lower limbs, measured using the photography method were reliable for measuring various postural asymmetries.



Figure 2.3 Measurement of thoracic kyphosis and lumbar lordosis using a photogrammetric method (reproduced from Furlanetto et al., 2016)

Although numerous studies (Chang, 2008; Fortin et al., 2011; Salahzadeh et al., 2014; Rosario, 2014; Ruivo et al., 2015; Furlanetto et al., 2016; Sutkowski et al., 2017) have reported the photogrammetric method of posture analysis, the most common limitation is the inconsistency used in the data collection procedure. For example, the distance between the subject and the placement of the camera varied between studies. The body segment length increases or decreases depending on how close the camera is

to the surface of the human body. Additionally, from 2D photographic methods, it is very difficult to study the deformities which has a rotational component in the transverse plane (Fortin et al., 2011; Viazzi et al., 2014). Similarly, in the sagittal plane, there is a possibility that the muscle mass of the erector spinae can obscure the median furrow of the back surface; thereby it is very difficult to study the true spinal curvature (Bettany-Saltikov et al., 2012).

In summary, two-dimensional spinal assessment tools do not provide a complete description of the three-dimensional nature of the back and other spinal deformities. To obtain the detailed three-dimensional description of spinal deformities together with the information of the 3D back surface, various three-dimensional surface and posture measurements tools have been reported in recent years. In the following section, three-dimensional measurement systems (both tactile and non-tactile methods) used to assess posture and back shape variables are reviewed.

### *2.5.2 Three-Dimensional Analysis of Posture and Back Shape*

In the last decade, three-dimensional analysis of posture and back shape has not only developed significantly, but its use in both the spinal research and clinical environment has also been extended to include both tactile and non-tactile instruments, which will be discussed below in turns.

### 2.5.2.1 Tactile tools of measurement of spinal curvature

#### 2.5.2.1.1 Posturometer-S

The Posturometer-S, is a specially designed, electronic, objective, non-invasive body posture measuring device (M.Stachoń et al., 2012) (see Figure 2.4). This tool consists of three coupled systems: 'P' a pointer to indicate the position of a measured point (mechanical), an element to compute the position of the pointer in a three-dimensional space (electronic), and informatique which is used to analyse the results obtained. This system not only enables a practitioner to visualise the curvature of the spine in all three planes, but also provides a quantitative description of the postural parameters.

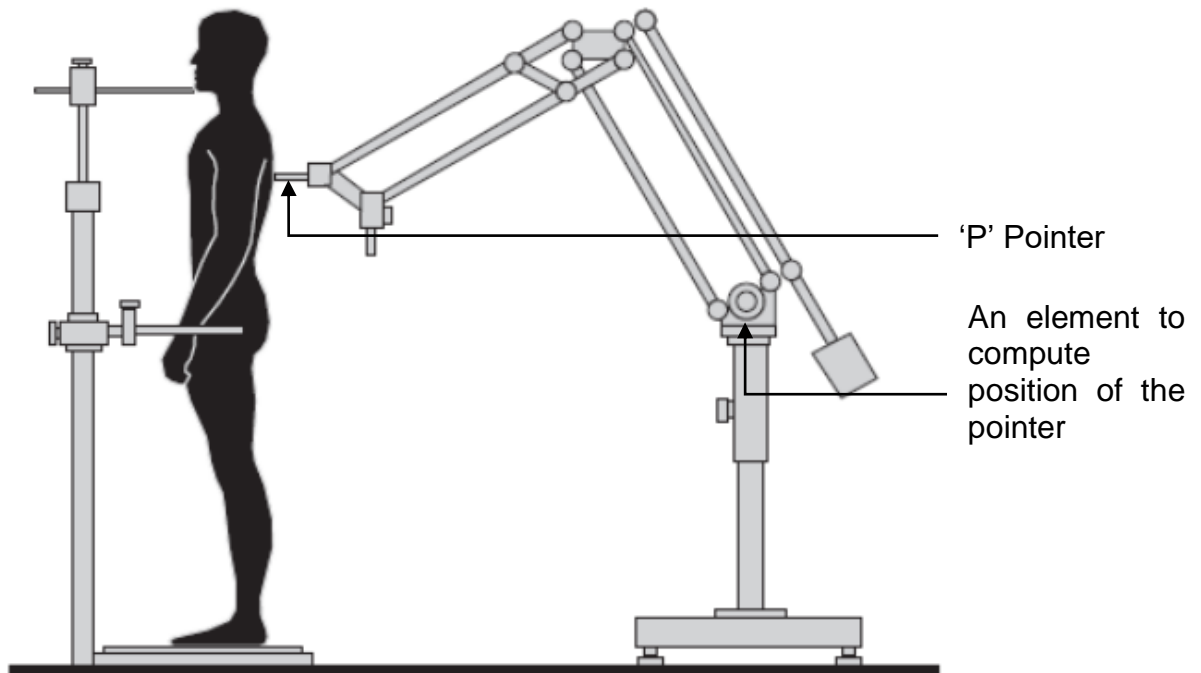


Figure 2.4 Schema of Posturometer-S device (source: Stachoń et al., 2012)

Previous research (Vernon, 1983; Sliwa et al., 1994; Lichota, 2008; Stachon et al., 2012; Mroczkowski, 2013) has not only demonstrated the reliability of the posturometer, but also its applicability in the assessment of posture in different age groups. Lichota et al. (2011) using the Posturometer-S examined the postures of 46 athletes who were aged between 20 – 24 years. Total of four sports groups were examined, namely handball (n = 16), athletics (n = 9), taekwondo (n = 5) and volleyball (n = 13). In this study, the “Posturometer-S” was used to describe various angles of the spine, for example lumbar lordosis, thoracic kyphosis, upper thoracic segment ( $\alpha$  angle), the thoracolumbar segment ( $\beta$  angle) and the lumbosacral segment ( $\gamma$  angle). The highest values for  $\alpha$  angle,  $\beta$  angle and  $\gamma$  angle were reported in volleyball (15.2°), athletics (12.6°) and taekwondo (14.0°) groups, respectively. The lowest values for the  $\alpha$  angle,  $\beta$  angle and  $\gamma$  angle were observed in athletics (12.4°), handball (8.8°) and handball (8.0°) groups, respectively. The authors contended that posture was affected by the specific type of sports training and that the type of sport influenced the type of posture. The main limitation the authors reported in the study were that the posturometer-S was not user-friendly, consumes more space in the room and it requires a thorough understanding of the equipment together with training before it can be used.

#### *2.5.2.1.1 Ultrasound*

Cheung et al. (2015) demonstrated the use of a radiation-free three-dimensional ultrasound system for the assessment of spinal curvature in twenty-nine scoliosis patients. Similarly, Kowalski et al. (2013) used an ultrasound-based volume projection



imaging method to compare the lumbar lordosis and thoracic kyphosis angle in patients with scoliosis as well as normal subjects or other people with spinal disorders. In this volume projection imaging method, the 3D representation of the spinal anatomy was generated using the ultrasound images together with corresponding 3D spatial information (see Figure 2.5). The structure of the spine anatomy was reconstructed from image data ranging from 16MB to 96MB in size (Cheung et al., 2015). The results of this feasibility study, showed good intra- and inter-rater reliability with ICCs larger than 0.92,  $p < 0.001$ . The results also showed that the spinal curvature obtained by the new method had a good linear correlation with the X-ray Cobb method ( $r^2 = 0.8$ ;  $p < 0.001$ ).

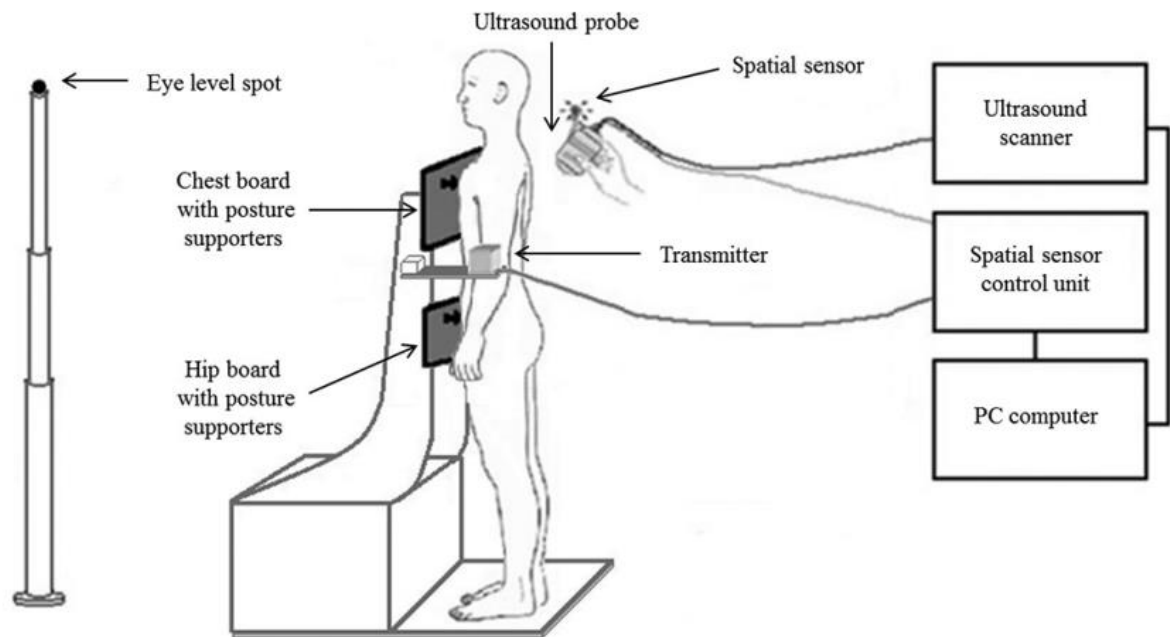


Figure 2.5 Illustration of 3-D ultrasound system for measurement of spinal deformity (Cheung et al., 2015).

Although these results suggest that the ultrasound volume projection imaging method can be a promising approach for the assessment of spinal deformity, there were still a number of factors that contributed to errors. For example, the ultrasound system and its data were susceptible to the distortion of the electromagnetic field, leading to a system offset/counteract or transient jitter in the spatial and orientation data. Therefore, precaution must be taken especially if the supporting frame is made of metal. The additional limitations of using the ultrasound volume projection imaging method were (a) it was heavy to carry around, (b) expensive (c) relatively dependant on the skilled operator (Scholten-Peeters et al., 2014; Graaf et al., 2014) (d) it only measures the spinal curvature and not the whole back and (d) time-consuming for the assessment of the whole spine. Therefore, this suggests that it is not an appropriate tool for clinical practice.

In summary, the main disadvantage of all tactile posture measurement systems is the error produced due to electromagnetic and patient interference during data acquisition process. This is because it is difficult for patients to maintain a static standing position for a long time.

#### *2.5.2.2 Non-tactile tools of measurement of spinal curvature*

In the following section, non-surface measuring systems, such as 3D radiographic imaging systems and inertial measuring units will be discussed. This is followed by various surface measurement tools, such as Moiré topography, integrated shape imaging system, laser triangulator system and the kinect sensor system.

#### *2.5.2.2.1 Non-Surface Measuring Systems*

##### *2.5.2.2.1.1 3D Radiographic imaging*

###### *CT SCAN*

Three-dimensional computed tomography (CT) scan is traditionally used for diagnostic purposes. It uses special X-ray equipment to produce cross-sectional images of body tissues and organs from different angles and planes. The computer-processed image helps to visualize the apical and the transient zone of the pelvis. The transverse plane data helps to study the rotation and distortion components of the spine. In addition to visualising the success of surgical spinal implants, CT scans are also useful in situations when preliminary diagnostics or symptoms indicate an abnormal condition requiring further analysis (Oestreich et al., 1998).

Although the CT images can produce high-quality 3D data, within current clinical practice CT scans are not routinely used to assess posture and back shape. One of the main limitations is its high risk of exposing patients to ionising radiation. Additionally, the duration for acquiring cross-section imaging induces errors and causes motion problems (Adams, 2009).

###### *3D X-RAY*

Cheriet et al. (2007) demonstrated the use of bi-planar X-ray images for the reconstruction of the three-dimensional spine and rib cage. These images are useful in evaluating patients with spinal deformities like scoliosis. In this method, the reconstruction of images is based on a direct linear transformation technique (DLT),

which requires the explicit calibration of an object with known 3D co-ordinates (see Figure 2.6). This method produced accurate 3D reconstruction of six manually identified anatomical landmarks per vertebra (centers of superior and inferior vertebral endplates and the tips of both pedicles). Similarly, the absolute differences between the Cobb angle obtained with the standard DLT and the explicit calibration methods were as low as  $0.3 \pm 0.42$  degrees. The absolute differences of the frontal and sagittal balance were  $0.15 \pm 0.15$  degrees and  $0.37 \pm 0.25$  degrees respectively.

Using 3D X-rays for clinical or research purposes has the same motion and radiation issues as the use of 2D X-rays. Additionally, most of these tools are complex to set-up, heavy and only can be applied in laboratory environments.

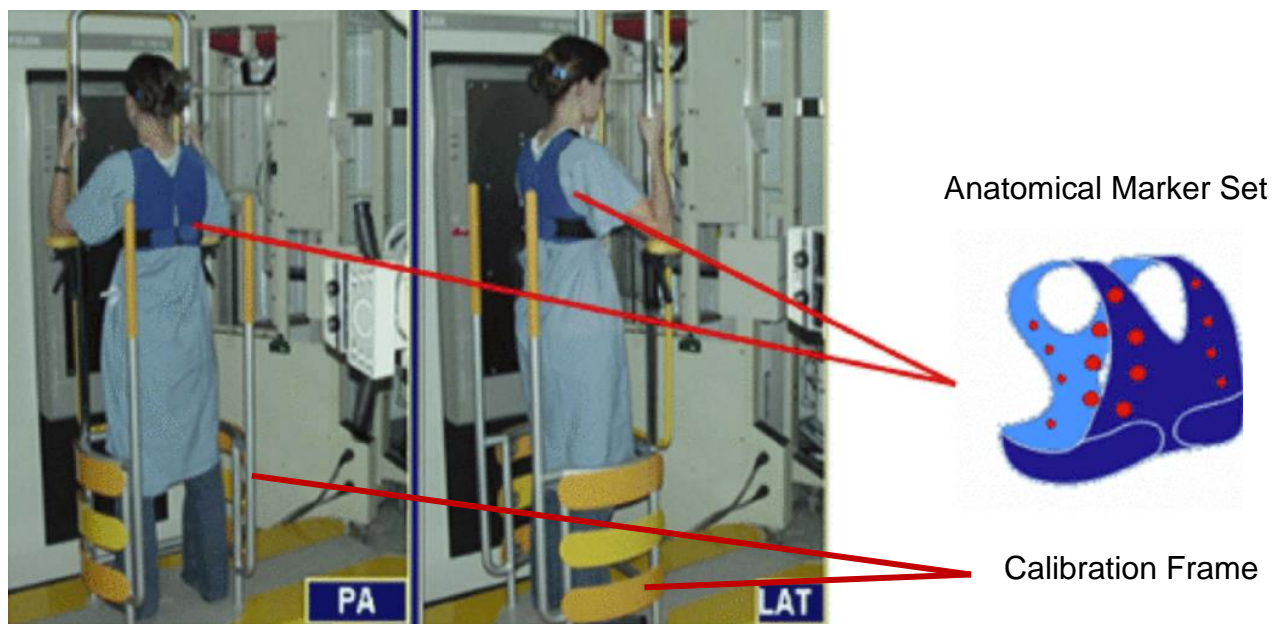


Figure 2.6 Biplanar X-ray (posterior anterior (PA) and lateral view) acquisition system with calibration apparatus (Cheriet et al., 2007)

#### *2.5.2.2.1.2 Inertial Sensors*

The recent advancement and application of electronic systems and sensors namely accelerometers, gyroscopes, flexible angular sensors, electromagnetic tracking systems and sensing fabrics have enhanced the quality of clinical practice. Allum and Carpenter (2005), Wong et al. (2007), Godfrey et al. (2008), Tao et al. (2012) and Fathi and Curran (2017) all reported the use of sensors in the evaluation of human posture. The following section reviews their clinical applications, together with their problems and limitations.

An inertial measurement unit (IMU) is an electronic device, that primarily contains accelerometers, gyroscope and magnetometer sensors. All these sensors are based on measuring and converting the global position of human body segment, momentum/inertia or changes of path length. An accelerometer is a sensor which measures a specific force and acceleration. In this context, an accelerometer is used to determine the orientation of the spinal segment in relation to Earth's gravitational field. A gyroscope sensor measures the rate of change of angles. Using these sensors, a three-dimensional (3-D) position together with displacement data is calculated by combining inertial sensors orientation data, together with its known distance between the sensors (Wong and Wong, 2008; Voinea et al., 2016).

Kent et al. (2015) in their randomised controlled study, used DorsaVi's hardware (which contains two IMU movement sensors) (see Figure 2.7) to measure posture and movement in sub-acute and chronic low-back pain patients ( $n = 58$ ). The results not only demonstrated the procedure for posture measurement, but also its applicability in

providing postural bio-feedback. Similarly, Fathi and Curran (2017) demonstrated the effective application of wireless IMU sensors to detect the curvature of the spine with 85% to 95% accuracy in Ankylosing Spondylitis patients.

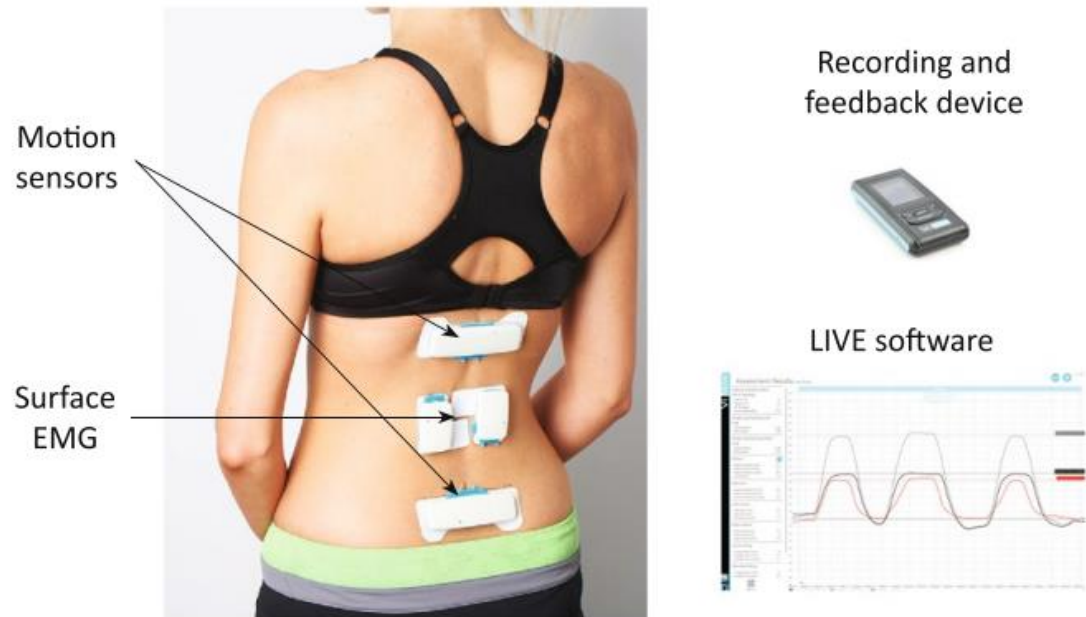


Figure 2.7 ViMove wearable motion-sensor system with IMU sensors and Surface EMG electrodes (Kent et al., 2015)

Other portable, non-invasive sensors used in the assessment of posture are E-textiles. Many studies (Lorussi et al., 2004; Mattiman et al., 2007; Rajdi et al., 2012; Sardini et al., 2015) have reported the use of textile sensors to detect the curvature of the spine. The specially designed fabric contains an inductive sensor, a circuit board, and a piezoelectric actuator (a component of a machine responsible for moving and controlling the piezoelectric system) (see Figure 2.8). Any change in posture and spinal

movement is calculated by a change in the length or position of the sensor's together with the percentage of change in electrical resistance.

Sardini et al. (2014) compared the E-textile output data with an optical motion system (Vicon). The trials performed on four subjects obtained on different days demonstrated that the wireless wearable sensor described in this paper is capable of producing reliable data compared with the data obtained with the optical system.

As the above IMU and e-textile tools were low-cost, portable and easy to use, it might be appropriate to use these for monitoring movement. The reliability of the above tools for measuring spinal curvatures or other back parameters has not yet been reported. The potential limitation of the IMU and e-textile tools is that their interaction with metal in the environment could affect the sensor data extraction due to its capacity to distort electromagnetic waves. In addition, these tools do not provide back surface and whole-body data.

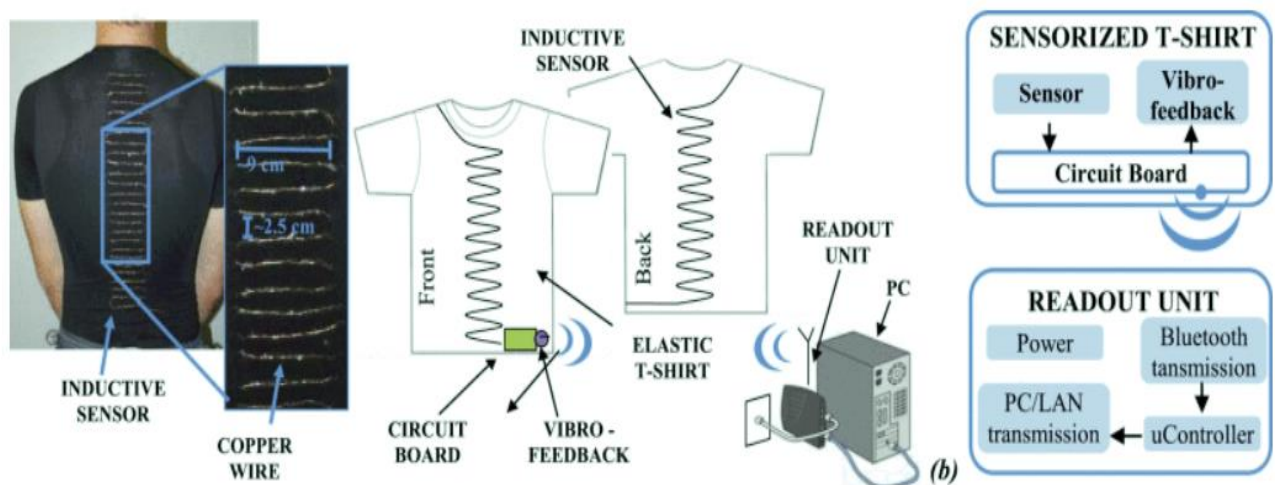


Figure 2.8 E-textile with inductive sensors (Sardini et al., 2014)

#### *2.5.2.2.2 Surface Measuring Systems*

Berryman et al. (2008), Betsch et al. (2013) and Furian et al. (2013) detail that back surface observation and measurement methods have been widely used by both clinicians and researchers for the evaluation of posture and spinal curvature in patients with spinal disorders patients. The following section aims to review both the qualitative and quantitative studies that describe skin surface measurement tools.

##### *MOIRÉ TOPOGRAPHIC METHODS*

Moiré topography and rasterstereophotography systems are the most valuable and widely used non-radiographic tools in the measurement of posture/back-surface. Additionally, these instruments are also used for screening three-dimensional spinal deformities, furthermore for quantifying the progression of the 3D spinal curvature.

The above topographical systems work on the basis of projecting a structured light onto the back surface. Based on the reflection of the structured light from the subject, Moiré topography images are produced (see Figure 2.9). The contour map image, help to visualise back asymmetry and record the spatial information of the subject's three-dimensional back shape and posture. The quantification of Moiré fringes typically involves the derivation of quantitative angular and/or linear measures by comparing the left and right side back surfaces.





Figure 2.9 Example of Moiré topographic images of a subject with scoliosis (reproduced from Kotwicki et al., 2007).

Numerous authors (Sahlstrand, 1986; Stokes and Moreland, 1989; Grivas et al., 1997; Uetake et al., 1998; Kotwicki et al., 2007 and Rankine et al., 2012) have described the use of the Moiré topography method to evaluate back shape and spinal deformity. The main limitation of Moiré topography method is that the measurement depends on the absolute order of Moiré fringes.

A Moiré pattern is a low-frequency line image produced from two high-frequency line images or grids. For example, by projecting a high-frequency grid onto an object and viewing the reflection of this projected pattern through another high-frequency grid is called Moiré fringes (Chiang, 1975). The formation of the Moiré fringes depends on a patient's position. A slight change in the patient's position or movement can produce considerable changes in the Moiré topogram. Thus, a direct inspection of Moiré fringes

may be misleading. Further Stokes et al. (1987) states that the data analysis is a complex procedure, requiring much expertise. Additionally, Nissinen et al. (1989) also reported that the correlation of Moiré topographs with X-rays is poor and ranges from  $r = 0.24$  to  $0.45$ . This suggests it is unsuitable for objective back shape measurements.

#### *THE INTEGRATED SHAPE IMAGING SYSTEM 1 AND 2 (ISIS1 & 2)*

The integrated shape imaging system (ISIS) is a widely used optical scanning system for the measurement of human back shape and posture within a clinical environment (Turner-Smith et al., 1981; Turner-Smith et al., 1988). The ISIS system consists of an optical scanner (A), which projects a horizontal beam of structured white light onto the patient's back (B). The camera (C), mounted below the projector, captures the position of the light blade on the back from different perspectives (see Figure 2.10). Based on the geometry of the illumination/camera system together with the coordinates of the blade of light, the three-dimensional shape information is derived.

The validation of this system was carried out in the late 1980s and early 1990s (Weisz et al., 1988; Legaye et al., 1992, Bettany-Saltikov et al., 2002). Although the reliability and validity of this tool was good to excellent for clinical use, the original ISIS system was getting old and data acquisition was slow which led to potential movement errors. The system was modified and redesigned by Berryman (2008) with the new addition of a clinical parameters and renamed ISIS2. This automated non-invasive surface topography system measures three-dimensional shape of the back with improved speed, accuracy, reliability and ease of use (Zubovic et al., 2008).

Berryman (2008) described the data collection procedure, involving palpation and marking bony landmarks on the subject's back with small coloured stickers. A digital camera is then used to take a photo. The projector then projects a grid of horizontal black lines onto the patient's back. The pixel size is approximately 0.5 mm with fringe frequency of approximately 0.16 fringes/mm. Fourier transform profilometry is used to convert the distortion of the reference grid lines into a three-dimensional surface map of the back.

The data processing with ISIS2 takes only 40s, compared to 10 minutes in ISIS. Knott et al. (2012) suggests that by reducing the duration of data collection, the error due to natural postural sway of the body decreases, thereby the accuracy ( $\pm 1$  mm) increases. The results are stored in a database so that the data of the particular patient can be recalled at any given point of time. ISIS2 helps in the screening and monitoring of the development of spinal deformity over time (Patias et al., 2010; Glinkowski et al., 2014; Talasila et al., 2017; Pino-Almero et al., 2017).

Zubovic et al. (2008) carried out a study to validate the ISIS2 system against X-rays. They reviewed 520 ISIS2 scans on 242 scoliosis patients not only for quantifying postural variables but also to assess their validity. The average number of scans per patient was 2.01 with a range of 1-10 scans. The median values and 95% CI were reported for the linear, angular and volumetric asymmetry of scoliosis patients. The results of this study showed no statistically significant differences in their investigations between ISIS measurements and X-ray images.

Similarly, Berryman et al. (2008), in their study on measuring three-dimensional back shape in scoliosis patients, found good correlations ( $r=0.84$ ) between the Cobb angle and the lateral asymmetry of the ISIS scans.

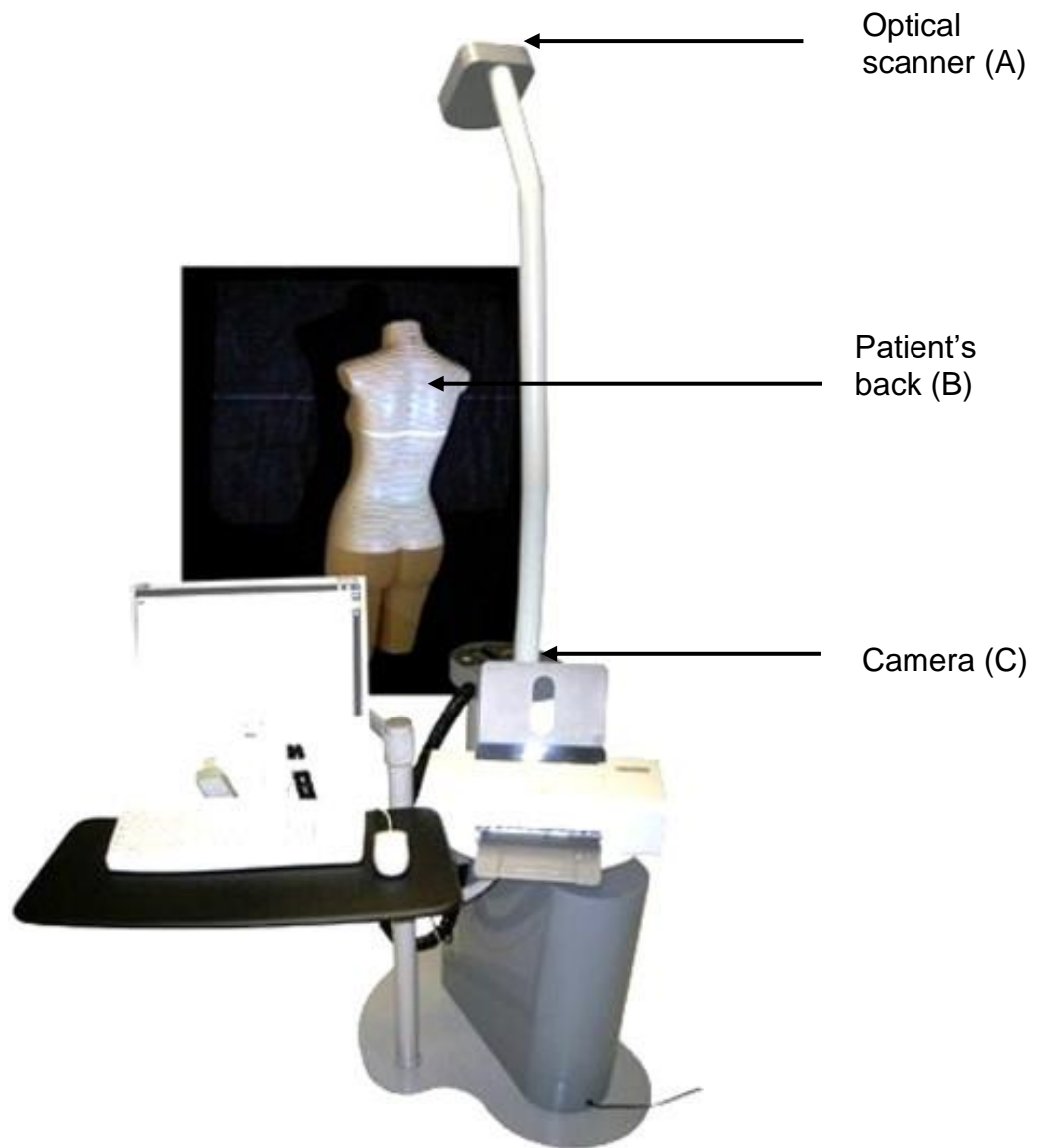


Figure 2.10 Integrated shape imaging system (ISIS2) (reproduced from Porto et al., 2010).

As seen in Figure 2.11, the ISIS2 system provides additional data to simple radiographic examination, describing the three-dimensional characteristics of back surface (Berryman et al., 2008; Anwary, 2012). Previous studies (Patias et al., 2010; Glinkowski et al., 2014; Talasila et al., 2017; Pino-Almero et al., 2017) have demonstrated that the ISIS2 produces reliable, valid and accurate data that can monitor the progression of spinal deformities. Berryman et al. (2008), Frerich et al. (2012), Sadani et al. (2012), Brewer et al. (2013) and Knott et al. (2014) suggest that the additional advantage of ISIS2 is to reduce the exposure to radiation.

However, Fortin et al. (2011) and Bettany-Saltikov et al. (2012) identify the ISIS2 system as being very heavy, is not easily moved and requires skilled clinicians to operate it. In addition, Berryman et al. (2008) suggests that identifying the bony landmarks for marking spinous process is more difficult for patients who are extremely obese or have heavy musculature. Similarly, the above authors also found it difficult to mark bony landmarks in patients with congenital curves that had little rotation. The main limitation of the ISIS2 system is that it can only measure back shape and not the whole body.

Non-contact optical imaging techniques for the assessment of back shape and posture has also been achieved by using the laser triangulators method.

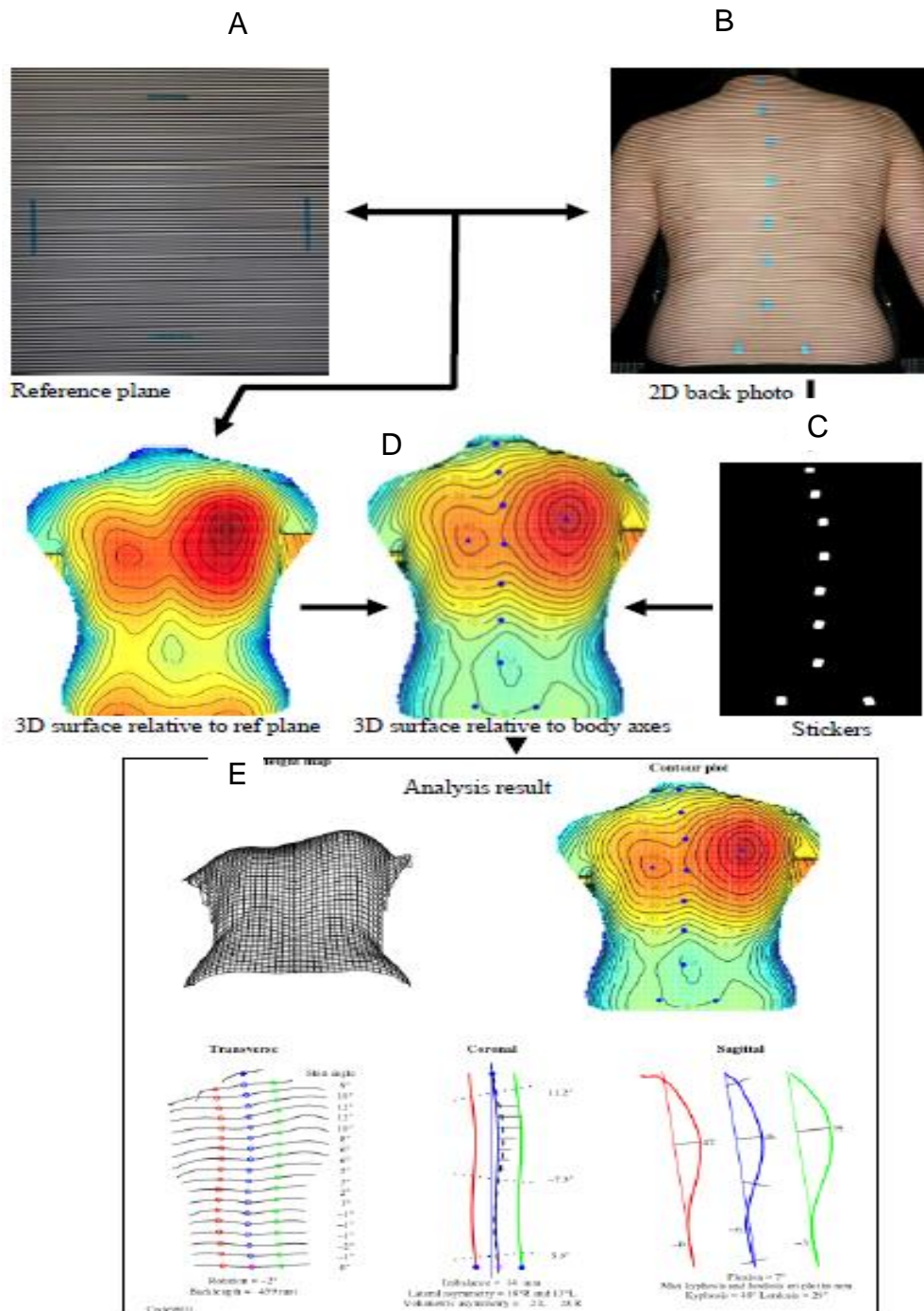


Figure 2.11 Illustration of data processing and a sample report of ISIS2 method (Anwary, 2012). A - The reference frame with calibration markers; B - example of patient image with fringes projected on to the back; C – representation of symmetry line analysis in frontal and sagittal plane to obtain lateral deviation, kyphosis and lordosis angles; D - back height map with rib hump, contour plot (representing the shape using contour lines and colour; blue lowest to red highest) and E – Example of ISIS2 report with representation of contour plot and quantification of curve in all planes.

### *Laser Triangulators*

Celan et al. (2015) and Poredoš et al. (2015) used the laser triangulation method to evaluate the three-dimensional human spine curvature. The main purpose of these studies was to estimate the spatial bend of the thoracic and lumbar spine curvature in all three planes. The laser triangulation imaging system used in Poredoš et al.'s study consisted of two basic elements: a grey-scale camera (A) and a laser line projector (B) (see Figure 2.12). The spinal path or region of interest (ROI) of the human model is manually marked by the palpation of the subject's bony landmarks. The laser projector illuminates the light on to subjects back and the intersection of the laser line with the spinal path or region of interest (ROI) provides the intersection curve, which is then measured using a greyscale camera. The distance between the laser projector and the camera is known. The intersection angle in 3D space is calculated using the triangular method (Amann et al., 2001).

The laser scanning triangulation method was assessed for both validity and repeatability. Using a point-to-point analysis, the average error ( $\pm 1$  mm S.D) (distance between markers) for a regular shape (cylinder) was as low as  $4.99 \pm 1.56$  mm, versus  $6.91 \pm 2.29$  mm for an irregular shape (mannequin) (Chang, 2008). Research by Majid et al. (2005) demonstrated the performance of the 3D laser scanning system. In this laboratory-based study, craniofacial measurements of mannequins demonstrated that the photogrammetric/3D laser scanning system had an accuracy of  $\pm 0.7$  mm (1 standard deviation [SD]).

The same measurement in human models demonstrated an accuracy of  $\pm 1.2$  mm. This decrease in accuracy was due to facial movement during data acquisition.

However, this method also has limitations. The manual spinal path determination is also likely to cause palpation errors. This limits the usage of the system to only experienced health-care practitioners who have good palpation skills. Additionally, this tool is capable of only measuring the shape of the human spine and not the complete back or human body.

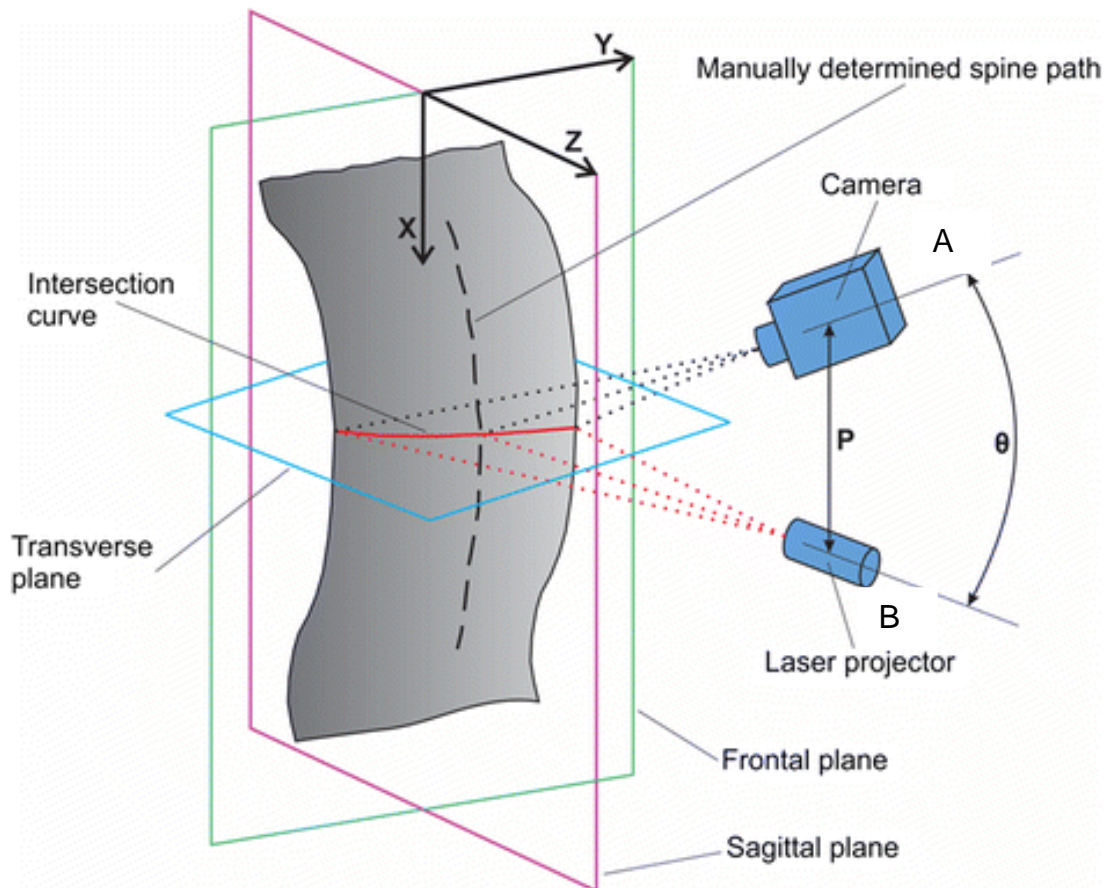


Figure 2.12 Illustration of one-laser-plane triangulation method in all planes. (Reproduced from Poredos et al., 2015).



### *Kinect Sensors*

Microsoft kinetic sensors are currently being used in a range of disciplines from biomechanics to clinical applications (Lange et al., 2011; Zhang, 2012; Nguyen et al., 2012). Castro et al. (2017) described the use of the Microsoft's Kinect™ to measure back surface and posture. The Kinect sensor used in their study is similar to the Structure Sensor(R) (used in the research reported in the current thesis). The Kinect sensor consists of two cameras; a colour camera (RGB camera) (A), a depth (infrared IR) camera (B), and a projector (C) (please see Figure 2.13). These cameras does not require passive markers to determine anatomical landmarks. By measuring the deformations of the projected speckle pattern, a 3D map of the dorsal skin surface is created by using the appropriate software.

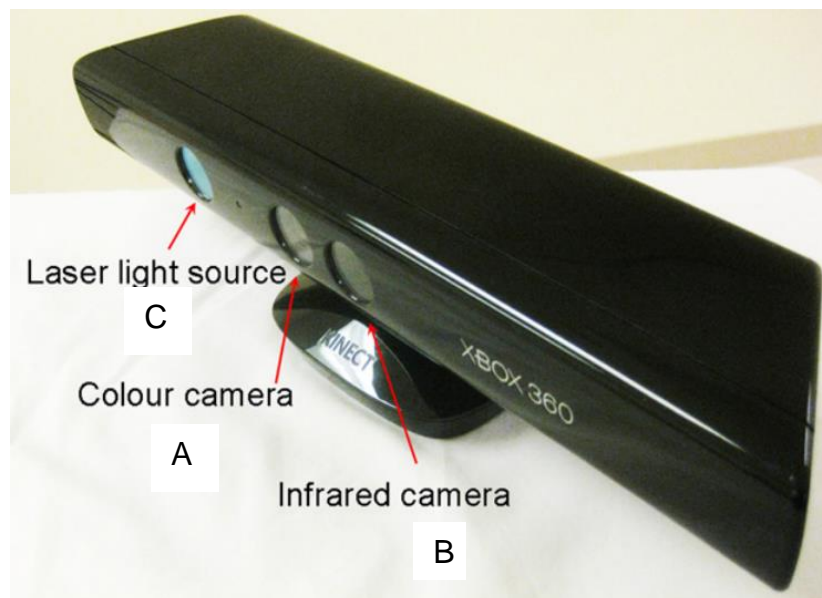


Figure 2.13 Microsoft Kinect Sensor

The results from previous studies have demonstrated that the depth sensor is valid in measuring 3D back surface in patients with scoliosis and in healthy volunteers (Kyeong-Ri Ko et al., 2013; Lachat, 2015; Castro et al., 2017). The Microsoft Kinect™ system had comparable inter-trial reliability (ICC difference =  $0.06 \pm 0.05$ ; range, 0.00 – 0.16) and excellent concurrent validity against a benchmark reference, a multiple-camera 3D motional analysis system, with Pearson's r-values > 0.90 for the majority of measurements ( $r = 0.96 \pm 0.04$ ; range, 0.84 – 0.99).

Whilst the Microsoft Kinect™ is inexpensive, portable and offers good repeatability of the 3D map of the back surface, it also has a few limitations. The measurements are limited only to the back surface and not the whole body. Additionally, the Kinect system software is mainly restricted to the Microsoft operating system and is not applicable to any other mobile applications.

## **2.6 Requirements for a Novel System**

A number of different techniques for the assessment of posture and back shape within clinical practice and research have been described above. Most are expensive, difficult to use, need specialised training are heavy to move or cannot be used for regular clinical use (Fortin et al., 2011). When considering a new system, the following requirements are necessary.

1. A novel tool needs to be simple, portable, low cost, easy to use and less time-consuming for the purpose of using within clinical practice. This can be achieved by innovatively using a mobile low-cost scanner, such as the Structure Sensor™ together

with freeware software. This has previously been used in the construction and fashion industry (D'Apuzzo, 2007; Yap & Yeong, 2014; Taneva et al., 2015).

2. The most conventional photographic systems, used in clinical practice at present, do not provide the three-dimensional information of patients' posture and back shape. A novel portable system providing three-dimensional information of patient's posture and back shape would help to better understand the three-dimensional nature of spinal deformities.

3. Most existing systems described in this chapter provide information either on back shape or spinal posture and not the whole body. A system providing information on the whole body and its relation to spinal posture would yield more information on the relationship between the orientations of the extremities to the trunk.

4. Technological advances in imaging and computerized image-processing led to the development of new three-dimensional (3D) image acquisition techniques. There is a demand for bridging the gap between technological advancement and medical practice for the assessment and treatment of spinal disorders (Eysenbach, 2002; Gammon et al., 2005). The continuous increase in 3D imaging technology provides opportunities for the development of a novel system that provides reliable and valid results for assessment of whole-body posture and back shape.

## 2.7 The 'Structure Sensor™'

### 2.7.1 Technical specifications

In the current thesis, the author innovatively used a highly original novel system to capture the back and body shape and posture: an iPad based three-dimensional mobile scanning tool called 'Structure Sensor™', manufactured by the spatial computing company called Occipital. The sensor is similar to the Kinect sensor that straps onto a commercially available iPad. The Structure sensor™ weighs only 95 grams, its dimensions are 119.2 mm in length, 28 mm breadth and 29mm height (see Figure 2.14). Consists of an infra-red (IR) camera and IR projector; these are designed to be incorporated into both iPads and iPhones.

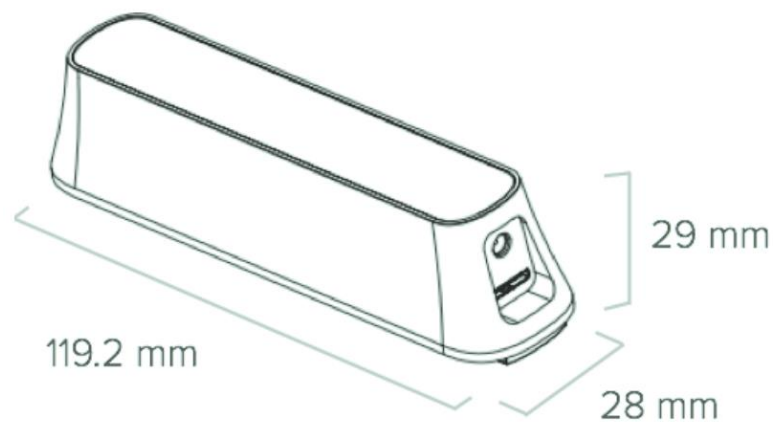


Figure 2.14 Dimension of Structure Sensor™

### 2.7.2 Capturing the image

Valgma (2016) detail the depth sensor of Structure Sensor™ which has three infrared light sources that project waves at different amplitudes to a known structure pattern.

The image capture or scanning process involves the projection of a series of known patterns onto the object being scanned. The red green blue (RGB) camera of an iPad and the infra-red (IR) or depth camera captures the scene together with the reflected wave. Three different amplitudes of lights are then emitted by the sensors to enable good resolution 3D data and to measure the long distance.

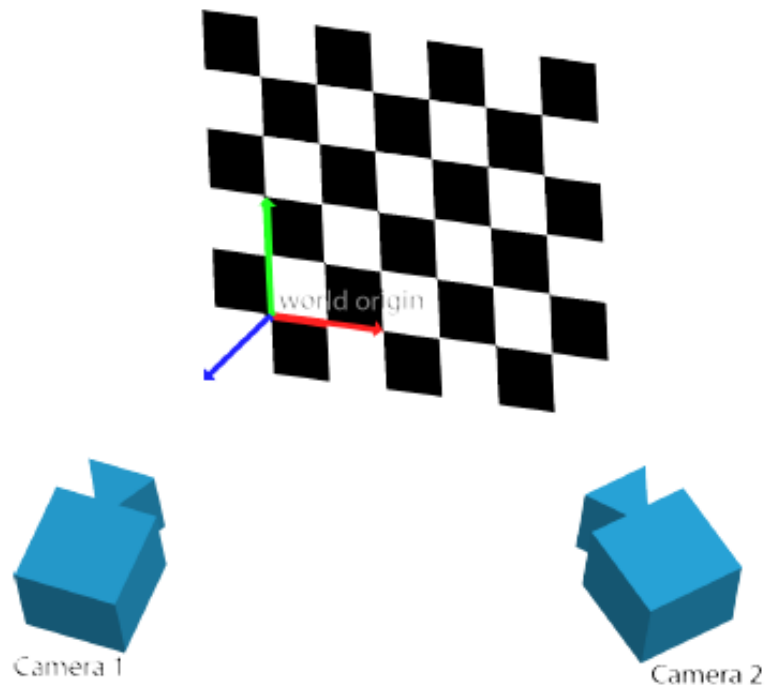


Figure 2.15 The orientation and position of an object is captured by two cameras. This allows the formation of a common reference point in three-dimensional space (reproduced from Herakleous & Poullis, 2014)

The method of measuring the distance is through the optical Time of Flight (ToF) technique. The ToF principle is based on measuring the time required by the light wave emitted by the infrared light source to travel to the object and back to the depth sensor. Thousands of invisible infrared light waves projected onto the object are distorted

according to the geometry of the object being scanned. The geometry of the object is then computed by identifying the corresponding IR dots or pixels in the captured image. In order to be able to identify these pixel correspondences, the projected pattern is encoded such that every pixel in the projected pattern can be uniquely identified in the images captured by the cameras. This provides an efficient and accurate method of mapping corresponding pixels between the images captured by the two cameras (see Figure 2.15). The mapping between corresponding image pixels, makes it possible to calculate the accurate 3D positions and geometric pattern of the pixels.

### *2.7.3 Decoding and processing the patterns*

Herakleous and Poullis (2014) suggest that mapping between the depth and colour cameras is required as they are two different sources of information. In order for surface matching and registration, each pixel in the captured image is decoded into their corresponding decimal number (1 or 0) representing the column (x) and the row (y). This numbering of each pixel helps in mapping corresponding pixels in the captured images, which corresponds to the same projector (as shown in Figure 2.16). By repeating the process for all images and cameras, the whole object is then mapped for model reconstruction.

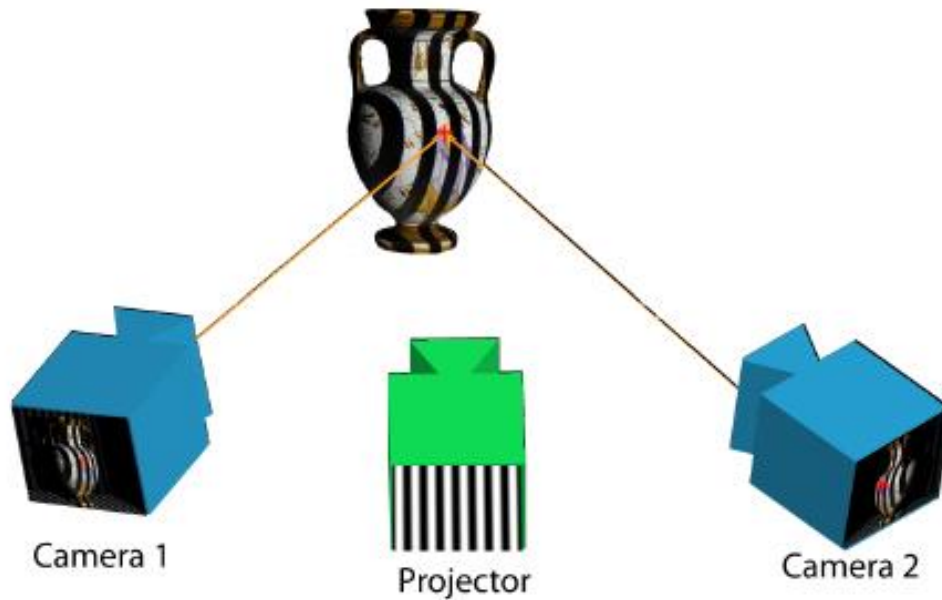


Figure 2.16 Two different cameras (1 and 2) view a 3D point in the object. The decoding aims to derive a map between pixels of two cameras, corresponding to the same 3D point (reproduced from Herakleous & Poullis, 2014).

#### *2.7.4 Reconstruction of the model*

Sansoni et al. (2009), Herakleous and Poullis (2014) and Grivon et al. (2014) state that a 3D point is computed by relating and combining all decoded captured pixels and points in both rows and columns (x and y points). This reconstruction is achieved by creating a mesh of an object through the triangulation method (see Figure 2.17). As described by Herakleous and Poullis (2014), the first step in creating a 3D mesh is by inter-connecting the points, vertices and edges to each other to produce the surface of an object (see Figure 2.18). Each point in the cloud represents the area in the surface that is lit by the related projectors' pixels.

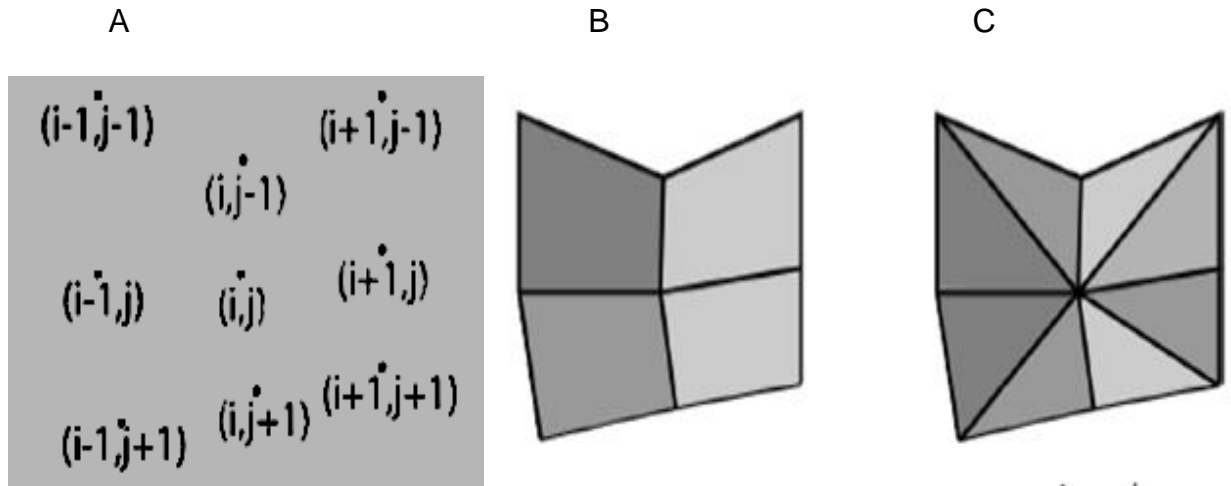


Figure 2.17 Illustration of converting point-cloud to mesh. A) 3D points, B) first level connection to form quadrilateral surfaces, C) further combining points obliquely leads to triangular surfaces (reproduced from Herakleous & Poullis, 2014).

The depth camera sensor is able to sense a depth of up to 12 feet; hence it is highly suitable for scanning in indoor rooms (Geng, 2011). The Structure Sensor™ captures 3D high-quality imagery data instantaneously, which helps to create highly reliable 3D models with high resolution in seconds. This system, based on structured-light scanning, has emerged as the most cost-effective and accurate method to capture three-dimensional geometry and appearance of a real object. Furthermore, Structure sensor™ is able to carry out 3D scanning of a subject very rapidly.



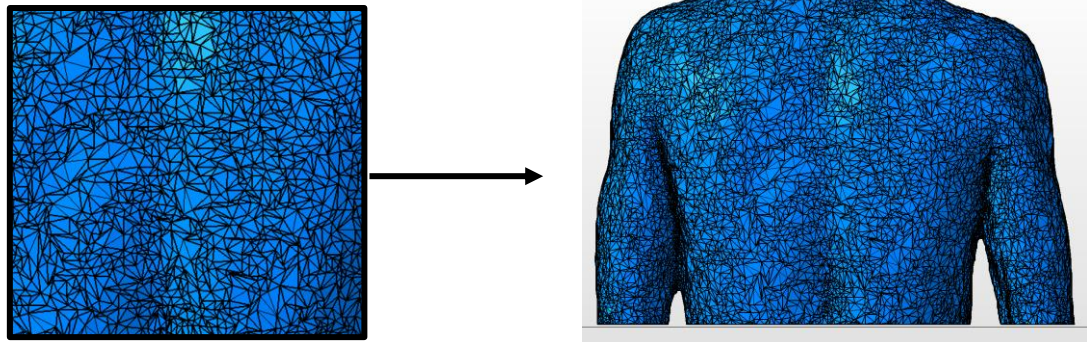


Figure 2.18 Repeating the triangulation process for all viewpoints allows aligning all the point clouds and thus recreating the entire object surface.

In summary, the accurate three-dimensional reconstruction of a surface through the triangulation method is potentially highly beneficial to study the surface of the body and back surface in patients with spinal deformities. The aim of this study was to explore the use of the novel mobile surface topography system (MSTS) system (both hardware and software) to capture and measure human back shape and whole-body posture in all three planes. Specifically, to evaluate reliability and validity of the MSTS. Furthermore, the research presented the clinical acceptability of the tool together with evaluation of personalised self-care management of patients with low-back pain.

# **Chapter 3. Measurement of Three-Dimensional Back Shape of Normal Adults Using a Novel Three-Dimensional Imaging Mobile Surface Topography System (MSTS): An Intra- and Inter-Rater Reliability Study**

### **3.1 Chapter Aim**

The main purpose of this chapter is a) to describe the MSTS equipment together with the process used to measure three-dimensional back shape and b) to assess the intra and inter-rater reliability of the posture screening MSTS in healthy adults. The validity of the MSTS will be discussed in Chapter 4.

### **3.2 Introduction and Literature Review**

Musculoskeletal (MSK) disorders are the second-most-common cause of disability worldwide, with spinal pain being one the most frequently cited symptom (Menken et al., 2000, Driscoll et al., 2014). Anderson (1999) projected the worldwide annual incidence of spinal pain in adults to be 15% together with the point prevalence to be as high as 30%. Similarly, Papageorgiou et al. (1996) identified that at least 50% of adults would have experienced an LBP episode in their life time. In the adult population, several contributing factors (varying from physical to psychosocial factors) for spinal pain have been identified (Valat et al., 1997; Yeung, 2012; Ganesan et al., 2017).

One of these major contributing factors is postural or spinal deformity (for example: scoliosis, increased thoracic kyphosis or lumbar lordosis as well as marked asymmetries between the right and left sides of the back) (Glassman et al., 2005). Significant asymmetries in back posture/deformity can lead to abnormal stress and loading on the spinal MSK structures (Davies et al., 2006). The main risk and

predisposing factors for low-back pain are primarily due to any mechanical or postural changes in the shape of the back (Glassman et al., 2005; Davies et al., 2006).

In the adolescent and older adult population, one of the most common causative factor for spinal pain is idiopathic scoliosis (2-3%) ( Bunnell, 2005; Asher and Burton, 2006; Fong et al., 2010). This three-dimensional deformity of the spine increases substantially with increasing age from adolescent to adulthood (Ohrt-Nissen et al., 2016). There is a consensus that correction of posture at an early age in school can prevent progression and reduce morphologic deformities (Torell et al., 1981; Ashworth et al., 1988; Thilagaratnam, 2007). This can, therefore, reduce the need for subsequent surgery (Morais et al., 1985).

Conservative management applied at the early stages of onset have been reported to result in better clinical outcomes particularly on pain, functional activities, appearance as well as participation in activity (Berdishevsky et al., 2016). This biomechanical-based approach addressing the 3D deformities based on the causative factors and has been actively promoted over the past few decades as a means of improving patient management ( Gallagher, 2006; Vardeh et al., 2016). Therefore, it is critical to screen larger populations at an early stage thereby helping to lower curve magnitude in the growing child at skeletal maturity.

Musculoskeletal screening is a form of secondary prevention, aimed at improving outcomes through earlier diagnosis. Willner and Uden (1982) and Soucacos et al. (1997) and suggest early detection/screening is the most-effective management of

spinal deformities. Recently, Prowse et al. (2017) identified screening as a powerful tool to identify children who might perhaps have scoliosis or at high risk of developing scoliosis. Scoliosis screening in schools is generally a subjective assessment by visual inspection of the alignment of spine to look for asymmetry of the shoulders, scapular prominence, and hips (Adobor et al., 2011). Several techniques and equipment have been proposed for the early detection of spinal deformity (Altaf et al., 2017; Kuroki et al., 2018). Zaina et al. (2009) suggest that it is of great importance that the clinical evaluation tool used to either screen or monitor spinal deformity needs to be reliable, valid, feasible and acceptable by clinicians for evidence-based practice. Furthermore, Grivas et al. (2007) and Prowse et al. (2017) and suggest that the tools used for screening need to be easy to administer, portable, safe and inexpensive and with ability to provide essential topographical back surface information thus replacing the need for repeated radiation from radiographs.

Traditionally, the gold-standard method for assessing any spinal morphologic deformity was through X-ray imaging. However due to its radiation risk, it is not frequently used in children and adults for assessment and screening purposes (Knott et al., 2014; Richards & Vitale, 2008; Dutkowsky et al., 1990). Various tactile and non-tactile techniques have been used to measure the shape of the back and spinal curvature (see Chapter 2). The problems associated with tactile and non-tactile techniques are discussed in detail in Chapter 2, Section 2.5.

In the last decade the most well-known non-tactile methods to assess the degree of deformity were structured-light techniques, such as the well known ISIS scanner

(Integrated Shape Imaging System; Turner-Smith et al., 1988) Quantec (Oxborrow, 2000; Goldberg et al., 2001) and Jenoptik Formetric (Frobin & Hierholzer, 1991; Drerup & Hierholzer, 1996). Non-tactile methods have the advantage of minimal interference with the subjects. These instruments have the capacity to produce convincing pictures, quickly.

Furthermore, most of the current tactile and non-tactile equipment is laboratory-based, very expensive, very heavy to carry around, and can only measure the back and not the whole body. All these factors significantly reduce the use of the afore mentioned equipment in school- or large-population-screening. There is a demand for a reliable, quick, low-cost, easy-to-perform, portable, mobile back-shape measurement system that will allow an extended full body and back-shape measurement in all planes (Fortin et al., 2010; Nilstad et al., 2014).

In posture screening and assessment, recent technological advancement, together with its application in biomechanics, has embraced a new mode of data capture. Capturing the 3D surface pattern using the Kinect sensor together with its clinical implications is one example (Macpherson et al., 2016). In the current study, the author evaluates the both intra and inter repeatability of using a mobile structured light sensor with a structured light pattern for building an accurate 3D human model together with its use in postural screening.

According to Fortin et al. (2011), the key postural variables commonly measured in posture screening are lumbar lordosis, thoracic kyphosis and cervical lordosis in

sagittal plane, shoulder elevation and lateral pelvic tilt in the frontal plane and scapular prominence in the transverse plane. Chen and Wei (2009) and Jang et al. (2009) suggest that these postural variables are the crucial components in maintaining balance in neutral upright alignment. It is also important to note that different authors propose different evaluation methods for measuring posture variables in posture screening.

The presented mechanism is currently being used commercially in fashion, object-scanning and 3D-printing ( D'Apuzzo, 2007; Yap & Yeong, 2014; Taneva et al., 2015), but its use in healthcare has so far been limited. The main aim of this study was to introduce a novel MSTS, together with the evaluation of the intra- and inter-rater reliability, for assessing back and full-body shape in normal subjects. The research question guided in the study is in the following: is there any variation in intra-rater reliability and inter-reliability of the posture and back shape measurement variables by using MSTS?

The originality of this tool lies in the fact that 1) the researcher has developed the tool from previously available software and mobile applications that were used for other purposes. 2) To the authors' knowledge, no research studies have to date used this tool for the measurement of posture/back shape; together with the measurements of its reliability.

### 3.3 Methodology

#### 3.3.1 Sample Characteristics

A convenience sample of 16 young males (age:  $25 \pm 5.6$  years, height:  $172 \pm 5.3$  cm, weight:  $69 \pm 8.6$  kg) participated in this study (refer Table 3.1). The participants were healthy asymptomatic subjects without any musculoskeletal pain or pre-existing leg or spinal abnormalities.

Table 3.1. Descriptive statistics of both participants and raters.

	n	Gender	Age (Years) Mean (SD)	Height (Cms) Mean (SD)	Weight (Kgs) Mean (SD)	Profession	Years of Experience Mean (SD)
Participants	16	Male	25 (5.6)	172 (5.3)	69 (8.6)	-	-
Raters	5	Male (4)	36 (7.6)	-	-	Physiotherapist (2)	10(7.0)
		Female (1)	32	-	-	Sports Therapist (2)	8.5(4.9)
						Bio mechanist (1)	2

Prior to testing, all participants were informed about the study both orally and in writing and completed consent forms before participating. Five raters (four males and one female) took part in the inter-rater reliability study. The mean clinical experience of the raters were  $10 \pm 7$  years for the physiotherapists and  $8.5 \pm 4.9$  years for the sports therapists and 2 years for the biomechanist. The summary of the descriptive statistics



of participants in each group is seen in Table 3.1. The protocol and the procedure for the current study received ethical clearance from Teesside University (February 2016).

### *3.3.2 Equipment*

A commercially available iPad based 3D mobile scanning tool 'Structure Sensor™' (Figure 3.1a) was used to capture the participants' back and whole-body shape. Structure Sensor (Figure 3.1b) is a 3D sensing accessory that uses an eye-safe infrared laser to project invisible structured infrared light onto an object and captures it with an infrared camera to produce a depth map (Figure 3.1c) (Structure Sensor, 2016). RGB-D cameras consist of an infrared (IR) projector, which emits a known pattern of structured IR light, an IR camera and an RGB camera.

As explained in Chapter 2, the estimation of depth is based on the internal triangulation process. The IR structured light source emits a constant pattern of speckles projected onto the back and body. When a speckle is projected onto an object, whose distance to the sensor is smaller or larger than that of the reference plane, the position of the speckle in the infrared image will be shifted towards the direction of the baseline, between the IR projector and the projection centre of the IR camera. These shifts are measured for all speckles by a simple image correlation process to generate a disparity map (see Figure 3.2).

For each pixel the distance to the sensor can then be retrieved from the corresponding disparity pixel (Alhwarin et al. 2014). This pattern is acquired by the infrared camera and is correlated against a reference pattern.

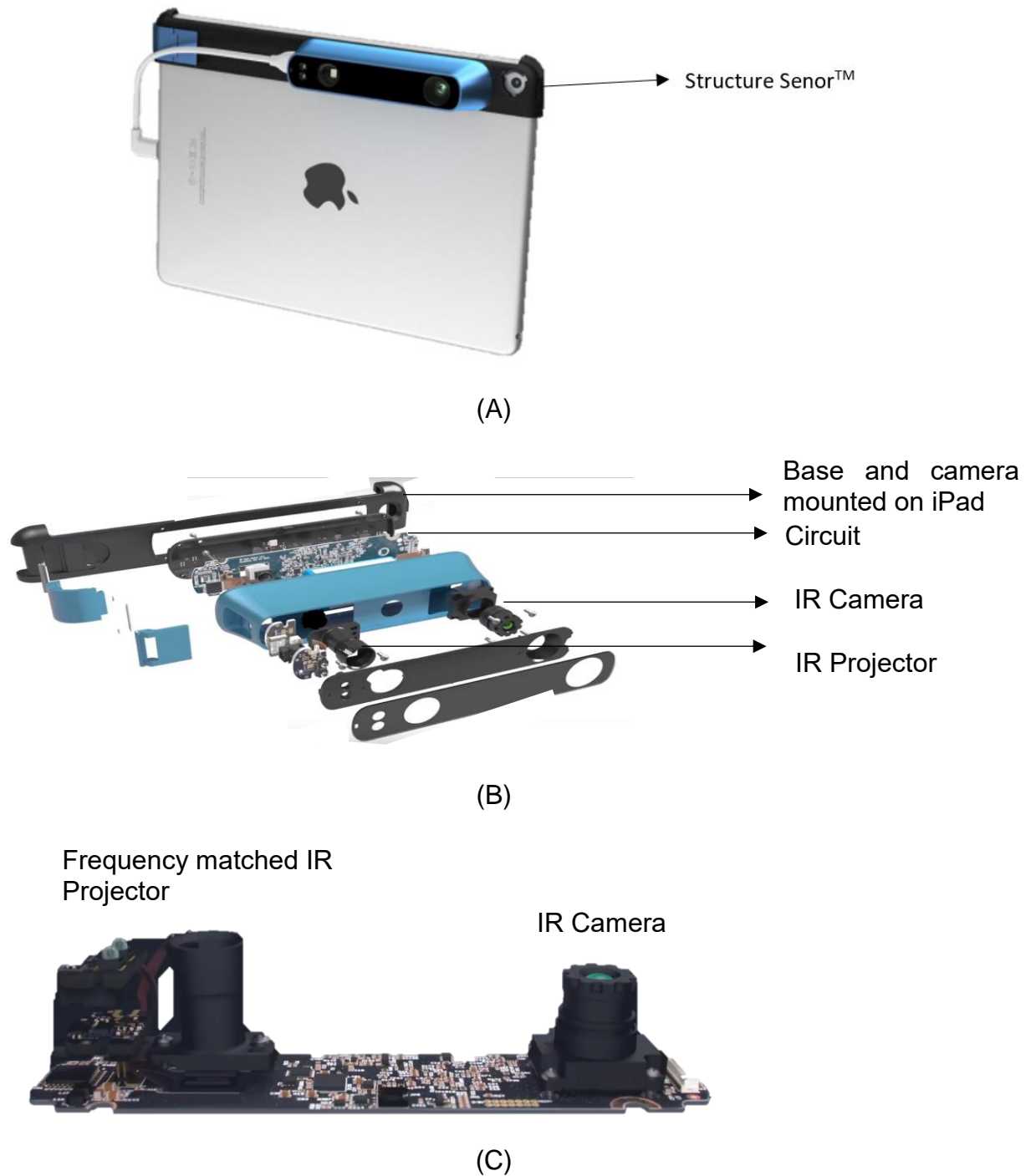


Figure 3.1 Equipment used in data capture (3D depth surface topography imaging tool). A) iPad along with Structure Sensor™; B) Tear down of structure Sensor; C) Structure Sensor circuit with camera and projector. b) and c) reproduced from <https://www.allaboutcircuits.com/news/teardown-tuesday-occipital-3d-structure-sensor/> (Hughes, 2017).

The reference pattern is generated by capturing a plane at a known distance from the sensor and is stored in the camera's memory. This sensor along with the normal iPad camera provides real-time anatomical landmarks and reconstructs the whole back and body shape using the triangulation method (Poredos et al., 2015) (see Figure 3.3).

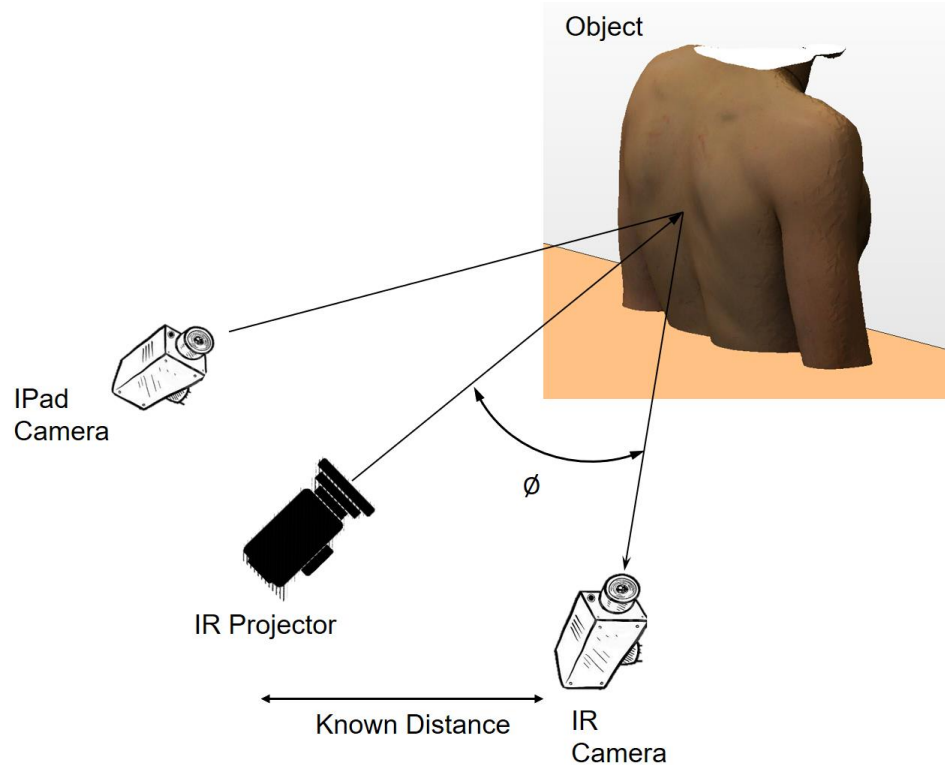


Figure 3.2 Illustration of structured light projection system. The IR projector projects the infrared light pattern generated in the Structure Sensor™ system. The IR camera records the structured light pattern projected on the object surfaces. The iPad RGB camera captures the colour and texture of the surface. ' $\Phi$ ' is the angle between the projection and viewing directions.

This method is popular due to its robustness for point cloud reconstruction. There are multiple reasons for greater accuracy. Firstly, there is the capability of the MSTs to reduce the influence of the ambient light and part reflection (Tortschanoff et al., 2014). Secondly, a structured-light figure, when combined with stereo photogrammetry to

measure the light figure precisely, for generation of an accurate 3D plan (Karatas & Toy, 2014). Thirdly, the mobile surface-topography system triangulates depth by solving a correspondence problem between each camera and projector pixel. This is often framed as a local stereo-matching task, correlating patches of pixels in the observed and reference image. Moreover, the requirement for accurate performance is achieved by the primitive pattern where the pixel-to-pixel calibration strategy is utilized to increase the accuracy of the surface capture system (Xu et al., 2011).

In the current study, the data (3D model) that was collected was realigned and processed in the open-source software called Netfabb Basic™. This software was originally designed for the 3D-model-building and printing in the fashion and civil engineering industries as well as the mechanical industry. The author adapted this tool for use in the assessment of posture and back shape.

### 3.3.3 Procedure

For each subject, five trained raters (two physiotherapists, two sports therapists and a biomechanist) individually measured three trials of standing back and body posture on two separate occasions to enable both intra and inter rater reliability to be calculated. Each rater completed the palpation of bony landmarks and placed nineteen 10mm spherical reflective markers on the following anatomical landmarks: spinous process (C2, C4, T1, T4, T7, T12, L3 and S1), occiput, right and left acromion process, anterior superior iliac spine (ASIS), posterior superior iliac spine (PSIS), knee inter articular joint line and calcaneus (see Figure 3.4).

Anatomical reference points, for example the midpoint of the patella and ankle joint line, were also used for angle calculation. Following the familiarization procedure, each participant's standing 3D back shape and whole body were captured manually by the raters with the commercially available iPad camera and Structure Sensor™. A footplate was created with marks to standardize foot position and a chart was placed on the wall in front of the subject with markers to focus on. Previous work has found improvements in repeated measurements with foot and vision standardization (Batavia, 2001; Warren et al., 2002; Braun & Amundson, 1989).

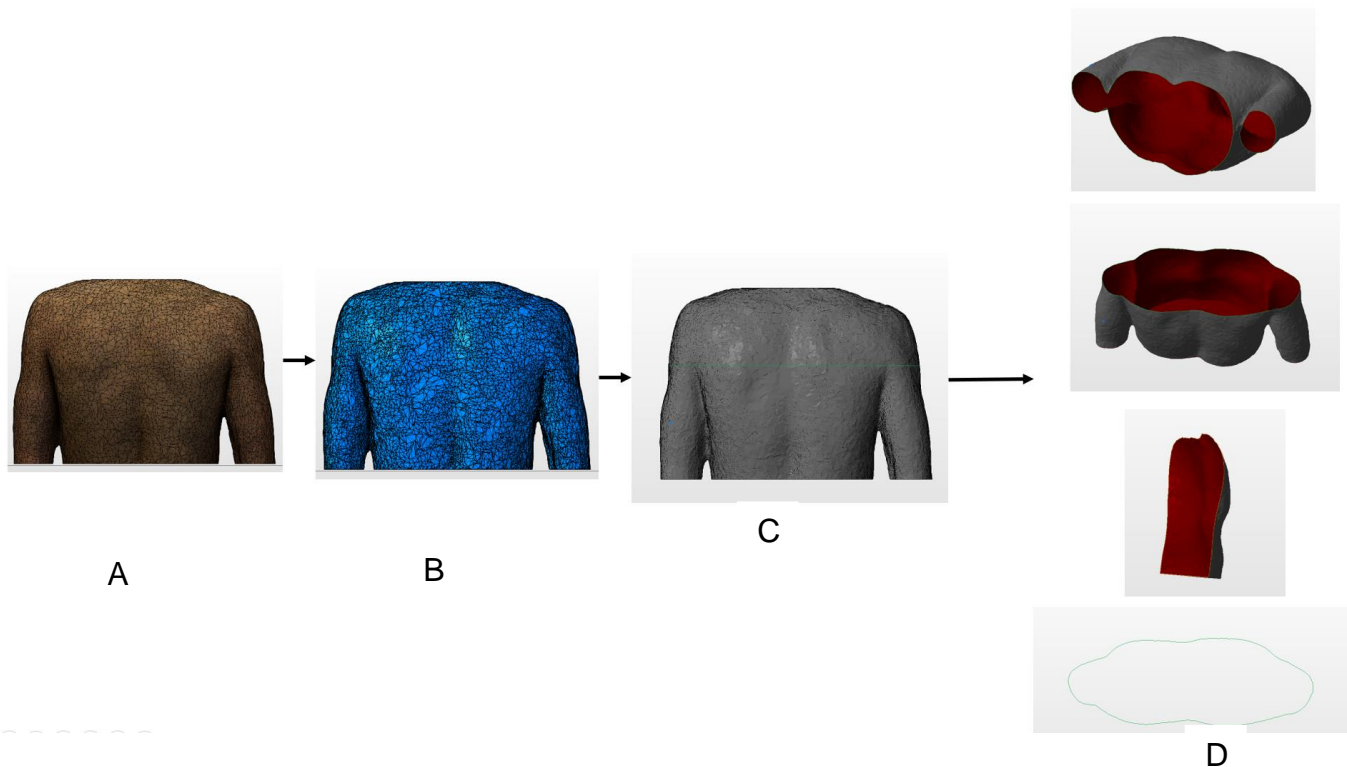


Figure 3.3 Result (visualisation) of a reconstructed 3D object from projected structured light trajectories using the Structure Sensor™. A) Surface reconstruction thorough triangulation process B) Texture-mapped model C) Reconstructed 3D model and D) Visualisation of a 3D model in different perspectives (bottom, top, cross section and outline border).



Figure 3.4 A participant in standing with anatomical marker set

In order to capture the data, the rater walked around the subject with the camera pointing towards the subject in a 360 degrees circle at three different heights (participant's shoulder, pelvic and knee). Throughout the data collection, the distance between the camera and the model was between 0.5 to 1 metres. In order to limit the variability associated with the participants' positions and standardize the data collection process, two reference lines for foot placement were drawn on the floor at the X and Y axis (Figure 3.5).

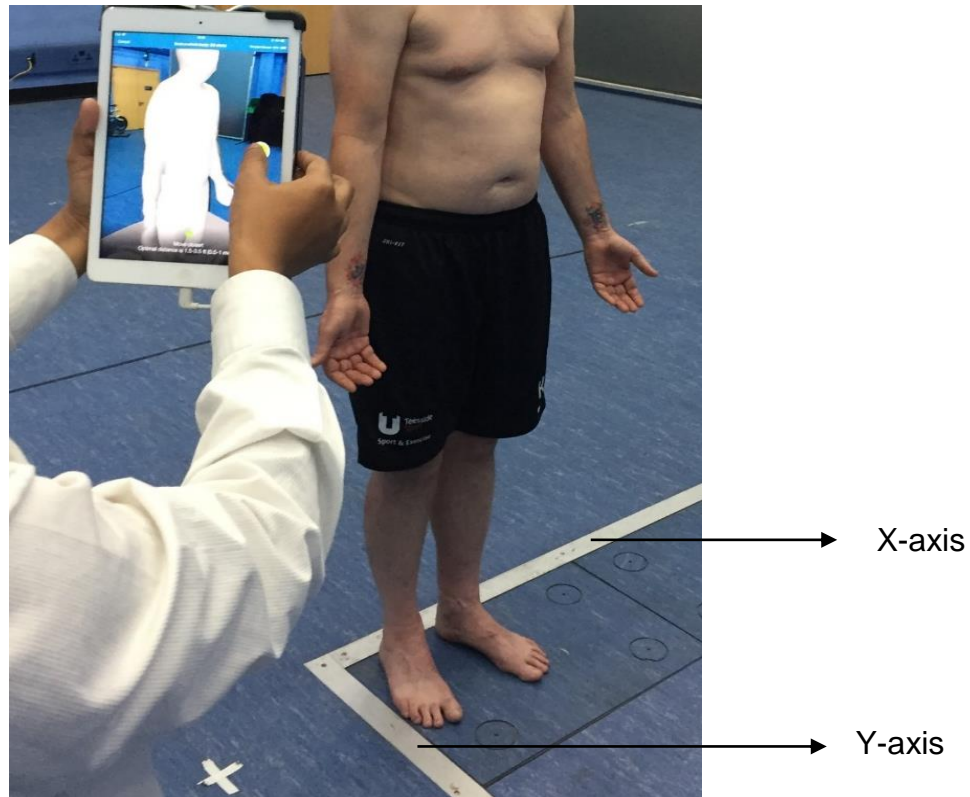
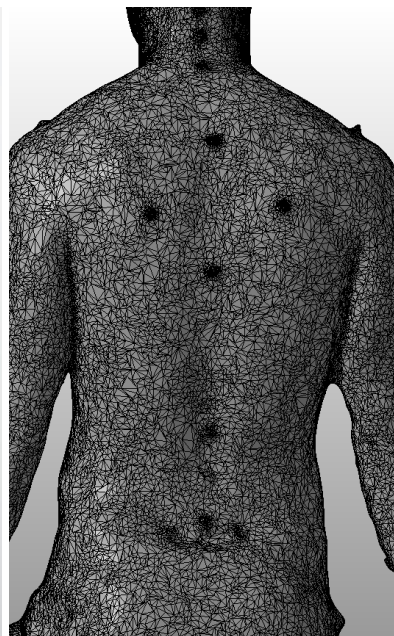


Figure 3.5. A participant standing with feet placement towards X and Y axis.

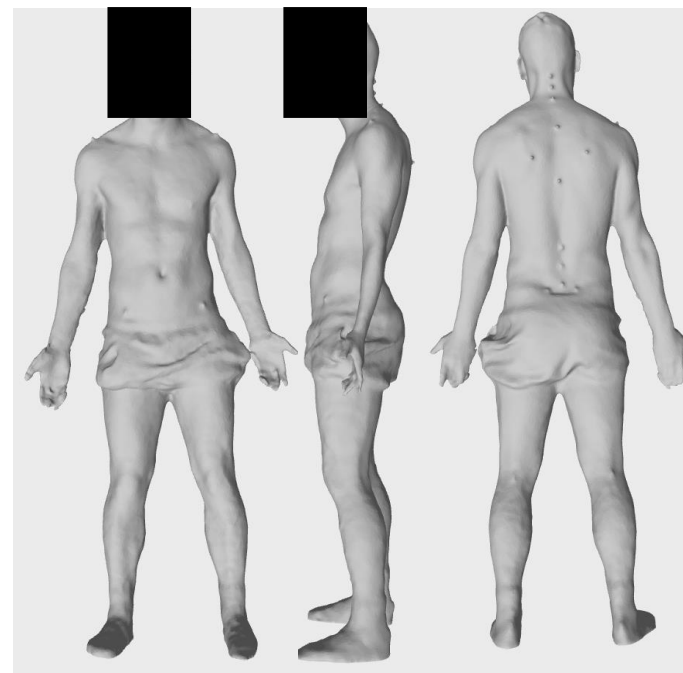
Participants were asked to look straight ahead and stand in a comfortable position. Data acquisition followed a specific sequence as explained above and took 30 to 40 seconds per trial. To avoid any bias in the selection of a trial and to obtain a better estimate of the raters' true score, the mean of three trials for each rater was used to determine the level of reliability. All the data captured through the 3D imaging MSTS was uploaded, realigned and processed through the open-source software called Netfabb Basic™ (see Figure 3.6 A). With the use of this software, nine postural variables and angular displacements, described in Table 3.2, were individually measured by the raters.



A

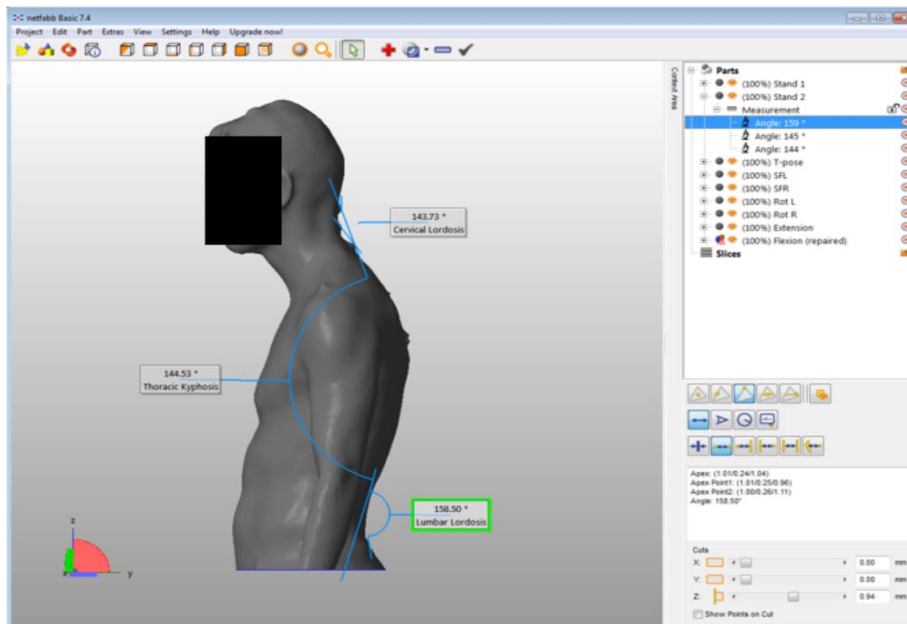


B

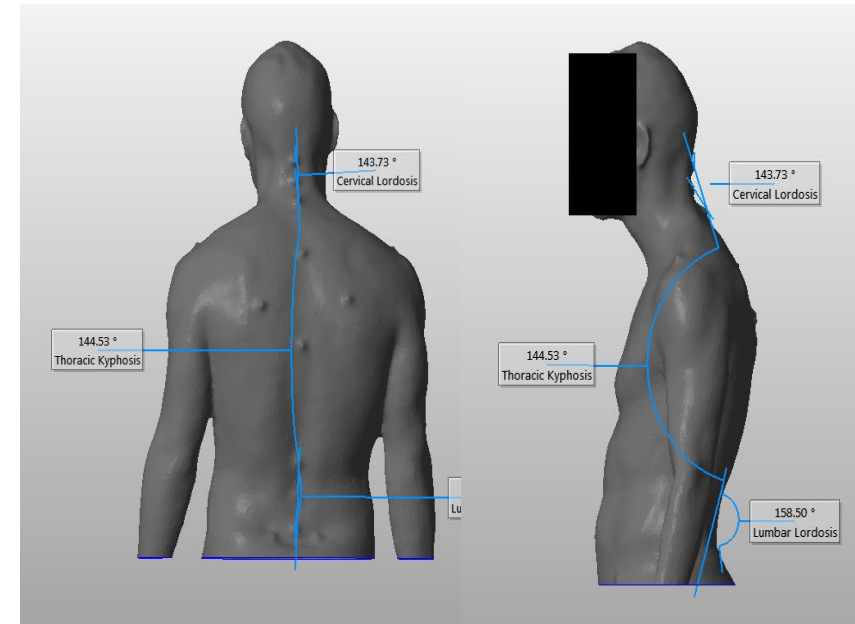


C





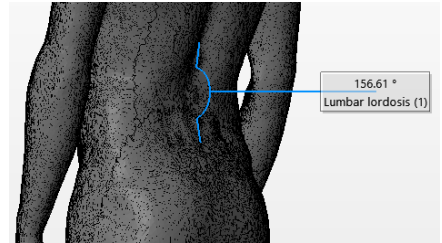
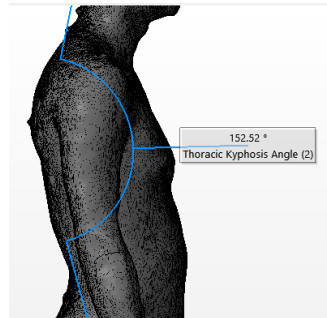
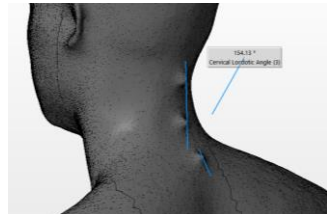
D



E

Figure 3.6 A - Placement of markers; B - Data collection (triangulation) - Structured light and invisible infrared dots generate high resolution 3D geometric pattern in seconds (Valgma, 2016); C - 3D model; D - Uploading and Realignment of the 3D Model in Netfabb™ for Analysing Posture in all 3 Planes. The data were then processed in the software and back shapes are manually measured by both the raters; E - Measurement of all types of postural objective measures in all planes.

Table 3.2 Definitions of the nine postural angles measured by the raters

Angle	Description	Picture
<b>Lumbar Lordosis Angle</b>	The angle formed by lines drawn through upper end vertebrae of the curve to the apex of the lordosis (T12) and the apex through S1	
<b>Thoracic Kyphosis Angle</b>	The angle formed by lines drawn through the upper end-vertebra of the curve (T1) to the apex of the kyphosis and the apex through the lower end-vertebra of the curve (T12)	
<b>Cervical Lordosis Angle</b>	The angle formed by lines drawn through C2 and C4 and through C4 and T1	

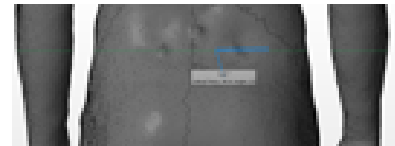
**Shoulder  
Elevation in  
Angles**

The angle formed by a line drawn between the left and right acromion process markers, and the angle of this line to the horizontal



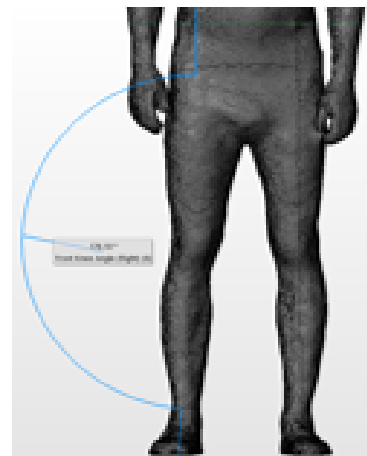
**Lateral  
Pelvic Tilt in  
Angles**

The angle formed by the horizontal and by the line joining the two PSIS



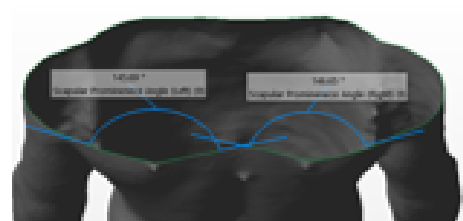
**Frontal  
Knee Angle  
(Right)**

The angle of intersection from a line drawn between the ASIS and the mid-pole of the patella, and a second line drawn between the mid-pole of the patella and the talus



**Frontal  
Knee Angle  
(Left)**

The angle formed by lines drawn through T7 vertebrae of the curve to the apex of the scapula prominence and the lower end angle of the curve (mid line to axilla)



**Scapular  
Prominence|  
(Left)**

### **3.4 Data Analysis**

The intraclass correlation coefficient test (ICC) has been widely used in clinical studies to evaluate inter-rater and intra-rater reliability (Leach et al., 2003; Clare et al., 2003; Owens et al., 2004; Cramer et al., 2010; Russell et al., 2012; Houweling et al., 2014; Battaglia et al., 2014; Koo & Li, 2016). Furthermore, Koo and Li (2016) suggest that the intraclass correlation coefficient (ICC) is an appropriate statistical test to assess both the intra- and inter-reliability in clinical studies. Another prominent application of the ICC is the assessment of consistency or reproducibility of quantitative measurements made by different observers measuring the same quantity (Portney & Watkins, 2000; Bruton et al., 2000).

In the current study, intra-class correlation (ICC) was used to test the intra-rater and inter-rater reliability of posture and back shape variables together with the standard error of measurement. The ICC test was calculated by using mean squares (ie, estimates of the population variances based on the variability among a given set of measures) obtained through analysis of variance. Based on the thresholds provided by Portney and Watkins (2000), poor intra-class correlation coefficients are interpreted as fair or below fair in a relationship ( $< 0.50$ ). Acceptable ICC's are deemed reliable and valid if they are found to be moderate to good ( $0.50 - 0.75$ ) or good to excellent ( $> 0.75$ ). To further examine the agreement between the trials and the raters for each posture variable, 90% confidence intervals (CI) (limits of agreement, LOA) were used. The LOA method uses the mean difference between the measures plotted against the standard deviation of the differences (Atkinson & Nevill, 1998).

It has been argued by Rankin & Stokes, 1998 that the information derived from ICC coefficients alone has limited utility within clinical practice, as it does not define the magnitude of disagreement between measurements. Previous researchers (Roebroeck et al., 1993; Rankin & Stokes, 1998) have shown that the interpretation of reliability data is more meaningful when ICC analysis is complemented with another test, the standard typical error (STE; the standard deviation of differences within a pair of raters or trials), which was performed in the present study. The STE values are more useful for the clinician in terms of decision-making because they describe the error in the same unit of measurement and serve to calculate the minimal detectable difference between two measurements (Roebroeck et al., 1993). As STE is a standard deviation, the usual scale of standardized effect sizes was halved to interpret STE magnitudes (Smith & Hopkins, 2011). These thresholds are 0.1 for a small error, 0.3 for a moderate error and 0.6 for a large error. The author used a customized spreadsheet for all calculations of ICC and STE (Hopkins, 2015).

### **3.5 Results**

#### *3.5.1 Intra-rater Reliability*

The summary of the intra-rater reliability results for each of the postural variables measured by the MSTS are presented in Table 3.3 and 3.4. The results of the sagittal, frontal and transverse plane *are* presented in the following section below.

### *Sagittal Plane Variables*

The mean lumbar lordosis angle between three trials was 27.37 degrees whereas the thoracic kyphosis was 25.36 degrees and the cervical lordosis was 31.12 degrees (see Table 3.3). The overall change in the mean difference between the trials for all the sagittal plane variables were ranged between 1.45 and 2.43 degrees (see Table 3.4). The reliability of the sagittal plane variables demonstrated excellent intra-rater reliability (ICC values ranging from 0.87 to 0.94). The sagittal plane variables also showed good LOA (90% CI) with ranges from 0.88 to 0.97 for lumbar lordosis, 0.74 to 0.94 for thoracic kyphosis and 0.84 to 0.96 to cervical lordosis angle. As seen in Table 3.3, the standardized typical error (STE) for the sagittal plane variables indicated good to moderate intra-rater reliability (0.26 to 0.39).

### *Frontal Plane Variables*

The mean shoulder elevation angle between three trials was 3.99 degrees whereas the lateral pelvic tilt was 3.91 degrees and the frontal knee angle was 4.75 degrees in right side and 3.94 degrees for the left side (see Table 3.3). The overall change in the mean difference between the trials for all the frontal plane variables were ranged between 0.79 and 1.21 degrees (see Table 3.3). The reliability of the frontal plane variables demonstrated moderate to good intra-rater reliability (ICC values ranging from 0.60 to 0.93). The frontal plane variables (frontal knee angle) showed good to excellent LOA (90% CI) with ranges from 0.70 to 0.98, whereas the shoulder elevation angle demonstrated low to moderate LOA (90% CI) with ranges from 0.24 to 0.84. The Standardized Typical Error (STE) indicated moderate intra-rater reliability (0.30 to

0.57) for lateral pelvic tilt and frontal knee angle and low (0.67) for shoulder elevation angle (see Table 3.3).

#### *Transverse Plane Variables*

The mean shoulder prominence angle between three trials was 30.27 degrees for the right side and 28.6 degrees for the left side. The overall change in the mean difference between the trials for the transverse plane variables ranged between 1.37 and 1.85 degrees. The reliability of the transverse plane variables demonstrated excellent intra-rater reliability (ICC values ranging from 0.93 to 0.99). The transverse plane variable (Scapular prominence angle) showed good to excellent LOA (90% CI) with ranges from 0.83 to 0.99. The Standardized Typical Error (STE) indicates good to moderate intra-rater reliability (0.17 to 0.31) for both the right and left scapular prominence angles.

Table 3.3 Mean, standard deviation (SD), minimum and maximum values of postural variables in all planes.

	Variables (In degrees)	Trial 1		Trial 2		Trial 3		Overall mean of all three trials	SD of all three trials	Min	Max
		Mean	SD	Mean	SD	Mean	SD				
Sagittal Plane Variable	Lumbar lordosis angle	27.3	5.7	27.4	5.9	27.4	5.4	27.37	5.41	18.66	34.92
	Thoracic kyphosis angle	25.3	5.9	26.6	5.8	24.3	6.6	25.36	5.6	13.55	34.08
	Cervical lordosis angle	30.6	7.5	31.9	7.1	30.9	8.8	31.12	7.33	22.49	48.33
Frontal Plane Variable	Shoulder elevation in angles	3.9	2.2	3.9	1.8	4.2	1.6	3.99	1.56	1.71	7.04
	Lateral pelvic tilt in angles	3.6	2.4	3.9	1.9	4.3	1.3	3.91	1.62	2.05	7.64
	Frontal knee angle (Right)	4.7	3	4.9	3.4	4.6	3	4.75	2.88	0.96	9.12
	Frontal knee angle (Left)	3.8	2	4	2.1	3.9	1.8	3.94	1.77	1.23	6.72
Transverse Plane Variable	Scapular prominence (right)	30.2	6.2	30	5.2	30.6	6.7	30.27	5.57	21.14	39.73
	Scapular prominence (left)	27.9	8.7	28.9	8.1	28.9	7.9	28.6	7.71	16.12	40.68



Table 3.4 Intra-rater reliability of posture variables measured using the MSTs.

	Variables	Overall change in mean difference between trials (in degrees); ( $\pm 90\%$ CI)	ICC R value; ( $\pm 90\%$ CI)	Standardized Typical Error
Sagittal Plane Variables	Lumbar lordosis angle	1.45 (1.18 to 1.94)	0.94 (0.88 to 0.97)	0.26 (Small)
	Thoracic kyphosis angle	2.37 (1.93 to 3.16)	0.87 (0.74 to 0.94)	0.39 (Moderate)
	Cervical lordosis angle	2.43 (1.98 to 3.24)	0.92 (0.84 to 0.96)	0.30 (Moderate)
Frontal Plane Variables	Shoulder elevation in angles	1.21 (0.94 to 1.78)	0.60 (0.24 to 0.84)	0.67 (Large)
	Lateral pelvic tilt in angles	0.95 (0.73 to 1.38)	0.73 (0.44 to 0.90)	0.57 (Moderate)
	Frontal knee angle (right)	0.94 (0.72 to 1.37)	0.93 (0.84 to 0.98)	0.30 (Moderate)
	Frontal knee angle (left)	0.79 (0.61 to 1.16)	0.87 (0.70 to 0.96)	0.40 (Moderate)
Transverse Plane Variables	Scapular prominence (right)	1.85 (1.42 to 2.70)	0.93 (0.83 to 0.98)	0.31 (Moderate)
	Scapular prominence (left)	1.37 (1.06 to 2.00)	0.98 (0.95 to 0.99)	0.17 (Small)

### *3.5.2 Inter-rater Reliability*

The summary of the inter-rater reliability for each of the postural variables measured by the MSTs are presented in Table 3.5.

#### *Sagittal Plane Variable*

The overall change in the mean difference between the raters ranged between 2.80 to 5.03 degrees for the sagittal plane variables. The reliability of the postural sagittal plane variables demonstrated good to moderate inter-rater reliability (ICC values ranging from 0.56 to 0.79). The STE score for the lumbar lordotic angle demonstrated good inter-rater reliability with low error of 0.48, whereas thoracic kyphosis and cervical lordosis demonstrated large errors between 0.63 and 0.69 score (see Table 3.5)

#### *Frontal Plane Variable*

The overall change in the mean difference between raters ranged between 1.35 to 2.14 degrees for the frontal plane variables. Moderate to low reliability was shown for frontal plane variables (shoulder elevation, frontal knee angle and pelvic tilt) (ICC values ranging from 0.09 and 0.40) (see Table 3.5). These variables also showed very low LOA (90% CI) ranging between -0.06 and 0.52 with large STE scores (0.70 to 0.96).

#### *Transverse Plane Variable*

For the transverse plane variable, the shoulder prominence (SP), overall change in the mean difference between the raters ranged between 3.70 to 4.67 degrees (see Table 3.5). The reliability of the transverse plane variables demonstrated good to moderate

inter-rater reliability (ICC values were 0.67 (left SP) and 0.75 (right SP). The transverse plane variable (Scapular prominence angle) showed moderate to good LOA (90% CI) with ranges from 0.49 to 0.87, together with a poor (large) STE score (0.60) for the left SP and moderate (0.53) for the right SP.

Table 3.5. Inter-rater reliability of posture variables measured using MSTs.

	Variables	Overall Change in Mean difference between raters (in degrees); ( $\pm 90\%$ CI)	ICC R value; ( $\pm 90\%$ CI)	Standardized Typical Error
Sagittal Plane Variables	Lumbar Lordosis Angle	2.80 (2.40 to 3.48)	0.79 (0.65 to 0.90)	0.48 (Moderate)
	Thoracic Kyphosis Angle	3.89 (3.33 to 4.83)	0.56 (0.36 to 0.75)	0.69 (Large)
	Cervical Lordosis Angle	5.03 (4.30 to 6.24)	0.63 (0.44 to 0.80)	0.63 (Large)
Frontal Plane Variables	Shoulder Elevation in Angles	1.36 (1.17 to 1.69)	0.26 (0.07 - 0.52)	0.87 (Large)
	Lateral Pelvic Tilt in Angles	1.35 (1.15 to 1.67)	0.09 (0.07 - 0.34)	0.96 (Large)
	Frontal Knee Angle (Right)	2.10 (1.79 to 2.60)	0.40 (0.20 - 0.64)	0.70 (Large)
	Frontal Knee Angle (Left)	2.14 (1.83 to 2.66)	0.10 (-0.06- 0.35)	0.89 (Large)
Transverse Plane Variables	Scapular prominence (Right)	3.70 (3.16 to 4.59)	0.75 (0.60 - 0.87)	0.53 (Moderate)
	Scapular prominence (Left)	4.67 (4.00 to 5.80)	0.67 (0.49 - 0.82)	0.60 (Large)

### **3.6 Discussion**

#### *3.6.1 Summary*

The objective and evidence-based evaluation of postural parameters is essential for health-care practitioners to enable both the quantitative assessment of spinal conditions, as well as the longitudinal evaluation of clinical interventions. The current study evaluates the use of a portable, 3D MSTs to quantify posture during standing. This innovative postural screening tool is designed for use by healthcare professionals in both clinical and non-clinical settings. To the best of the author's knowledge, this is the first study to report the intra-rater and inter-rater reliability of an infra-red structured light mechanism that captures the 3D human body surface. The results indicated good to excellent intra-rater and good to moderate inter-rater reliability for measuring 78% (7 out of 9) of postural variables with an ICC ranging from 0.70 to 0.98. The remaining 22% of variables (2 out of 9; lateral pelvic tilt and right frontal knee angle) showed moderate to low inter and intra-rater reliability with ICC's ranging from 0.26 to 0.79.

While the STE values in the current study had a wide range of scores having a large magnitude, the author believes it is important to acknowledge that the overall change in means between trials were very low ( $0.94 - 2.43^\circ$  for intra-rater and  $1.35 - 5.03^\circ$  for inter-rater reliability). In biomechanical assessments, these mean difference scores of 5 or less than 5 degrees are within the standard acceptable range of errors (Winter, 2009). For example, Akizuki et al. (2016) demonstrated that intra-rater reliability less than 5 degrees of error is acceptable in measuring knee flexion using universal goniometer in healthy adults. In another study by de Carvalho et al. (2012) evaluated

the intra- and inter-examiner reliability and reproducibility of goniometry in relation to photogrammetry of hand, comparing the angles of thumb abduction, PIP joint flexion of the second finger and MCP joint flexion of the fifth finger. The results of the study reveal that no significant differences were found between the groups for most of the measurements and any difference in angle less than 5 degrees is acceptable in biomechanics study.

In the current study, an overall comparison of change in means and STEs do, however, show an apparent contradiction: the former (difference in means) indicates clinically consistent very small differences, whereas the latter (STE scores) varies considerably. The results of the current study were similar for both the intra-rater as well as the inter-rater reliability for most posture variables in the sagittal, frontal and transverse planes. In the following section each postural variable in each plane is discussed in turn.

### *3.6.2 Sagittal Plane Variables*

The overall 3D MSTS demonstrated excellent to good reliability results for measuring lumbar lordosis, thoracic kyphosis and cervical lordosis. Each variable is discussed in turn below.

#### *Lumbar Lordosis (LL)*

Adams et al. (1999), Chen and Wei (2009) and Jang et al. (2009) infer that LL is a crucial component in maintaining sagittal balance or neutral upright sagittal alignment of spine. Furthermore, Jang et al. (2009) and Been and Kalichman (2014) identify that the measurement of the LL angle as a major sagittal-plane variable is due to its wide use in assessing postural abnormalities. Although the LL measurement method and

its angle are widely reported in the literature, different authors propose different evaluation methods and describe different factors that influence the lumbar lordotic angle. Cil et al. (2005), Suzuki et al. (2010), Schuller et al. (2011) and Been and Kalichman (2014), suggest that the most common method for measuring LL is by the angle formed between the five lumbar segments (L1 to L5) (as shown in Figure 3.7).

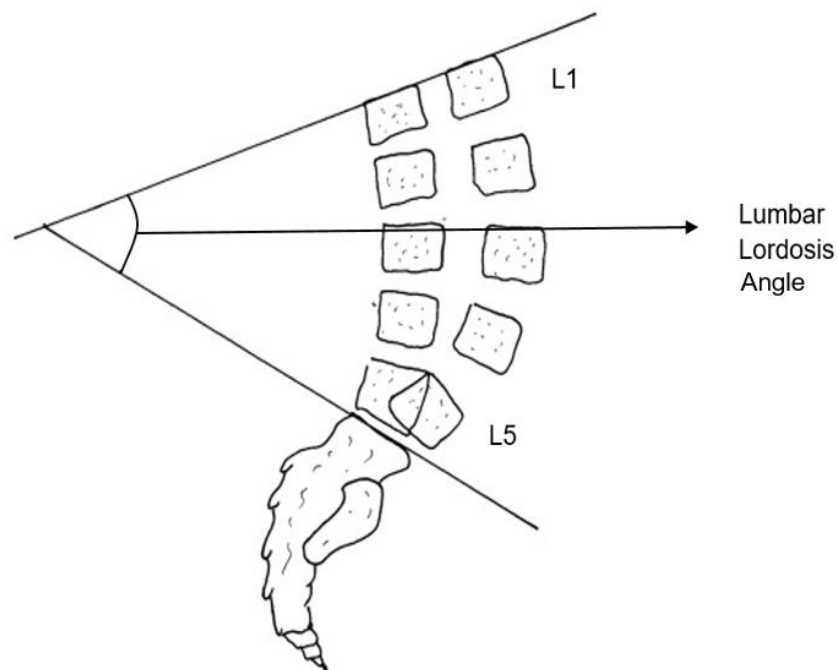


Figure 3.7. Lumbar lordosis curve measured between the superior endplate of L1 and S1 vertebrae (reproduced from Been & Kalichman, 2014).

However, Neuschwander et al. (2010) propose the Cobb method (line connecting superior endplate of L1 and S1) to measure LL. Mac-Thiong et al. (2007) however interpret the radian of the 180 degrees arc formed between L1 and S1 vertebrae (as

seen in Figure 3.8), while Gigilo and Volpon (2007) use the line intersecting the spinous process of L1 and L5.

In the current study the lumbar lordotic angle (as seen in Table 3.2) is formed by the intersection of lines drawn through T12 spinous process to the apex of the lordosis (L3 vertebrae) and the apex through the S1 spinous process. The mean lumbar lordotic angle ( $27.37 \pm 5.4$  degrees) presented in the current study is similar to that from previous studies using the same calculation. Vialle et al. (2005) reported that the LL angle measured by the radiography method can widely vary between 14 degrees to 69 degrees. Similarly, Danielson and Willen (2001), Been et al. (2010) and Hong et al. (2017) presented LL angles ranging from 31.1 degrees to 42.9 degrees in healthy normal adults and patients with low back pain. Further, Pezzan et al. (2011) reported a LL angle in an adolescent female ( $n = 50$ ) normal healthy population as  $40 \pm 5.3$  degrees when measured through the photographic method.

The large variation in the LL angle may be due to several inter-related factors. For instance, the alignment of the spine is influenced by both the balance as well as the position of the upper trunk such as thoracic kyphosis, occupational loading, athletic training and physical fitness (Vialle et al., 2005; Been & Kalichman, 2014 and Bailey et al., 2016). Several non-mechanical factors such as age, sex, height and body mass; genetic factors have also be shown influence LL (Been & Kalichman, 2014).

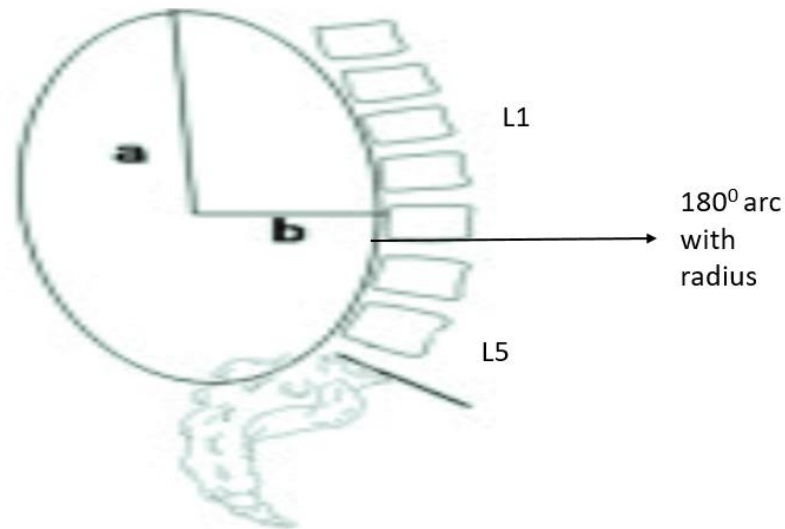


Figure 3.8. Lumbar lordosis curve measured using 180-degree arc between L1 and S1 vertebrae (adapted from Been & Kalichman, 2014).

The measurement of LL using the 3D MSTS demonstrated excellent intra-rater reliability (ICC value of 0.94) and good inter-rater reliability (ICC value of 0.79). The results of the current study are similar to previous studies using photography, radiography and Moiré topography methods where a mean intra class correlation coefficient (ICC) > 0.98 was found ( Grivas et al., 1997; Dunk et al., 2004; McAlpine et al., 2009; Fortin et al., 2012; Frerich et al., 2012).

Poussa et al. (2005) and Penha et al. (2008) demonstrated the reliability of the photogrammetry method for LL measurement to be relatively high (interobserver ICC with 0.70–0.85) in an adolescent population. Similarly, Fortin et al. (2012) presented the postural assessment of the back based on the calculation of body angles and



distances on photographs demonstrated good inter-rater and intra-rater reliability (ICC > 0.99).

In contrast, a recent study by Sedrez et al. (2016) demonstrated the reliability of the flexicurve to measure LL in children and in the young adolescent population (n = 40). The reliability was moderate in terms of intra- (ICC = 0.50;  $p < 0.01$ ) and inter-rater reliability (ICC = 0.56;  $p < 0.01$ ). Similarly, Vrtovec et al. (2009) identified that the reliability was not as good as radiologic methods (interobserver ICC is >0.87). According to the authors, the results may be due to the large variation in the participants' age (5-15 years).

Furthermore, in the current study, together with good reliability, the absolute changes in mean values across trials that achieved 90% confidence limits was as low as  $1.45^\circ$ . This is similar to the surface topography method (Frerich et al. 2012), demonstrated with a  $2.1^\circ$  difference between trials. The good intra-rater reliability (retest reproducibility) with small STE values for the measurement of LL variable makes the MSTS an ideal tool to use within a clinical environment; one that is comparable to photogrammetry and radiography.

### *Thoracic Kyphosis (TK)*

In the current study, the TK angle (as seen in Table 3.2) is formed by lines drawn through the upper end vertebrae of the curve (C7 spinous process) to the apex of the kyphosis and the apex through the lower end vertebrae of the curve (L1 spinous process). The mean TK angle ( $25.3 \pm 5.6$  degrees) presented in the current study was similar or marginally lower than in previous studies. The measurement of the spinal

angle by the radiographic method is considered as the gold-standard method for clinical assessment (Schwab et al., 2002). Fon et al. (1980) reported the normal TK angle to be  $26.27 \pm 8.12$  degrees in the age group 20 – 29 years and  $29.04 \pm 7.93$  in the age group 30 – 39 years. Sedrez et al. (2016) presented the mean TK angle as measured by the flexicurve to be as high as  $37.5 \pm 9.3$  degrees in children. Similarly, Czaprowski et al. (2017) reported a mean of  $33.1 \pm 11.3$  degrees when TK was measured by an inclinometer within a large sample ( $n = 193$ ; age group 10 - 14). In addition, Morais et al. (2016) reported  $31.40 \pm 6.90$  degrees when TK was measured by the photographic method in a small sample ( $n = 15$  adults). Furthermore, Kaya et al. (2017) presented a non-radiographic method of measurement using the Spinal Mouse. Higher ranges for the mean TK angle ( $38.35 \pm 9.19$ ) in an adult population ( $n = 53$ ) were demonstrated. It is important to note that the variability in the TK angle is due to the different population groups as well as variations in the instruments as well as in the measurement methods.

With regards to the reliability of measuring TK, the MSTS demonstrated excellent intra-rater reliability (ICC value of 0.87) and moderate inter-rater reliability (ICC value of 0.56). The results were similar to those of previous studies using the flexicurve (Hinman, 2004; Teixeira & Carvalho, 2007), photogrammetry (Dunk et al., 2004; 2005; Saad et al., 2012), inclinometer (Lewis & Valentine, 2010; van Blommestein et al., 2012; Czaprowski et al., 2012), radiography (Rillardon et al., 2003) and Moiré topography (Melvin et al., 2010; Frerich et al., 2012) methods, with mean ICC > 0.83.

The flexicurve method is a recognized technique to measure TK in clinical environments due to its portability, easy of use and low cost (Kado et al., 2009; Arnold et al., 2000; Yanagawa et al., 2000). Greendale et al. (2011) reported that the flexicurve method had good intra-rater and inter-rater reliability coefficients of 0.88 and higher ( $p < 0.01$ ) for measuring TK. Similarly, Wongsat et al. (2012) established the indirect TK measurement method using the wall-distance method (distance between C7 vertebrae to the wall), demonstrated excellent reliability among raters ( $ICC > 0.90$ ,  $p < 0.001$ ) in elderly women ( $n = 179$ ). However, the photogrammetry method showed mixed results. Saad et al. (2012), reported excellent intra-rater ( $ICC$  0.93 to 0.95) and inter-rater ( $ICC$ , 0.97) reliability. In contrast, Dunk et al. (2004) and (2005) reported moderate reliability with  $ICC$  values of 0.69 and 0.72 respectively. The trivial variability in the reliability results maybe due to the natural variation of the thoracic kyphosis between different age groups as well as between different postural standing poses between trials (D'Ostualdo et al., 1997) or due to the instrument itself.

To summarise, in the current study, the absolute differences in mean values of TK were as low as  $2.37^\circ$  across trials with 90% confidence limits. The good intra-rater reliability (retest reproducibility) together with the moderate STE value for the measurement of TK variable makes the MSTS a suitable tool to use within the clinical environment, comparable to photogrammetry.

### *Cervical Lordosis (CL)*

In the current study the CL angle (as seen in Table 3.2) is formed by intersection of lines drawn through C2 and C4 spinous process and through C4 and C7 spinous

process. The mean CL angle ( $31.12 \pm 7.33$  degrees) presented in the current study was similar to previous studies. Harrison et al. (1996), Grob et al. (2007), Motta et al. (2017), Been et al. (2017) and Hey et al. (2017), and reported that the mean cervical lordotic angle ranged from 25.2 to 39.2 degrees when measured using the radiography method. Further, Been et al. (2017) identified no difference in the CL angle when comparing between genders. The non-symptomatic ( $n = 61$ ) males presented with  $39.2 \pm 11.5$  degrees of CL and females ( $n = 60$ ) with  $36.7 \pm 9.5$  degrees. Similarly, Abelin-Genevois et al. (2014) reported normal CL angles in a paediatric population as  $32.1 \pm 11.3$  degree.

Furthermore, Raupp et al. (2017) reported that the CL angle measured using the flexi-curve method was marginally higher than reported in the current study at  $51.2 \pm 8.9$  degrees. The variation in the above reported angles between radiography and the flexi-curve methods was likely due to the different methods of measurement and instruments. Within radiography, Ohara et al. (2006) described several techniques to measure the CL angle in lateral radiographs, for example an angle formed between C1 and C7 endplates or C2 and C7. Therefore, there is no single universally applicable method for measuring the CL angle. Similar to the present study, the angle formed between C2-C7 angle is the most widely reported method for measuring the CL angle in the sagittal plane (Reitman et al., 2004; Grob et al., 2007; Erkan et al., 2010; Radcliff et al., 2011). Moreover, Harrison et al. (1996) reported that the main limitation in standardising the CL angle is that it is not always lordotic. The alignment of the curve

varies from lordosis to neutral to kyphosis and may take complex forms such as an S shaped or inverted S shaped curves.

Harrison et al. (2000) and Shin et al. (2016) reported good intra-rater (ICC, 0.97) and inter-rater reliability (ICC, 0.95), with a smaller standard error of measurement when the CL angle was measured through lateral cervical radiographs. Furthermore, Raupp et al. (2017) reported that the low-cost, easy-to-use flexi-curve method produced good to moderate intra-rater (ICC = 0.65;  $p = 0.001$ ) and inter-rater (ICC = 0.679;  $p > 0.01$ ) reliability in measuring the CL angle. These results are similar to the current study. The CL angle measured through the 3D MSTS demonstrated excellent intra-rater reliability (ICC = 0.92) and moderate inter-rater reliability (ICC = 0.63).

Although there are several studies that have reported the quantification of the CL angle, majority of studies used radiographic method with only a few studies using non-radiographic methods (flexi-curve and photogrammetry method) (Fedorak et al., 2003). Thus, the novel, moderately reliable, low-cost, easy-to-use MSTS would be useful within a clinical environment, in addition to radiography or the flexi-curve method.

Overall each method of evaluation of the sagittal plane variable has its advantages and disadvantages, but the major problem is that it is difficult to compare measurements when performed by different methods and instruments. The results of the study need to be interpreted with caution as the manual placement of markers and measurements of the variables are prone for error. Further development of the MSTS to automated process will reduce the measurement error, this needs to be confirmed in the further studies. The main advantage of measurements using the MSTS is the

lack of radiation, thus allowing for the frequent evaluation of spinal curves and monitoring of the changes in the alignment of spine in the sagittal plane.

### *3.6.3 Frontal Plane Variables*

Despite good to excellent reliability for majority of sagittal plane postural variables, moderate to low inter-rater and intra-rater reliability was found for two of the frontal plane variables (shoulder elevation and lateral pelvic tilt). Additionally, these variables had the larger STE values together with wider limits of agreement. Each frontal plane variable is discussed in detail in the subsequent section.

#### *Shoulder Elevation (SE)*

In the current study the SE angle (as seen in Table 3.1) is formed by a line drawn between the left and right acromion process markers and the angle of this line to the horizontal. The mean SE angle ( $3.9 \pm 1.56$  degrees; range between 1.74 and 7.04 degrees) presented in the current study was marginally higher than those found in previous studies. Ferreira et al. (2011) reported that the mean SE angle measured by the photographic method as  $1.3 \pm 2.0$  degrees (ranging from 3.5 to 7.0 degrees) in healthy young adults. Similarly, Raine and Twomey (1997) reported the mean SE angle as being  $1.2 \pm 2.2$  degrees in a large sample size ( $n = 78$ ) with wide range of age group between 17 and 55 years and above. The marginal variations of 2 degrees in SE angle may be due to the different instruments used. This difference in SE angle is small and unlikely to be observable by naked eyes (Raine & Twomey, 1997).

With regards to the reliability of measuring SE, the 3D MSTs demonstrated moderate intra-rater reliability (ICC value of 0.60) with a low inter-rater reliability (ICC value of

0.26). In contrast the photographic method for measuring the SE angle demonstrated high reliability (ICC = 0.89) (Raine & Twomey, 1997; Ferreira et al., 2010). Similarly, in idiopathic scoliosis (n = 70) patients, Fortin et al. (2012) presented excellent intra-rater (ICC = 0.95) and inter-rater (ICC = 0.98) reliability when measuring the SE angle using a photographic method.

In the current study, the potential reason for the low LOA and inter-rater reliability between five raters is perhaps due to the combination of raters (experienced vs non-experienced; health-professionals' vs bio-mechanist) included. Given the small sample size, it was not possible to perform subgroup analysis between raters. Future studies need to compare both the reliability between different professions groups as well as different raters. Another potential challenges in similar reliability studies, is the accurate palpation of anatomical landmarks, especially when the angle is small (less than 5 degrees). Billis et al. (2003) and Haneline and Young (2009) noted that the accuracy of palpation of anatomical landmarks generally depends on the skill of the raters. Further analysis of the results obtained between raters may perhaps provide additional information for the differences obtained. Good to moderate intra-rater reliability (retest reproducibility) for measuring the SE angle makes the MSTS an excellent tool to evaluate this coronal plane variable in the clinical environment one that is comparable to photogrammetry.

#### *Lateral Pelvic Tilt (LPT)*

Freburger and Riddle (1999), Vialle et al. (2005), Gangnet et al. (2006), De Carvalho et al. (2010) and Ferreira et al. (2011) stated that comparing pelvic position data with

other studies was challenging. The potential reason for the inconsistency in reporting pelvic tilt measures was due to not only different methods of assessment used but also different instruments was used. For example, the pelvic tilt in the coronal plane can be measured by comparing the position of the iliac crest, ASIS anteriorly and/or PSIS posteriorly (Gajdosik et al., 1985; Burdett et al., 1986; Ferreira et al., 2011). Most pelvic parameters described in the literature used radiographic (De Carvalho et al., 2010), photographic (Ferreira et al., 2011; Fortin et al., 2012) or goniometric (Lavy et al., 2003) methods.

The evaluation of pelvic tilt in the coronal plane used in present study was based on the posterior views of the frontal plane of the 3D model. The LPT angle was calculated between the horizontal line and by the line joining the two posterior superior iliac spines (PSIS) (see Table 3.2). The mean LPT angle presented in the current study ( $3.91 \pm 1.62$  degrees; minimum 2.05 and maximum 7.64 degrees) was marginally higher than those reported in previous studies. Pinto et al. (2008) presented the normal lateral pelvic tilt measured by a 3D optoelectronic device as being  $-0.77 \pm 1.83$  degrees in small sample size of  $n = 14$  healthy young adults. Using photogrammetry methods, Fortin et al. (2012) and Ferreira et al. (2011) reported the coronal pelvic angle as being  $-1.9 \pm 3.2$  degrees and  $-0.9 \pm 2.2$  degrees, respectively, in a large sample size ( $n = 115$ ). Even though the MSTS estimated the mean LPT angle to be 2 degrees higher than previous published results, it is difficult to compare, as the measurement method used in the current study were based on surface topography data.



Fortin et al. (2012) reported excellent intra-rater (ICC = 0.90) and inter-rater (ICC = 0.93) reliability, with a smaller standard error of measurement when the LPT angle was measured through photogrammetry. However, Hagins et al. (1998) presented good intra-rater reliability (ICC = 0.84) and moderate inter-rater reliability (ICC = 0.65) when measured using a palpation meter (PALM). In contrast, the current study results demonstrated moderate intra-rater reliability (ICC value of 0.73) and low inter-rater reliability (ICC value of 0.09) when the LPT angle was measured with the MSTs. As explained above, the potential reasons for poor inter-rater reliability might perhaps have attributed to variations in the experience of raters and their palpation skills.

#### *Frontal Knee Angle (FKA)*

The mean FKA angle presented in the current study ( $3.94 \pm 1.77$  degrees on the left side and  $4.75 \pm 2.88$  degrees on the right side) was consistent with previous studies using the photogrammetry method. Fortin et al. (2012) and Tomkinson and Shaw (2013) presented the left and right mean FKA as being  $< 4.1$  and  $< 4.9$  degrees, respectively. To the author's knowledge, this is the first study reporting the FKA using a surface topography method. As there are not many posture studies that have reported the FKA it is difficult to compare the results of the current study with previously published results.

Similarly, the intra-rater reliability was similar to previous studies. Fortin et al. (2012) and Tomkinson and Shaw (2013) demonstrated excellent reliability when the FKA was measured using photography at different times on the same day where an ICC of  $> 0.95$  was found. Like other frontal plane variables, the current study found poor inter-

rater reliability with an ICC = 0.10. However, Berryman et al. (2008) suggests that the amplitudes of curvature lower than two-degree variations remain less relevant within clinical practice.

#### *3.6.4 Transverse Plane Variables*

##### *Scapular Prominence (SP)*

The mean SP angle presented in the current study was  $30.2 \pm 5.57$  degrees on the right side and  $28.6 \pm 7.71$  degrees on the left side. Although SP measurement methods together with its angle are widely reported, different authors have proposed different evaluation methods and describe SP using various terminologies, such as shoulder rotation, scapular asymmetry and trunk rotation. Furthermore, numerous methods have been used to evaluate the scapular prominence, ranging from complex radiographic methods (Seoud et al., 2011) to simple two-dimensional photographic (Fortin et al., 2010; Stolinski et al., 2014) and three-dimensional surface-topographic methods (Pazos et al., 2007; Seoud et al., 2010; Gorton et al., 2012; Seze et al., 2013). Non-standardised procedures together with various definition of SP, make it very difficult to compare the current results with existing literature.

The intra-rater reliability results was similar to those reported in previous studies. Seoud et al. (2010) demonstrated excellent intra-rater reliability (ICC < 0.91) of upper trunk rotation in the transverse plane when measured using a three-dimensional surface topographic method. Similarly, Seze et al. (2013) demonstrated moderate to good inter-rater reliability (ICC, 0.70 to 0.74) for the measurement of thoracic humps

(‘gibbosites’ – as described by the author) using a surface topographic method in scoliotic patients ( $n = 46$ ) with a minimum 15 degrees of cobb angle in the frontal plane.

Likewise, the current study presented excellent intra-rater ( $ICC = 0.93$  and  $0.98$ ) and moderate inter-rater ( $ICC = 0.75$  and  $0.67$ ) reliability, when SP was measured using the novel MSTS. Therefore, this highly reliable MSTS was useful to measure both the sagittal and transverse plane postural variables within the clinical environment. This was found to be comparable to radiography or other complex surface topographic methods.

#### *3.6.5 Practical Implications*

Although there are various commercially available tools that are able to measure 3D posture and back shape with high reliability, these instruments are mostly used within a research setting and not within a clinical environment. The difficulty is that these tools are either complex to use, very expensive or heavy to carry around. For example, the duration for data collection in Fortin et al.’s postural screening method using photographs took 20 -25 minutes of patient time on average (Fortin et al., 2012), and the ISIS technique took 10 minutes (Bettany-Saltikov & Cole, 2012), whereas the MSTS method took an average of less than 6 minutes per subject (which includes marker placement). In addition, the current study reveals details of the whole-body profile, as recommended by Fortin et al., which to date has not been documented.

The MSTS has the advantage of presenting objective outcome measures that similar to the human observation of posture. The MSTS method of quantification of postural variables also has the advantage of minimal interference with the patients. In addition,

the instrument has the capacity to produce good quality pictures very quickly and shown to the patients. The images can be captured at the time of measurement and stored for further or later analysis. This tool is easy to use within a clinical setting as the components (iPad, Structure Sensor™ and software) is accessible. The training of therapists is minimal (2 hours were allocated in this study) and the time required for a global whole-body evaluation is less than 10 minutes. Furthermore, the MSTS has the secondary advantage of allowing users to capture and measure different poses like the forward-bend test, which is recommended for patients with scoliosis and other spinal deformities.

#### *3.6.6 Limitations*

There are a few limitations to this study. Firstly, although the author used only a small and homogenous population (people being scanned and not the practitioner). As the MSTS together with the methodology was successfully able to measure small angular differences between participants, trials and raters accurately, the author believes that the results also apply to other clinical populations (participants with spinal deformity) as well as spinal pain patients. Further research is required to confirm this. Secondly, although the current study minimized the measurement error by setting up standard procedures, as well as training the raters, the results need to be interpreted with caution, as this study could not quantify any influence of postural sway on the results. Further studies on different standing/starting position are needed to evaluate this.

### *3.6.7 Further Research*

Developing a tool with automatic recognition of markers as well as the calculation of automatic angles may potentially decrease measurement error and further reduce the time required to collect and analyse posture data. Future development of an automated bespoke 3D posture mobile application. This automation could further benefit clinicians by decreasing the time required for data capture and help improve the reliability of measurement as well as evidence-based clinical practice. In order to decrease the duration of data acquisition further the author is also considering the feasibility of using more than one structure sensor together with synchronized data capture. This will further help by not only decreasing the duration but will also improve the quality of the data for both screening patients as well as for the assessment of patients with back pain or different types of spinal disorders.

Since the MSTS used in this study was found to have moderate to good reliability for the measurement of sagittal and transverse plane postural variables, several possible future studies can be identified. As the posture and back shape variables differ in populations with different ages, gender and ethnicity, studies with a larger and wider sample size on healthy participants could provide a normative database for wide range of population. Additionally, the MSTS has the potential to measure more posture variables for example, forward head posture. Similarly, mass screening could be undertaken to develop risk-factor modelling for different types of spinal deformities. This is because numerous research studies have shown that early intervention can not only keep spinal deformity to a minimum, but also reduce future discomfort and deterioration (Hawes, 2003). Potential studies on patients with spinal deformities may

also be related to different postures and medical conditions for example 'Schuerman's disease'. Furthermore, the MSTS can also be used for the objective measuring of pre- and post-treatment clinical trials to measure the impact of both conservative and surgical interventions.

### **3.7 Conclusions**

The current study has examined the inter-rater and intra-rater reliability of a mobile application-based 3D modelling method for the objective quantification of clinically identified postural alignment. The variables of the neck, trunk and lower limb in standing were measured. This is the first study to evaluate the inter-rater and intra-rater reliability of the MSTS system. These reliability results provide a base for future studies. This device has the potential to be used as a complementary tool alongside subjective assessment for patients with a wide variety of spinal pathologies.

## **Chapter 4. Validation of a Novel 3D Imaging Mobile Surface Topography System (MSTS) for the Measurement of Posture and Back Shape**

## **4.1 Chapter Aim**

The main purpose of this chapter is to describe and discuss the methods and results from the validation study of the 3D imaging mobile surface topography system (MSTS) system in measuring the standing posture variables. Both the MSTS and the posture variables used in this study will be discussed in detail in the following sections. The tool's clinical uses are examined in the subsequent chapters.

## **4.2 Introduction and Literature Review**

Spinal pain refers to pain that originates from either the cervical, thoracic or lumbar segments of the spine. This can be associated either with or without radiation of the pain to the extremities. The prevalence of spinal pain in the UK population is 12-35% (Cross et al., 2014; Fayaz et al., 2016). Spinal pain is very commonly encountered within clinical practice as well as one of the leading causes of disability (Vos et al., 2012). Linton et al. (1998) estimated that the prevalence of spinal pain in the general population in the UK as 66%, with 44% of these patients reporting pain in the cervical region, 56% in the lumbar region, and 15% in the thoracic region. In addition to the high prevalence of spinal pain, pain is also associated with a significant negative impact on the economic, societal and health status of patients (Manchikanti et al., 2009). The total UK costs to the economy, including work days lost and care for spinal pain was estimated to be £512 million per year in 2012 (Maniadakis & Gray, 2000; NICE, 2012).



Spinal pain is associated with numerous risk factors (biomechanical, psychological and physical conditions) that have all been postulated to be possible causative factors. The biomechanical factors influencing spinal pain have been explored in several studies (Nelson-Wong et al., 2010; Chou et al., 2016; Kayla et al., 2016). For instance, Nelson-Wong et al. (2010) reported that prolonged standing on a sloped surface ( $\pm 16^\circ$ ) resulted in a 59.4% decrease in low back pain scores.

From a theoretical standpoint, postural misalignments may include numerous deviations from an ideal symmetrical back shape and posture; this can occur anywhere between the left and right as well as between the front and back sides of the body (Kendall et al., 2005; Egoscue & Gittins, 2014). The physical function of the spine (its mobility and movement pattern) within regular activities of daily living (ADL) have also been found to affect the severity of any resulting postural deviations (Katzman et al., 2007), for example, McClure et al. (1997), demonstrated that patients with LBP have an altered movement pattern. In healthy individuals, hip movement dominates the movement pattern during extension from trunk flexion. However, participants with LBP demonstrate that a greater percentage of the extension motion originates from the lumbar spine rather than from the hip.

Therefore, to assess and treat spinal pain patients, there is a need for appropriate valid and reliable objective tools that are capable of measuring and monitor any changes in posture. Assessing the validity of any new instrument is imperative for the practice of evidence-based clinical practice to ensure that the instrument is measuring what is it

supposed to be measuring. This would assist practitioners and patients in making decisions about appropriate healthcare and improve guidelines.

As discussed in the previous chapter, there are various approaches as well as a diverse range of tools for postural assessment and screening. These include subjective measurements (Fourchet et al., 2014), handheld tools (Greendale et al., 2009; Sheeran et al., 2012), photographs (Dunk et al., 2004; Fortin et al., 2011), X-ray images (van Niekerk et al., 2008; Fortin et al., 2011), as well as three-dimensional images (Ehara et al., 1997; Thewlis et al., 2013; Sahin et al., 2013). Although 3D-imaging is often used for motion and gait analysis, it can also be used to determine the relative position of static anatomical landmarks (Godwin et al., 2009; Brink et al., 2013; Galna et al., 2014), such as in postural assessments.

Several studies have reported both radiographic and non-radiographic (flexi-ruler, Photogrammetry and inclinometer) instruments in the validity of measuring postural and back shape variables in all planes (Fortin et al., 2010; Oliveira et al., 2012; Saad et al., 2012). The non-radiographic MSTS used within this study used a structured light pattern that is able to capture the 3D human position data at different points and with different postures. Whilst the reliability of an instrument is the most paramount importance, additionally other variables like size, portability and low cost has great potential for use in clinical environment. However, the actual use of this tool in healthcare is very limited. Despite numerous comprehensive searches, no studies to the authors knowledge could be found that have used the MSTS in clinical practice.

The current study explored the use of a mobile structured light pattern for building an accurate 3D human model to measure posture and back shape variables. The MSTS has not yet been widely used for measuring posture variables as it was developed by the author and hence further validation is required. The validity (the extent to which the tool is measuring what it is supposed to be measuring i.e the true value) of the tool has important decision-making clinical implications for both clinicians for whom the main use of the tool is to obtain objective evidence-based spinal measures for the assessment and monitoring spinal posture/back shape.

#### *4.2.1 Objective*

The objective of this study was to evaluate the concurrent validity of the 3D imaging MSTS for measuring posture and back-shape variables. In the current study, the optoelectronic system (Vicon Motion System, Ltd, UK) was used as the gold standard criterion to measure 3D posture and back-shape variables.

#### *4.2.2 Hypothesis*

The hypotheses were as follows.

For this validation study, the hypothesis and null hypothesis were considered to be the same.

The null hypothesis was that there would be no differences between the measurements taken with the 3D MSTS tool and the Vicon measurements (gold standard) for the assessment of three-dimensional posture and back shape variables.

The postural and back shape variables measured within this study were as follows.

*Sagittal plane variables:* Cervical lordosis, Thoracic kyphosis, Lumbar lordosis

*Frontal plane variables:* Shoulder elevation, Lateral pelvic tilt, Front knee angle

*Transverse plane variables:* Scapular prominence

### **4.3 Methods**

#### *4.3.1 Research Design*

A repeated measures design using a linear regression model was used. The concurrent validity of the 3D imaging MSTS was tested for the measurement of the posture and back shape variables. Within the current study, the optoelectronic system (Vicon Motion Systems Ltd, UK) was used as the gold-standard comparison to measure posture.

#### *4.3.2 Ethics*

This study was submitted and approved by Teesside University Research Ethics Committee, Middlesbrough, UK.

#### *4.3.3 Participants*

A sample of twenty-five healthy volunteers (16 males (64%), 9 females (36%), mean age group of 27.76 (SD = 4.97) years) with no history of spinal pain participated in this study. The summary of the descriptive statistics of participants in each group is seen in Table 4.1. All the participants were students from Teesside University. Participants with complaints of any type of current pain or the inability to stand pain-free for one hour were excluded from the study.

#### 4.3.4 Informed consent

Participants were informed of all information relevant to participation in this study via an information sheet. Participants were informed that they could keep the information sheet. The author further discussed the study with the participants who were given the chance to clarify any questions and concerns. Informed consent was gained.

Table 4.1 Descriptive statistics of participants

	Height	Weight	Age
Mean	164.48	70.64	27.76
Std. Error of Mean	1.05	2.64	.99
Std. Deviation	5.26	13.20	4.97
Variance	27.76	174.32	24.77
Skewness	-.05	.63	1.86
Std. Error of Skewness	.46	.46	.46
Kurtosis	-1.35	-.24	4.99
Std. Error of Kurtosis	.90	.90	.90
Range	17.00	52.00	24
Minimum	156.00	50.00	21
Maximum	173.00	102.00	45

#### 4.3.5 Recruitment

The author contacted potential participants in person, email and/or by telephone. For all the potential recruits' full details of the study and a consent form was given before

the study. Additional enquiries about their general health confirmed their eligibility to take part in the study.

#### *4.3.6 Equipment*

##### *Three-Dimensional Imaging MSTS*

A commercially available iPad based 3D mobile scanning tool Structure Sensor™, was used to capture the shape of the back as well as the participant's whole body. The details of the equipment was previously discussed in the Chapter 2 and 3 (see Section 2.7 and 3.3.2).

##### *Optoelectronic system (Vicon) (Reference system)*

The 3D imaging of the MSTS data from the Structure Sensor™ system was compared with concurrently collected data from a commercially available six-camera motion capture solution (Vicon MX13 and Vicon Nexus 1.7, Vicon Motion Systems, UK). This six-camera system is a passive video-based 3D motion capture system.

Following the manufacturers' guidelines, the Vicon system was calibrated prior to every session, with the image error set to below 0.18 mm. Sampling frequency for the six-camera system was set to 100 Hz. All the cameras of this six-camera system were set at a height of 1.9m for good visibility of passive marker set.

This three-dimensional motion analysis imaging requires placement of a set of passive retroreflective markers on participants' anatomical landmarks (please see Figure 4. 1). The infrared light emitted from the camera lenses is reflected to the cameras and is used to determine the position of the markers as X, Y and Z coordinates.

The position of markers relative to each other was used to determine the distances between markers and joint angles. Due to the precise measurement (15 µm) for the location of reflective markers, the 3D imaging technology (Vicon) was a criterion measure for positional measurements of the human body (Brink et al., 2013; Godwin et al., 2009). Although this 3D imaging (Vicon) is often used for motion and gait analysis, it can also be used to determine the relative position of static anatomical landmarks (Godwin et al., 2009; Brink et al., 2013; Galna et al., 2014), such as in postural assessments. The Nexus 1.4 116 software was used to analyse the data measured by Vicon system.

Within this study, nine postural variables were compared between the Vicon system and the MSTs. These were the lumbar lordosis, cervical lordosis, thoracic kyphosis, lateral pelvic tilt, shoulder elevation, left and right frontal knee angle and left and right scapular prominence.

#### *4.3.7 Procedure*

During the first measurement session, participants were asked to read and sign the consent forms, complete the demographic questionnaire and then change to appropriate clothing for data collection. Male participants wore shorts, whilst the female participants' wore shorts, and sports bra. Female participants with long hair were asked to tie their hair up above their neck. Additionally, all the participants' height and body mass were measured to the nearest 0.1 kg using a digital scale (Seca, 875, Seca Weighing and Measuring Systems, Birmingham, England).

Before data collection, spherical reflective markers, with a diameter of 14 mm were placed on the following bony prominences and spinous processes: C2, C4, T1, T4, T7, T12, L3, S1, posterior superior iliac spine (PSIS) and anterior superior iliac spine (ASIS) (see Figure 4.1). Double-sided tape was used to attach markers onto the skin and tight clothing.

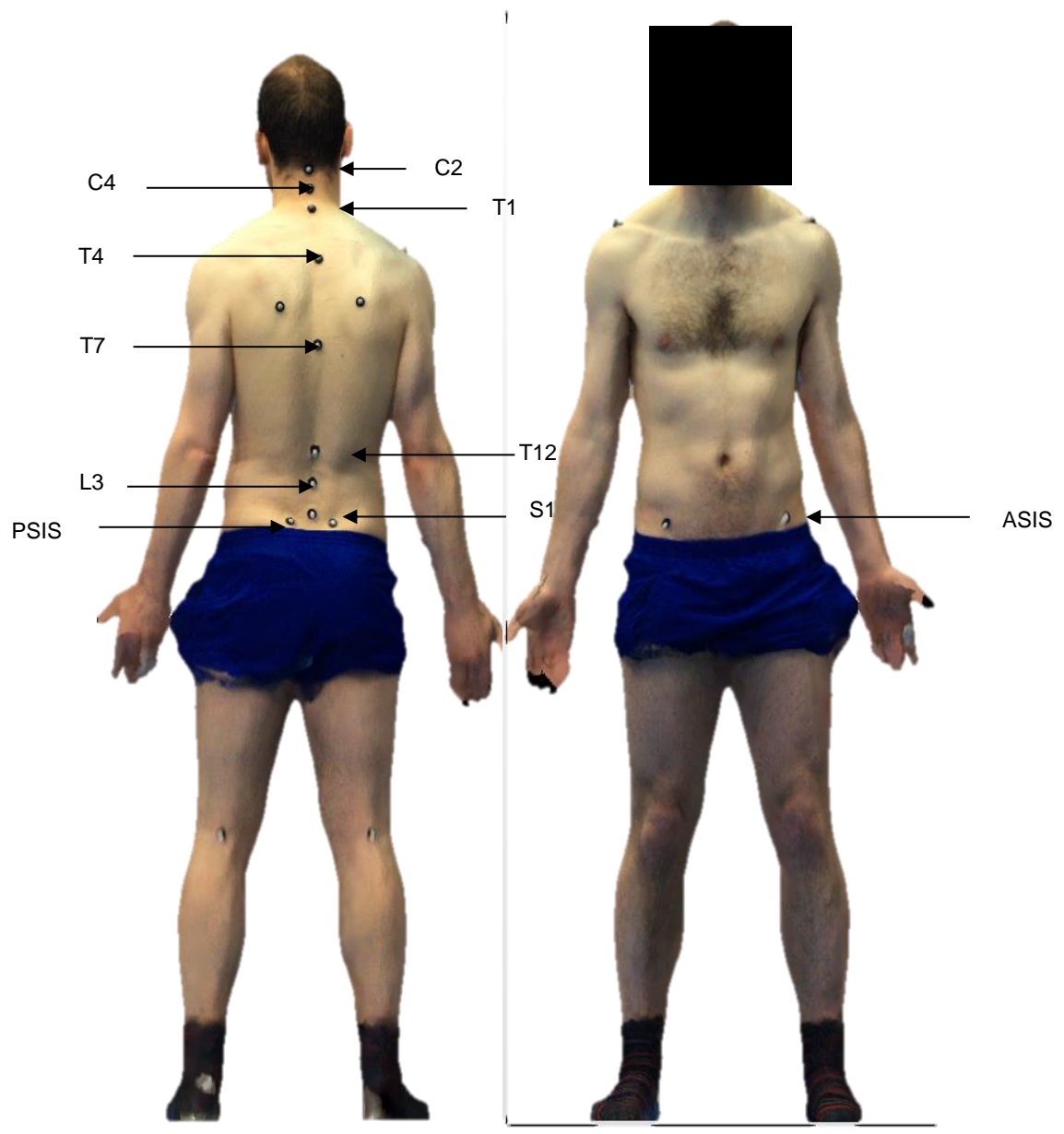


Figure 4.1. Placement of reflective markers (14 mm)



After walking around for 5 minutes for the familiarization session, each participant was asked to assume and stand in their 'normal' standing posture on a standard footplate, with a drawing of X and Y-axis facing the Vicon system (see Figure 3.5).

The standard foot plate was used to standardize the data collection among all the participants. The standing platform was positioned in such a way so as it can capture the volume of data recorded by both systems (Vicon and 3D imaging MSTs). Previous work by Batavia (2001) and Braun and Amundson (1989) has found improvements in repeated measurements with foot- and vision standardization in posture and gait analysis.

#### *Measurement of standing posture*

Three trials of standing posture data were collected simultaneously by both the systems. To capture the data through the 3D imaging MSTs, the author walked around with the camera pointing towards the participant in a 360-degree circle at three different heights (participant's shoulder, pelvic and knee).

Throughout the data collection, the distance between the camera and the model was kept between 0.5 and 1 meters. As mentioned above, the data acquisition followed a specific sequence and took 30 to 40 seconds per trial. To avoid any bias in the selection of a trial and to obtain a better estimate of a true score, the mean of three trials were used for inter-device comparison.

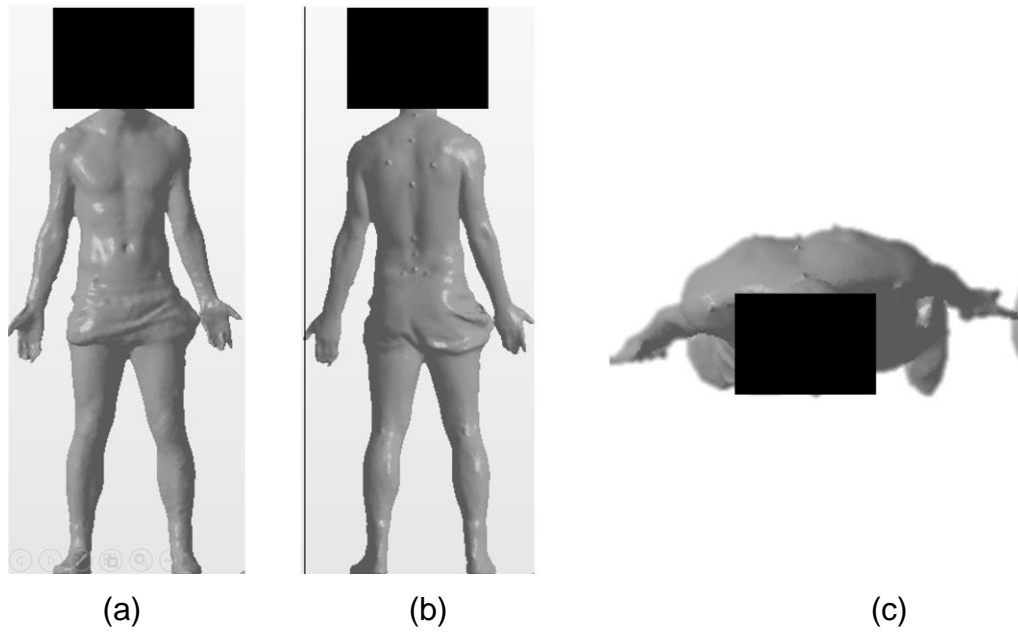


Figure 4.2. An example of posture and back shape data collected using the 3D imaging MSTS, seen from (a) front, (b) back and (c) top.

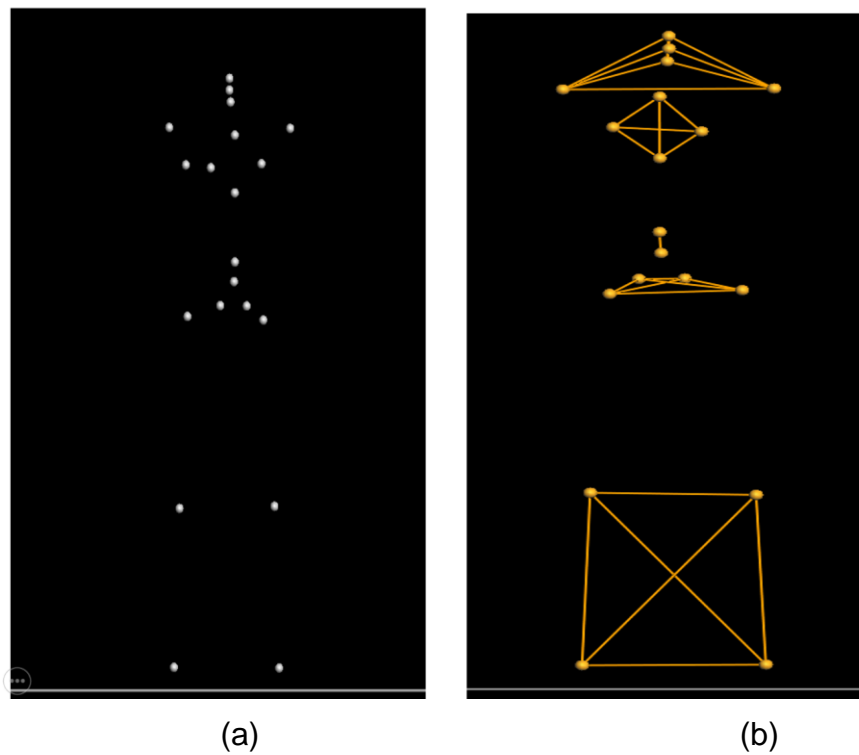


Figure 4.3. An example of standing posture data collected using Vicon system. (a) Unprocessed data with reflective marker set; (b) Processed data with applied spine model.

All the data captured through the 3D imaging MSTS was uploaded, realigned and processed through an open-source software called Netfabb Basic™. Please see Figure 4.2 for an example of data captured through the MSTS. All the data captured through Vicon system were processed through the Nexus 1.4 116 software. Please see Figure 4.3 for an example of data captured through Vicon system. The software program used to calculate postural and back shape variables are described in Table 3.2 in Chapter 3. There are total nine variables (lumbar lordosis, thoracic kyphosis, cervical lordosis, lateral pelvic tilt, shoulder elevation, frontal knee angle, bilateral frontal knee angle and bilateral scapular prominence) measured by both The MSTS and Vicon system.

#### **4.4 Data Analysis**

A paired t-test was used to assess any significant differences in mean values between the two systems. The relationship between the values obtained using the two devices were further evaluated using the Pearson product moment correlation ( $r$ ) (this gives an indication of the consistency of the relative measurement of variables within the group). To examine the level of agreement between the two measurement methods, the method recommended by Bland and Altman (1996) was used. The Bland and Altman plot analysis is a simple way of evaluating bias between the mean differences between the measurement tools together with its agreement interval (Giavarina, 2015). A statistical significance of 5% was used.

## 4.5 Results

The main objectives of the current study were to evaluate the concurrent validity of the 3D-imaging MSTS with the 3D Vicon system for measuring posture and back-shape variables.

### *4.5.1 Comparison of postural variables*

This section presents the findings of the validity study comparing the MSTS and Vicon systems for measuring postural variables. The mean scores for each of the nine postural measurements are presented in Table 4.2. Included are the mean difference, the standard error, 95% confidence interval (CI), Pearson's correlation ' $r$ ' value and ' $p$ ' value.

#### *Sagittal Plane Measurements*

*Lumbar Lordosis.* The comparison of the mean differences between Vicon and MSTS for measuring lumbar lordosis were identical with only a mean of 0.51 degrees difference. The 95% confidence interval (CI) was low with -2.05 as the lower limit and 1.02 as the upper limit. This was supported the 't' test results which showed non-significant differences ( $p = 0.49$ ) in the mean values. The lumbar lordosis angle as measured by Vicon system and MSTS also showed good correlation at  $r = 0.77$  (see Table 4.2).

From Figure 4.4 (A), The Bland and Altman limits of agreement (LoA) graph demonstrated that the MSTS was able to measure lumbar lordosis values, with only -6.81° differences in the lower values and 7.84° difference in the upper values. Along

with the low mean difference, the LoA falls within the acceptable range. The results from the current study indicated that the two methods used to measure lumbar lordosis angle were interchangeable.

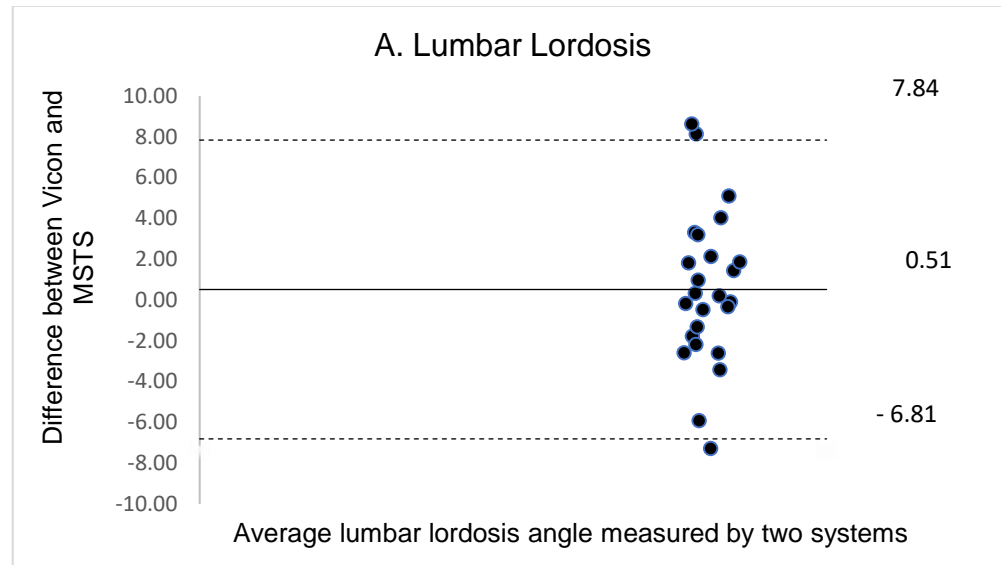


Figure 4.4 (A) The Bland and Altman graph for the measurement of lumbar lordosis angle. The graph displays a scatter diagram of the differences plotted against the averages of the two methods of measurement (Vicon and MSTS). Horizontal lines represent the mean difference of LL angles whilst the dotted lines represent the limits of agreement. The 'Limits of agreement' are given by the  $\pm 2$  SD limits.

*Thoracic kyphosis.* The comparison of the mean differences between the Vicon system and MSTS for the measurement of thoracic kyphosis only demonstrated marginal mean differences of 3.37 degrees with a small 95 % CI (-5.88 to -0.85). The Pearson's correlation of measurement for the thoracic kyphosis angle as measured by the two methods showed a statistically significant correlation at  $r = 0.47$ . Even though there were small mean differences and stronger correlation between the two instruments, the comparison of the mean values through the paired 't' test showed statistically significant differences ( $p = 0.01$ ) (see Table 4.2). The Bland and Altman's limits of

agreement graph demonstrated that the MSTS was able to measure thoracic kyphosis values, with only  $-8.56^{\circ}$  differences in the lower values and  $15.31^{\circ}$  difference in the upper values than those measured by Vicon (see Figure 4.4 (B)).

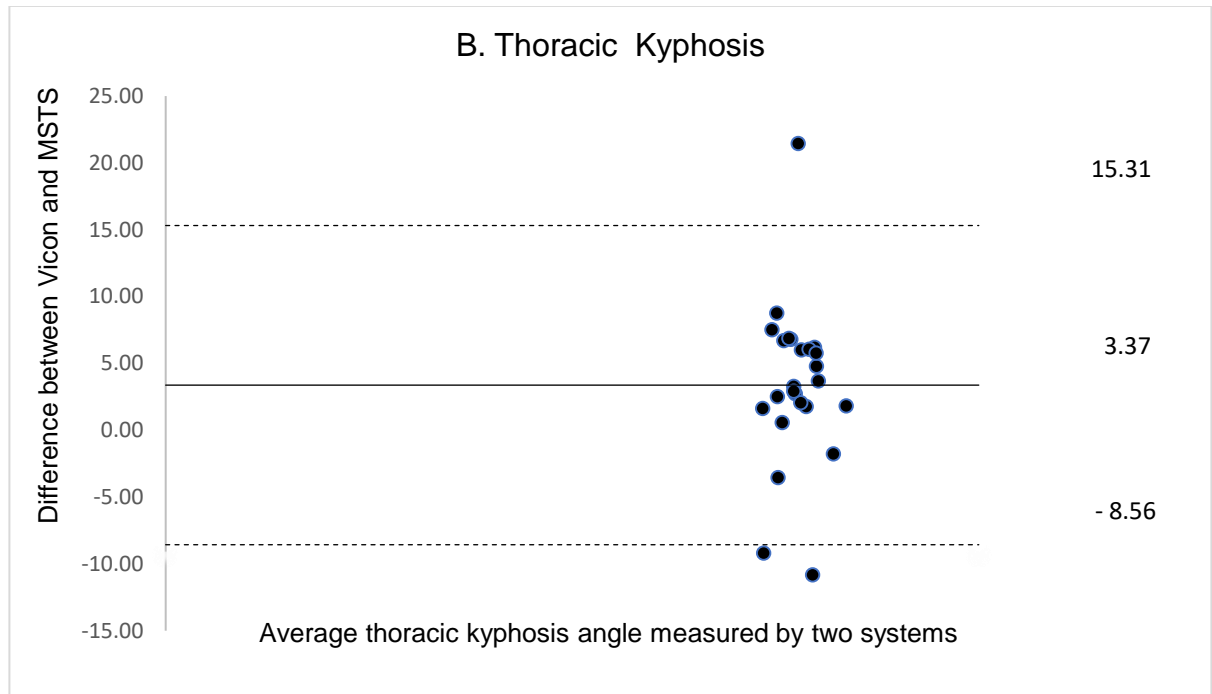


Figure 4.4 (B) The Bland and Altman graph for thoracic kyphosis angle.

*Cervical Lordosis.* Comparison of the mean differences between the Vicon system and the MSTS for the measurement cervical lordosis was found to be 7.35 degrees with a high 95 % CI (0.28 to 14.42). The Pearson's correlation of measurement of cervical lordosis angle measured by the two methods showed a statistically non-significant correlation with  $r = 0.15$ . The above result is supported by a paired 't' test which showed a statistically significant difference ( $p = 0.04$ ) (see Table 4.2). The Bland and Altman's limits of agreement graph was extremely wide with a  $-40.93^{\circ}$  lower limit and a  $26.21^{\circ}$

higher limit (see Figure 4.4 (C)). This indicated that the two methods used in this study to measure cervical lordosis angle was unacceptable.

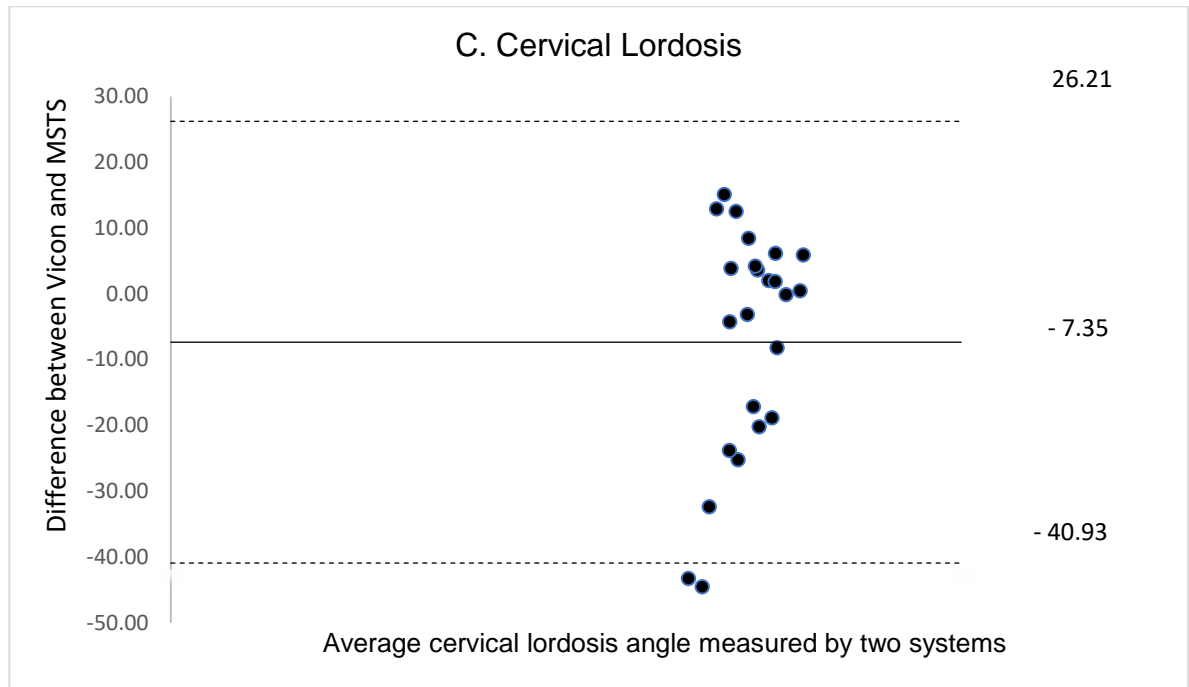


Figure 4.4 (C). The Bland and Altman graph for cervical lordosis angle.

#### *Frontal Plane Measurements*

*Shoulder elevation and pelvic tilt.* Comparison of the mean differences between the Vicon system and the MSTs for the measurement of shoulder elevation and lateral pelvic tilt angle was identical at 0.06 and 0.28 degrees respectively. The 95 % CI was also small for both the variables with -0.9 to 0.76° for shoulder elevation and -1.1 to 0.53° for lateral pelvic tilt. The results of the paired 't' test showed a non-significant difference ( $p = 0.86$  and  $0.48$  respectively).

Lateral pelvic tilt angle measured between two methods demonstrated good correlation ( $r = 0.40$ ) and moderate ( $r = 0.28$ ) for shoulder elevation (Please refer to

Table 4.2). The Bland and Altman's limits of agreement graph suggest that the MSTS was able to measure shoulder elevation values, with a mean of  $-3.90^{\circ}$  lower or  $4.04^{\circ}$  higher than those measured by the Vicon. The lateral pelvic tilt values also small limits of agreement with a  $-3.61^{\circ}$  lower and a  $4.17^{\circ}$  higher limit (Figure 4.4 (D and E)).

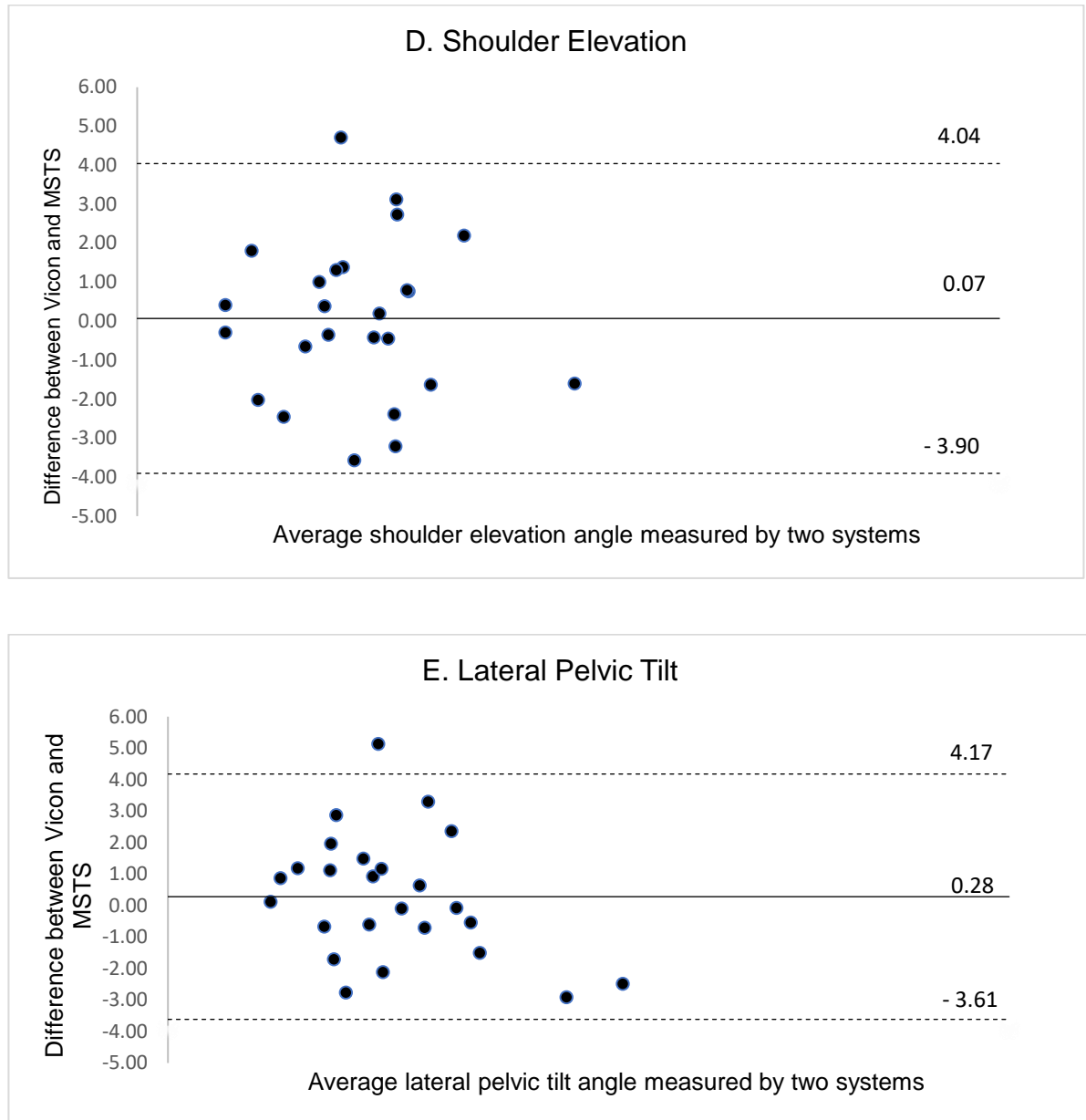


Figure 4.4, D and E. The Bland and Altman graph for shoulder elevation and lateral pelvic tilt angle



The result indicated that the two methods compared within the current study to measure shoulder elevation and lateral pelvic tilt angle are able to be used interchangeably.

*Frontal knee angle (right and left).* The comparison of the mean difference scores between the Vicon system and the MSTS for the measurement of the frontal knee angle on both sides was only marginal different of 2.61 and 3.99 degrees respectively. The 95 % CI, for the front knee angle was small for both sides (-0.61 to 5.84 for the right knee and 1.40 to 6.58 for the left knee). The results of the paired 't' test showed a non-significant difference ( $p = 0.10$ ) for the right-side knee and a statistically significant difference  $p < 0.001$  for the left side. The frontal knee angle measured between the two methods showed poor correlation for both sides ( $r = -0.27$ , right and  $r = -0.14$ , left) (see Table 4.2). The Bland and Altman's limits of agreement graph suggest that the MSTS measured the right front knee angle, with  $-17.97^\circ$  lower or  $12.73^\circ$  higher than those measured by Vicon. The left front knee angle also showed wider limits of agreement with a  $-16.30^\circ$  lower value and a  $8.30^\circ$  higher value (see Figure 4.4, F and G). The above results indicated that the two methods used in this study to measure front knee angle cannot be used interchangeably.

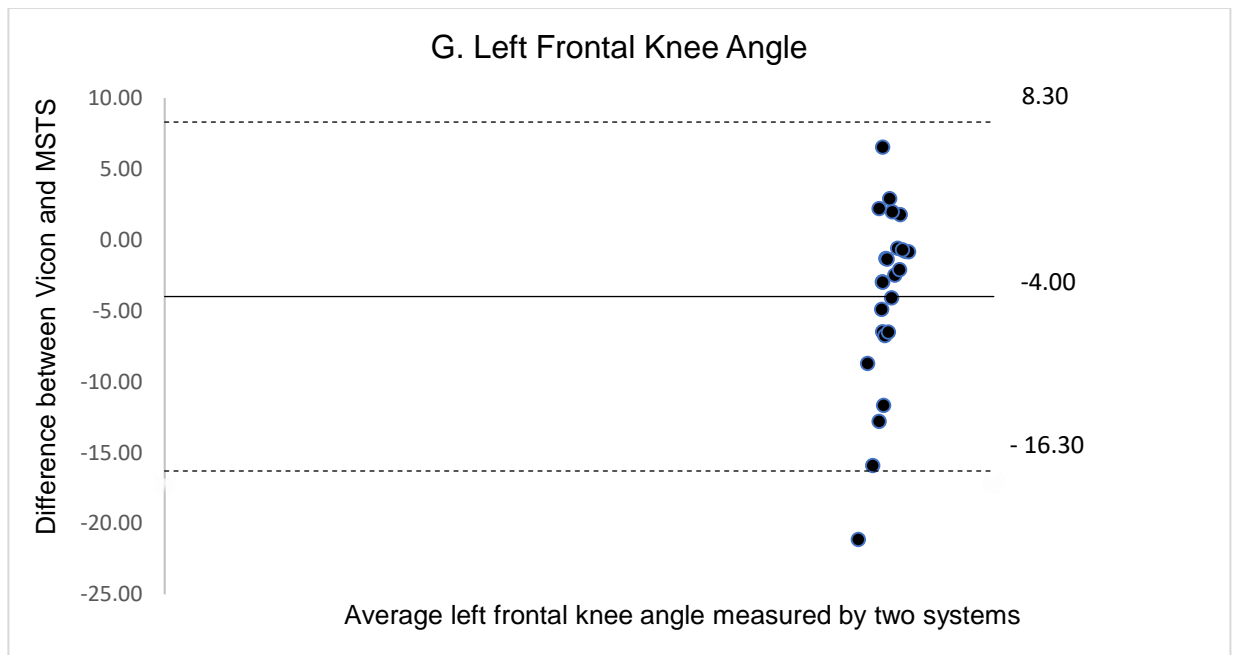
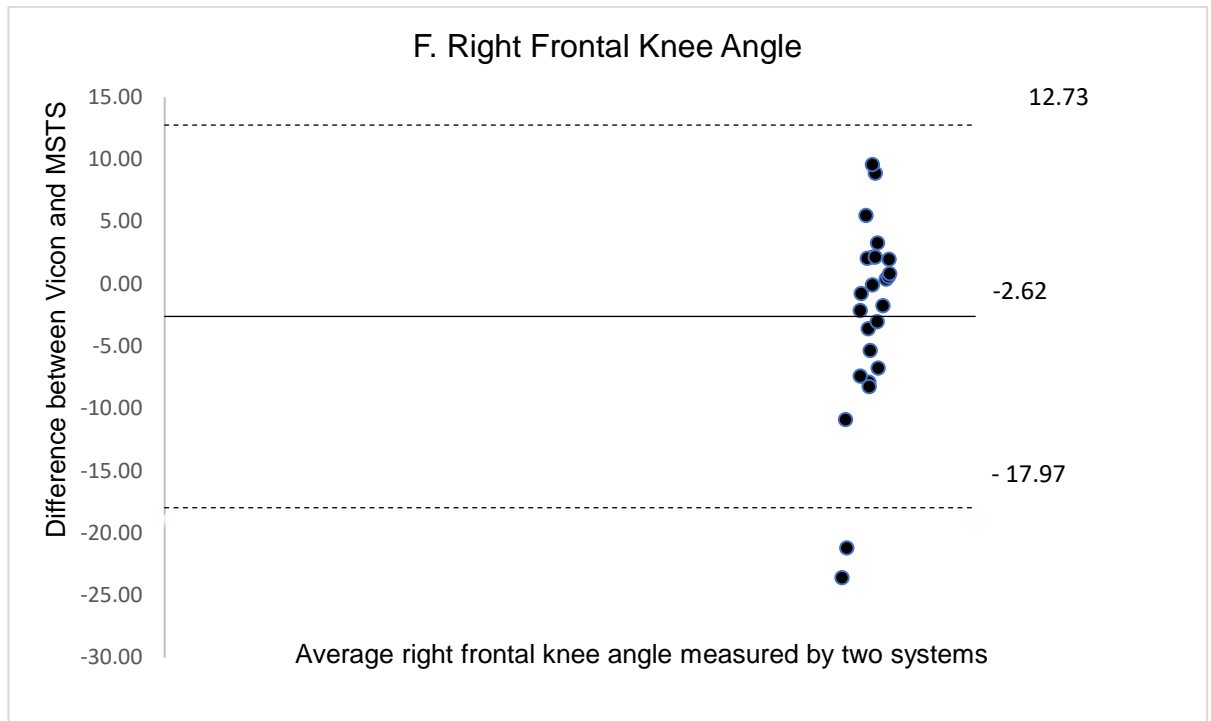


Figure 4.4, F and G. The Bland and Altman graph for frontal knee angle.

### *Transverse plane measurement*

*Scapular prominence (left and right).* Comparison of the mean difference scores between the Vicon system and the MSTS for the measurement of the scapular prominence angle on both the right and left sides found only a marginal difference of 6.47 and 6.59 degrees respectively. The 95% CI for the scapular prominence angle was wide for both sides (ranging -0.01 to 12.96 for right and 0.16 to 13.01 for left). The results of the paired 't' test showed significant differences between the Vicon and the MSTS ( $p = 0.05$  and  $0.04$ , respectively) on both sides. The scapular prominence angle as measured between the two methods found poor correlation on both sides ( $r = 0.03$ , right and  $r = 0.11$ , left) (see Table 4.2). The Bland and Altman's limits of agreement graphs suggest that the MSTS is capable of measuring the scapular prominence angle, with wider limits of agreement ( $-37.28^\circ$  lower limit and  $24.34^\circ$  higher limit in right side of the body;  $-37.08^\circ$  on the lower or  $23.90^\circ$  higher limit in left) than those measured by the Vicon (see Figure 4.4, H and I). The above results indicate that the two methods used in this study to measure scapular prominence angle cannot be used interchangeably.

In summary, the above results demonstrated mixed results. The estimation of the MSTS for measuring the sagittal and frontal plane variables (lumbar lordosis, thoracic kyphosis, shoulder elevation and lateral pelvic tilt) was found to be as good as the Vicon system. For the measurement of the cervical lordosis and transverse plane variables those measured with the MSTS either under- or overestimated angle. The results are further discussed in the discussion section.

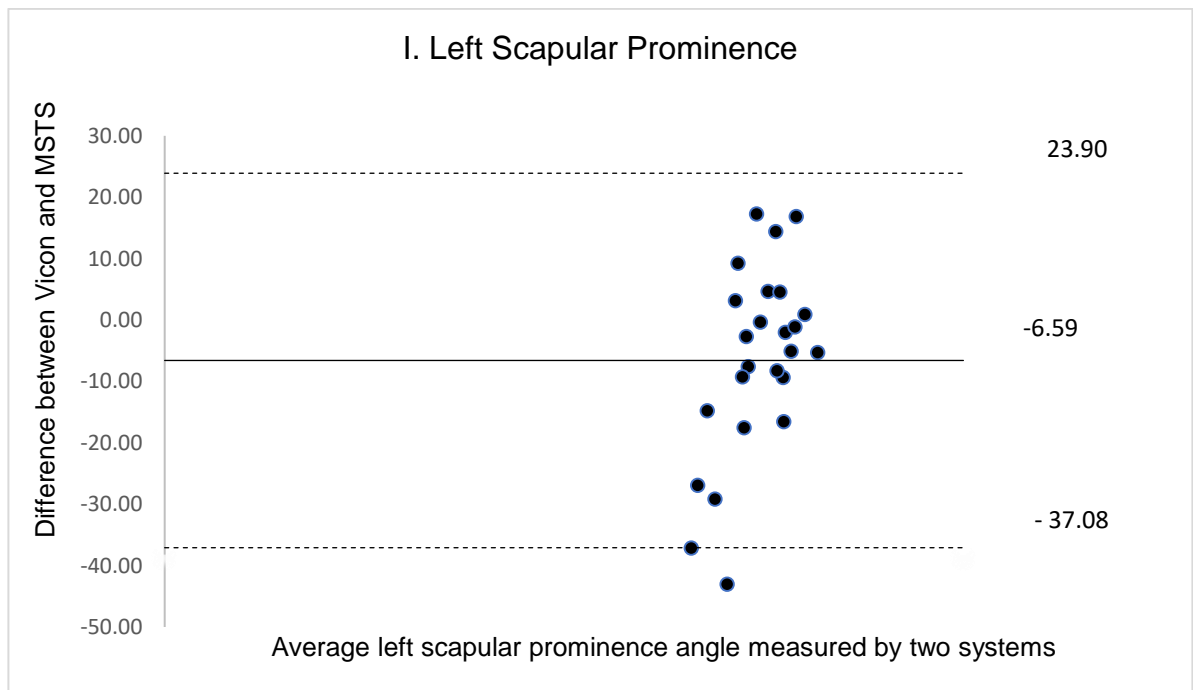
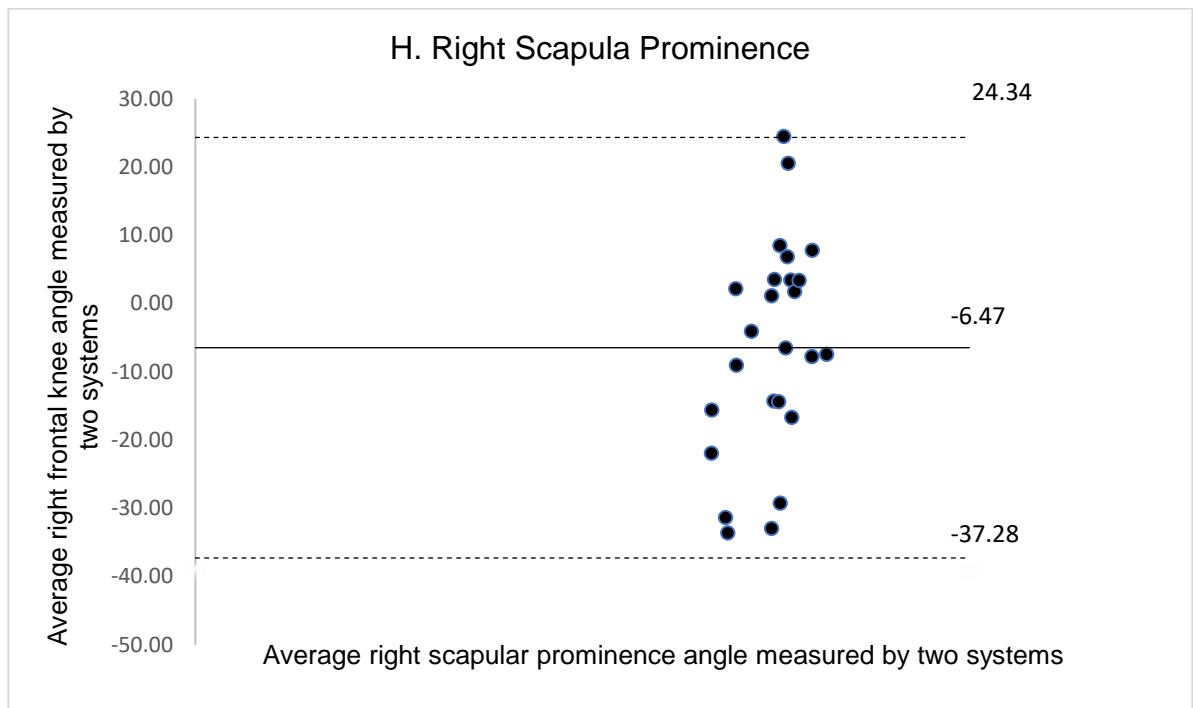


Figure 4.4, H and I. The Bland and Altman graph for scapular prominence angle.

Table 4.2. Comparison of accuracy of standing postural measurements between 3D imaging MSTS and the gold standard Vicon three-dimensional analysis system.

Variables		Mean (SD)		SE Mean Difference	Mean difference	95% CI of the difference		t value	p value	Pearson Correlation (r)
		Vicon	MSTS			LL	UL			
<b>Sagittal Plane</b>	Lumbar Lordosis	28.33 (5.58)	27.81 (5.59)	0.74	-.51	-2.05	1.02	-0.68	.49	0.77*
	Thoracic Kyphosis	26.34 (5.90)	22.97 (6.00)	1.21	-3.37	-5.88	-.85	-2.76	.01*	0.47*
	Cervical Lordosis	29.96 (8.34)	37.32 (13.7)	3.42	7.35	.28	14.42	2.14	.04*	-0.25
<b>Frontal Plane</b>	Shoulder Elevation	3.77 (1.7)	3.84 (1.66)	0.40	-.06	-.90	0.76	-0.17	.86	0.28
	Lateral Pelvic Tilt	3.86 (2.06)	4.15 (1.46)	0.39	-.28	-1.10	0.53	-0.71	.48	0.40*
	Front Knee Angle (Right)	4.53 (2.93)	7.14 (6.50)	1.56	2.61	-.61	5.84	1.67	.10	-0.27
	Front Knee Angle (Left)	3.71 (2.51)	7.71 (5.39)	1.25	3.99	1.40	6.58	3.18	.00*	-0.14
<b>Transverse Plane</b>	Shoulder Prominence (Right)	27.78 (8.34)	34.25 (13.61)	3.14	6.47	-.01	12.96	2.05	.05*	0.03
	Shoulder Prominence (Left)	27.97 (7.48)	34.56 (14.54)	3.11	6.59	.16	13.01	2.11	.04*	0.11

*SD, Standard Deviation; SE, Standard Error; CI, confidence Interval; LL, Lower limit; UL, Upper Limit; \* - Significant difference in p value ( $p < 0.05$ )*

## 4.6 Discussion

The main objectives of the current study were to validate the use of the 3D imaging MSTS to quantify posture and back shape using an optoelectronic system (Vicon) as a standard reference. To best of the authors knowledge, this is the first study to report the measures of validity of the MSTS for the measurement of posture and back-shape variables in all three planes. The validity results of the posture and back shape variables for twenty-five healthy adults are discussed in detail.

### 4.6.1 Overall Summary

The summary of results of the current study on healthy young adults found that the estimation of measuring both the sagittal and frontal plane postural variables (lumbar lordosis, thoracic kyphosis, shoulder elevation, lateral pelvic tilt and front knee angle) by the MSTS was as good as the Vicon system. The mean difference for all these variables ranged only from 0.06 to 3.99 degrees. Secondly, for the measurement of cervical lordosis and the right and left scapular prominence showed that the MSTS too either under- or overestimated the angle provided by the Vicon. The mean difference for these transverse plane variables ranged from 6.47 to 7.35 degrees. Thirdly, the patterns found for the Pearson correlation ( $r$ ) suggested moderate to good correlation for both the sagittal and frontal plane variables ( $r$  with a range of 0.40 to 0.77). Poor and negative values for the measurement of frontal knee angle, scapular prominence and cervical lordosis was found with  $r$  value ranging from -0.14 to 0.11. Fourthly, the Bland and Altman's limits of agreement were narrow and strong for the sagittal and frontal plane variables, but wider for the transverse plane variables.

#### *4.6.2 Postural Variables*

##### *Sagittal plane Variables*

Several studies have reported the validity of sagittal plane postural variables measured by both radiographic and non-radiographic instruments. The non-radiographic instruments widely range from the flexi-ruler (Dunleavy et al., 2010; Greendale et al., 2011; Letafatkar et al., 2011; MacIntyre et al., 2011; Oliveira et al., 2012), photogrammetry (Van Niekerk et al., 2008; Fortin et al., 2010; Saad et al., 2012) and inclinometer (Lewis et al., 2010; Czaprowski, 2012) to surface topography (Kovac & Pecina, 1999; Fortin et al., 2010).

In the current study, a novel MSTS was used to measure posture variables in all three planes. Within the sagittal plane, the estimation of the lumbar lordosis (LL) variable demonstrated good correlation ( $r = 0.77$ ;  $p = 0.49$ ) when compared to the optoelectronic Vicon system. However, for the thoracic kyphosis (TK) variable as well as for cervical lordosis (CL) demonstrated fair to moderate correlation with  $r = 0.47$  ( $P = 0.01$ ) and  $-0.25$  ( $p = 0.04$ ) respectively. The current study's correlation results and SEM values (0.74 to 3.42) for the sagittal plane variables are comparable to those previously reported by photogrammetry (Fortin et al., 2010), the plumbline (Grunstein et al., 2013) as well as the surface topography method (Frerich et al., 2012).

Further, Fortin et al. (2010) and Frerich et al. (2012) reported high correlations between surface topography and radiography methods for the measurement of LL ( $r = 0.81$ ; mean difference of 8 degrees) and TK ( $r = 0.799$ ; mean difference of 10.6 degrees) in adolescent idiopathic scoliosis patients ( $n = 78$ ). In addition, Fortin et al. (2010)

identified fair to moderate correlation for the TK, LL and thoracolumbar or lumbar scoliosis spinal indices when comparing 2D photographs with 3D trunk surface. In support, Stokes et al. (1987), Gracovetsky et al. (1995) and Chockalingam et al. (2002), suggested that the estimation error for the reconstruction of spinal curvature, based on external markers in optoelectronic and surface topographic system were minimized due to the technical and procedural advances in both data capture as well as in data processing.

Even though Fortin et al. (2010), Melvin et al. (2010) and Sedrez et al. (2016) used surface topography for the evaluation of kyphosis and lordosis, reported excellent concurrent validity, these studies cannot be directly compared because they refer to different systems (InSpeck 3D Digitizer System, Moiré Topography and Jenoptik Formetric).

Similarly, the tactile (Flexi-ruler, Kyphometer) method of measurement of LL and TK (Teixeira & Carvalho, 2007; Souza et al., 2009; Letafatkar et al., 2011; Greendale et al., 2011; Oliveira et al., 2012) demonstrated moderate to excellent correlation in comparison to radiological methods. Van Niekerck et al. (2008) proposed a photographic technique using reflective markers on the spinous processes. They showed a good correlation ( $r = 0.81$ ) with X-rays for the measurement of thoracic kyphosis in an upright sitting position among normal youths.

It is important to note that most of the postural studies did not report or validate the cervical lordosis angle using the surface or optical measurement method, so the results



presented in the current study could not be compared. The results of the current validation study, indicated good to moderate correlation when compared to an optoelectronic system for measuring sagittal plane variables using a novel MSTS. This could be attributed to the fact that the estimation of curves in both systems were made using the same reflective marker set. It is also important to note that the size of the curvature directly influences the estimation of angle. According to Mior et al. (1996) and Cheung et al. (2002), the larger the curvature the lower the estimation error. The lumbar and thoracic sagittal plane curvatures are comparatively larger in relation to cervical lordosis. The low mean differences and SEM values makes the MSTS a very suitable tool to use within a clinical environment for the measurement of sagittal plane variables.

#### *Frontal Plane Variables*

In the current study, the estimation of the variables shoulder elevation (SE), lateral pelvic tilt (LPT) and frontal knee angle (FKA) demonstrated fair to moderate correlation ( $r = 0.28, 0.40$  and  $-0.27$  respectively). The comparison of mean differences between the two instruments (the MSTS and Vicon systems) demonstrated non-significant differences with a  $p$  value of  $0.86, 0.48$  and  $0.10$ , respectively. The current study's correlation results and SEM values ( $0.40$  to  $1.56$ ) of the frontal plane variables are comparable to those previously reported by photogrammetry (Fortin et al., 2010), the scoliometer (Prowse et al., 2017), the plumbline (Hickey et al., 2000) and other surface topography methods (Fortin et al., 2010; Gorton et al., 2012; Pino-Almero et al., 2017).

Fortin et al. (2010) and Gorton et al. (2012) further reported a high correlation between the surface topography and photogrammetry methods for the measurement of LPT and SE angles ( $r = 0.88$  and  $0.90$ ; mean difference of  $1.2$  and  $1.6$  degrees respectively). Similarly, Gorton et al. (2012) identified good correlation ( $r = 0.704$ ;  $p < 0.001$ ) of shoulder obliquity together with moderate correlation for pelvic tilt ( $r = 0.333$ ;  $p = 0.04$ ) when comparing surface topography methods with optoelectronic measures. In the same study, Gorton et al. reported a moderate correlation ( $r = -0.528$  and  $0.554$ ;  $p = 0.02$  and  $0.017$  respectively) when the surface topographic method was compared with a qualitative based Spinal Appearance Questionnaire (SAQ).

It is important to note that even though the current study did not demonstrate excellent correlation (between MSTS and Vicon system) as within previous studies, the mean difference between the two-measurement systems ( $p$  value was  $0.10$  to  $0.86$ ) were similar or lower to those reported in previous studies (Fortin et al., 2010; Gorton et al., 2013). In addition, most of the postural studies did not report or validate the frontal knee angle using a surface or optical measurement method, so the results presented in the current study could not be compared.

The fair to moderate correlation within the current study might perhaps be attributed to the low sensitivity of the MSTS for measuring smaller angles in the frontal plane variables in normal healthy adults. Prowse et al. (2017) provided similar justification for their similar results when the frontal plane measurements were compared between the scoliometer and radiograph methods. Additionally, in comparison with the automatic estimation of angles in the optoelectronic systems, a small manual error for the

identification of the centre of markers in the MSTS might have contributed to a larger variation in the angle calculation (Sheeran et al., 2010; van Blommestein et al., 2012).

#### *Transverse plane variables*

In the current study, the estimation of transverse plane variables such as the right and left scapular prominence (SP) demonstrated low correlation ( $r = 0.03$  and  $0.11$ ). However, the comparison of the mean differences between the two instruments (the MSTS and Vicon systems) demonstrated non-significant difference with  $p$  value  $0.05$  and  $0.04$  for the left and right scapular prominence respectively. The transverse plane variables correlation results of the current study are in contrast to those reported by some previous studies, stating a strong correlation when using Scoliometer (Coelho et al., 2013; Prowse et al., 2017); radiography (Somaskeoy et al., 2012) and Photogrammetry (Fortin et al., 2010). Similar to the current study, few authors have reported a poor correlation when using a scoliometer (Mubarak et al., 1984; Amendt et al., 1990) and surface topographic method (Pearsall et al., 1992) to measure transverse plane variables.

Even though the above studies reported direct and indirect methods (though axial trunk rotation) for measuring the SP, the result of these studies cannot be directly compared because they refer to both different instruments as well as different measurement methods as also a lack of standardised agreement at the thoracic level of measurement.

Furthermore, in the present study the SP measurements obtained by the MSTS were not similar to the optoelectronic system, indicating that the presented method not essentially replace the optoelectronic method for calculating SP values from transverse profiles. The reference Vicon system used in this study calculated the scapular prominence angle by estimating the relative position of the reflective markers like acromion process, medial border of scapula and T7 spinous process. In contrast, the MSTS calculates the shoulder prominence angle in a cross-section of the mid-thoracic segment. The calculated angle formed by lines drawn through T7 vertebrae of the curve to the apex of the scapula prominence and the lower end angle of curve (please see Table 3.2). It is also important to note that the current MSTS also needs to be validated or verified with the other surface topographic system such as ISIS2 machine.

The measurement of posture variables is critical for the clinical diagnosis of patients with spinal disorders. This also helps the practitioner to diagnose and understand the impact of prolonged faulty postures on the development of musculoskeletal problems. The current advanced posture and back shape measurement methods are often too expensive, time consuming to set up and lack portability for the average clinical use. Thus, the current validity findings support the idea of using the novel MSTS for measuring posture variables in clinical practice.

#### **4.7 Limitation and Further Studies**

This study is not without its limitations. The sample size was small and only young healthy adults were included in this study; consequently, the results and conclusions

only apply to a limited section or proportion of the population. Nevertheless, similar validation is warranted in mixed samples of participants with spinal deformity to determine if any differences exist. The author also anticipates that bias and variation in postural measurements would be greater in populations who had difficulty maintaining a standing position, for example, the elderly and frail or individuals who complain of pain. Although in this study only one investigator was responsible for all data capture and analysis, the variability in the placement of the retroreflective markers on the subjects may have occurred. In gait analysis research, marker displacement is a major source of error in three-dimensional imaging (Della et al., 1999; Groen et al., 2012).

Based on the presented method and the results from the current study there is sufficient justification for the future development of an automated bespoke 3D-imaging posture-analyzing mobile application that recognizes markers and calculates angles which might perhaps be used in a clinical setting. This will also reduce any manual error in calculating postural variables. There is also a need for a study comparing the estimation of posture variables with and without reflective markers.

The duration of data collection for each trial using the Vicon system with six cameras lasted only an average of 3 secs. However, the limitation of MSTS is that it took an average of 30 – 40 seconds using one camera. Further studies on the simultaneous use of more than two MSTS cameras may potentially reduce the duration of data collection of the MSTS system and strengthen the quality of the 3D data produced and thereby strengthen the current validation results.

## **4.8 Conclusion**

The results of the current study suggest that the 3D MSTS is a valid tool to measure most of the three-dimensional posture variables in standing. This is the first study to quantify the 3D imaging MSTS for the measurement of standing posture. The current study also detailed the magnitude of postural and technical sources of error. The MSTS tool has been used widely within the clothing and textile design industries (Fraser & Olds, 2008; Gill, 2015), ergonomics (Kupke & Olds, 2007), sport (Raine & Twomey, 1997) and health (Su et al., 2006). The current study shows that the MSTS also has potential clinical applications in measuring standing posture and back shape variables.

## **Chapter 5. The Clinical Acceptance of a Novel Method of Measuring Back and Body Shape Using a 3D Imaging Mobile Application in Health-Care Professionals**

## **5.1 Chapter Aim**

The research presented in Chapters 3 and 4 investigated the reliability and validity of the MSTS for measuring three-dimensional posture and back shape. The purpose of the current chapter is to explore the clinical acceptance of the MSTS among healthcare professionals. A mixed-method design was adopted to investigate the clinical acceptance of the MSTS by exploring perceived usefulness, ease of use, user satisfaction and user experience. Semi-structured interviews and questionnaires were used to evaluate clinical acceptance variables among 23 clinical practitioners. In addition, this exploratory study also identified any barriers that prevent clinician from adopting this new novel method of measuring back shape and posture. The author believes that a greater understanding of clinical acceptance variables helps to improve the usefulness and user experience of the MSTS within a clinical environment.

## **5.2 Introduction and Literature Review**

For any healthcare practitioner, the measurement of the shape of the spine is an essential aspect of their clinical assessment in various spinal disorders. The assessment of spine and back shape helps to identify a variety of diseases. It can also help to identify the early signs of any disease prior to its occurrence. Been and Kalichman (2014) identified that reduced lumbar lordosis or limited lateral bending are the key predictors for the onset of a serious spinal pain. Another important reason for measuring back shape within clinical practice is that it can be used as an objective tool, to quantify the recovery rate of the patient as well as the outcome of the treatment. In the absence of standard method to measure the shape of the spine, it becomes difficult



to analyse the impact of treatment over time. Thus, there is a demand for a method to measure physical parameters (for example, the lordotic or kyphotic curves, lateral deviation and asymmetries) of the spine within a clinical environment. As discussed in previous chapters, many authors have proposed various techniques to measure back shape, using both tactile to non-tactile methods. Even though they were found to be reliable and valid, most were either laboratory-based, exceedingly expensive or exceedingly heavy to carry around. Therefore, in this study, the author set out to develop a low-cost, portable, mobile back-shape measurement system, that would allow an extended assessment of the full-back shape within the clinical environment.

According to Gagnon et al. (2016), the use of mobile or portable technology by healthcare practitioners' in clinical use, has grown significantly in the last decade. In support of this, Putzer et al. (2010) suggests that the recent advancement in computer processing power, improved mobile phone features (for example capturing 3D data) together with a high spec digital camera have enabled mobile technologies to perform functions that were previously not possible. In accordance with Safran (2001) and Spaziano (2001), high-quality three-dimensional digital objective information for the assessment of the spinal curvature and back posture is a major resource for spinal-healthcare practitioners in order to improve their clinical decision-making, efficiency, accuracy and quality of care. These high-quality images may also reduce any potential medical errors in diagnosing and managing patients with spinal pain or deformity.

However, Free et al. (2013) suggest these mobile tools were not fully utilised by healthcare practitioners in terms of their functions within their clinical environment. In spite of

a multitude of potential benefits, there are still many barriers to the adoption and acceptance of technology within clinical use.

As reported by Marangunic and Granic (2014), research into the acceptance of technology is significant and considerable progress has been made since the 1970s. Furthermore, Davis (1993), Taylor and Todd (1995) and Venkatesh et al. (2012), all agreed that user acceptance is the fundamental issue determining that the success or failure of any tool or system. Out of this consensus, theories have arisen either predict user acceptance or attempt to quantify it.

The main theory used to explain acceptance is through the Technology Acceptance Model (TAM). The model suggests that when users are presented with a new technology, a number of factors (perceived usefulness and perceived ease of use) influence their decision about how and when they will use it. In examining the adoption and acceptance of technological innovations, a number of previous studies have applied the Technology Acceptance Model (TAM) as well as the Diffusion of Innovations (DOI) theory as underlying models. The Diffusion of innovations theory is a theory that seeks to explain how, why, and at what rate new ideas and technology spread. TAM focuses on the factors and decision-making processes an individual will go through in any decision to accept and use a technology (Davis et al., 1989; Ward, 2013). The original research on TAM by Davis's (1989) has been repeated and validated many times (Davis, 1989; Adams, Nelson, & Todd, 1992; Szajna, 1994; Subramanian, 1994). Adams et al. replicated Davis's work and demonstrated the validity and test-retest reliability of the measurement scales. They also demonstrated

that the internal consistency and replication reliability of the perceived use and perceived ease of use scales. Hendrickson et al. discovered high reliability and good test-retest reliability. Davis's theory and measurement scales have been validated by the literature and shown that they can be used with different types of users as well as different types of health technologies (van Schaik et al., 2002; van Schaik et al., 2004; Robinson et al., 2015; Berry, 2016;).

Similarly, Davis's (1989) TAM has evolved over time with slight revisions and integration of different variables related to both human and social change processes (Szajna, 1996; Venkatesh et al., 2003; Legris, Ingham, & Collette, 2003; Lu, Yu, Liu, & Yao, 2003; King & He, 2006; Tsai, Wang, & Lu, 2011). Various TAM theoretical paradigms such as expectation confirmation, together with disconfirmation theory, have employed behavioural intention (BI) or conceptually similar constructs as determinants of technology use (Venkatesh et al., 2003; Bhattacharjee, 2001).

Brown et al.'s. (2014), expectation-confirmation theory (ECT) is regarded as the most popular model in TAM research (Chalomba, 2016). The ECT's ability to predict the adoption of technology or system together with its use has been demonstrated over a wide range of disciplines, for example information technology (Brown et al., 2016; Good et al., 2017), mobile applications (Kujala et al., 2017), education (Schwartz & Zhu, 2015) and health-care technology (Li et al., 2016; Zhang et al., 2017). The key variables used in ECT for predicting the adoption of technology were, perceived usefulness, perceived ease of use, perceived enjoyment, perceived satisfaction and resistance to technology.

According to Luxton et al. (2011) and Connor and O'Reilly (2016), perceived usefulness and perceived ease of use were identified as the most important positive predictors of healthcare professionals' intention to use technology. In addition, Venkatesh (2000) identifies perceived enjoyment and perceived satisfaction as valuable predictors within clinical acceptance model. Offenbeek et al. (2013) suggest that the resistance to use of technology emphasizes on factors like social and power relationships within in the organization.

Furthermore, studies by Vaezi et al. (2016), Liao et al. (2017) and Islam and Mantymaki (2017) have verified the positive relationship between satisfaction and behavioural intention to use a particular system, which provides the foundation for the current clinical acceptance research study.

Ventola (2014) and Borek (2018) suggest that using appropriate technology in health-care settings can improve the quality of clinical practice and enhance patients' experiences. In contrast any technological failure together with the complexity of using it, can also hamper the use of technology within a clinical environment (Rhoda & Brown, 2017; Sternberg et al., 2017). A lack of insight about the benefits of the tool, together with, a lack of knowledge about the measurement tool's capabilities and ambivalence about the changes that the technology could bring to improve their clinical practice discourages clinicians to use and allows the system to fail (Mair et al., 2012).

Wright et al. (2016) observes that a small number of clinicians are still hesitating to use technology either completely or partly in their clinical practice. One of the major reason

for a lack of acceptance of technology is due to its usability failure. The term usability failure refers to the complexity of the tool and its difficulty to use in regular clinical practice. In addition, factors such as fear of cost, confidentiality, security and privacy of patient data play a critical role for clinical acceptance (Johnson, 2001; Mair et al., 2012). Furthermore, Venkatesh and Davis (2000), Legris et al. (2003), Venkatesh et al. (2003), Venkatesh and Bala (2008) and Venkatesh et al. (2012) identify that limited computer knowledge, lack of training, fears concerning the effects of the system and low expertise in using the technology as additional factors that contribute to hesitation in using technology by clinicians within their clinical practice.

According to Esmaeilzadeh et al. (2010), clinicians are also burdened by the stress of anxiety about the new technology/system, resulting in high levels of stress and feelings of vulnerability in their profession. Nilsen et al. (2016) suggest that, lack of acceptance can also translate to active resistance to new practice implementation. According to Johnson (2001), users who have little psychological ownership and who resist the implementation of the tool can result in the failure of a technically appropriate system.

Without an appropriate analysis of the demand of healthcare practitioners and their prior knowledge of technology in clinical use, the implementation of new technologies could have a negative impact, ranging from the simple annoyance to total failure. Therefore, the aim of this study was to investigate the clinical acceptance and perceived user satisfaction and usefulness of this novel low-cost, innovative MSTs to capture and measure posture and three-dimensional back shape.

### *5.2.1 Hypothesis*

The hypotheses that will be tested in this study were as follows:

H1. Perceived user satisfaction (PS), perceived usefulness (PU), perceived ease of use (PEOU) and perceived experience (PE) would be correlated with behavioral intention to use the MSTS within a clinical environment.

H2. Expectation confirmation would be correlated with perceived satisfaction and perceived usefulness.

## **5.3 Methods**

### *5.3.1 Research Design*

The aim of this study was to examine the clinical acceptance of the MSTS for capturing and measuring three-dimensional posture and back shape. The purpose of this study was not to prove or disprove the technology acceptance model, but rather to identify factors that determine the behavioural intention of clinical practitioners' using the MSTS in clinical use. In this study, a mixed-methods design was used, using of both qualitative and quantitative methods for data collection and analysis (Gall, Gall, & Borg, 2010). This overarching analytical approach enables author to take advantage of the strength of both qualitative and quantitative methods.

From a quantitative perspective, the purposes were to evaluate the expectation and acceptance of the MSTS by using Brown et al's. (2014) TAM variables (perceived usefulness, ease of use, satisfaction, enjoyment and behavioural intention). The aim of using qualitative methods was to explore and articulate specific or additional reasons

for acceptance and rejection of the MSTS (for example, affordability, ease of use, time taken for data collection and analysis as well as clinical practitioners' intention to use the MSTS in a clinical setup). In the current study, as part of the qualitative research, interviews and observations were used to elicit information from the participants about the acceptance and usefulness of the MSTS within their own clinical practice.

At the end of each section of the expectation confirmation/disagreement questionnaire open-ended items were added. This provided an opportunity for the participants to add more information and share ideas that had not been previously covered in the closed items. This additional information provided the author with emergent themes and interesting quotes that was used to validate and embellish the quantitative survey findings (Creswell & Plano Clark, 2011).

The rationale for the use of both qualitative and quantitative components in this mixed-method design was to explore the interaction between the data sets. A further reason was to seek to use the results from one approach to help develop or inform the other approach (Bryman, 2006; Creswell & Clark, 2017). The author believed that this would develop a deeper understanding of the expectation and acceptance of the MSTS among clinical practitioners.

Results were reported in both numeric and narrative forms. According to Duncan and Nicol (2004), this combined approach to reporting is used to address the complexity of health-care research. Combining multiple methods and analytic strategies can provide

an overarching evaluation of the research question and can further provide rigor to the integrative efficacy (combined effects) of the results (Teddlie & Tashakkori, 2009).

### *5.3.2 Ethics*

This project was submitted and approved by Teesside University's Research Ethics Committee, Middlesbrough, UK.

#### *Informed consent*

Participants were given information relevant to participation in this study via an information sheet and were offered a discussion with the author, giving the chance to clarify any questions and concerns. Informed consent was gained and two copies of the signed consent form were produced: one was to keep for study records and subsequently stored at Teesside University, the other made available for the participants to keep as a record for themselves.

#### *Right to withdraw*

It was made clear to participants that they could withdraw from the study at any time throughout the study period by contacting the author. The author was in regular contact (on a daily basis) with the participants, which allowed the monitoring of any additional needs throughout the whole process of data collection and analysis.

#### *Confidentiality*

This project was conducted in accordance with the Data Protection Act (1998): participants were allocated a code by which data was collected and stored confidentially. Additionally, the laptop used for data storage were password-protected.



### *5.3.3 Participants*

The target population for the study was clinical practitioners who were mainly involved in assessing and treating patients with spinal pain. Patients were eligible to participate if they were aged 18 years and over, experiencing non-specific LBP for a minimum of 2 - 12 weeks and reported at least a moderate level of pain recorded as 3 or above on a numeric pain rating scale (Appendix 6). Participants (clinical practitioners) recruited in this study were health-care practitioners from private clinical-practice settings in the Northeast region of England. The author contacted private clinics in person, email and/or by telephone. Based on an advertisement through posters and leaflets in the private clinics, the private practitioners were given an option to contact the author. Participants were selected by the author from a group of clinical practitioners who had expressed an interest to participate in the study. Twenty-three health-care practitioners participated in this clinical-acceptance study. As presented in Table 5.1, the majority of participants were physiotherapists ( $n = 16$ ; 69.60%), followed by sports therapists ( $n = 5$ ; 21.70%) and osteopaths ( $n = 2$ ; 8.70%). Over half of the sample ( $n = 15$ ; 65.20%) had a postgraduate degree with a mean work experience of 6.91 (SD = 4.43) years (see Table 5.1 and 5.2). This indicates that the sample was highly qualified and had good clinical experience.

Regarding the average use of digital technology (for example, using PC or smart phone for Internet-browsing, e-mail and/or social activities) in their day-to-day activities at home and at work, the majority of participants spent 4-6 hours ( $n = 10$ ; 43.50%); 2-4 hours ( $n = 6$ ; 26.10%) or 6–8 hours ( $n = 4$ ; 17.40%). Participants rated their level of

digital technology expertise from very low (1) to very high (5). A majority (52.20%) rated themselves as 4 (high expertise) followed by eleven (47.80%) participants rated themselves as 3 (average expertise), with an overall mean rating of 3.52 (SD = 0.51). The participants age, average use of digital technology in hours per day and use of technology rating was positively skewed in the current study. According to Pallant (2010) the skewness value is an indicator for analysing the symmetry of distribution, whereas kurtosis provides information about the height of the distribution. A negative skew indicates that the distribution is shifted to the right; whereas negative kurtosis indicates a flatter distribution. A positive skew indicates a shift to the left, whereas the positive kurtosis value indicates a peaked distribution. Z-score is a statistic expression on how far a particular result or score is from the mean in terms of standard deviation units. According to Tabachnick and Fidell (2007), the normal range for standardised skewness-kurtosis values (Z-scores) is  $\pm 2.58$ . A summary of variance, skewness and kurtosis of the entire descriptive variable is presented in Table 5.2.

All the participants in the study used the MSTS to capture and measure 3D back and body shape in a minimum of ten patients each. The patient population was a mixture of both genders of all age groups and with either acute or chronic spinal pain.

Table 5.1  
Descriptive statistics of all participants

Background	Number of participants	Percentage
Age		
20-30	8	34.7%
30-40	12	52.1%
40-50	1	4.3%
50-60	2	8.6%
Gender		
Male	9	39.10%
Female	14	60.90%
Profession		
Physiotherapist	16	69.60%
Sports Therapist	5	21.70%
Osteopaths	2	8.70%
Qualification		
BSc	8	34.80%
MSc	15	65.20%
Average use of digital technology		
2-4 hours	6	26.10%
4-6 hours	10	43.50%
6-8 hours	4	17.40%
8-10 hours	1	4.30%
10-12 hours	1	4.30%
>12 hours	1	4.30%
Use of technology rating		
3	11	47.80%
4	12	52.20%

Table 5.2

Descriptive statistics of all the participants with Skewness and Kurtosis.

	Age (Years)	Experience (Years)	Average use of Digital Technology (hours/day)	Use of Technology Rating
Mean	33.13	6.91	2.3	3.52
Median	32	6	2	4
Mode	32	2	2	4
SD	7.94	4.43	1.29	0.51
Variance	63.11	19.62	1.67	0.26
Skewness	1.59	0.819	1.43	-0.09
SE (Skewness)	0.48	0.481	0.48	0.48
Z (Skew)	3.3	-1.42	3.09	2.97
Kurtosis	2.37	0.72	2.2	-2.19
SE (Kurtosis)	0.93	0.94	0.93	0.93
Z (Kurtosis)	2.53	-1.8	1.27	2.35

*Inclusion Criteria*

Health-care professionals had a minimum of two years work experience in treating patients with spinal pain within clinical settings. They had also experience in using a computer or smartphone for different activities such as work, hobbies, the internet, administration and data storage (see Appendix 1). The participants were not excluded on the basis of any demographics or other individual factors.

#### *5.3.4 Materials and Equipment*

##### *3D Data Collection Equipment – MSTS*

Both the mobile hardware and software used to collect posture and back shape data are described in detail in Chapters 2 and 3 (section 2.7 and section 3.3.2).

##### *5.3.5 Data Collection Tools*

The quality of psychometric measurement is generally evaluated by the validity and reliability of the instrument. The author first examined the content validity of the measurement scales. This established the degree to which a measure was represented the corresponding construct (Dinev et al., 2013). Six constructs were measured in this study: perceived usefulness (PU), perceived ease of use (PEOU), perceived satisfaction (PS), behavioural intention (BI), perceived enjoyment (PE) and resistance to technology (RT). All constructs were measured using multiple items. The expectation measurement questionnaire consisted of two constructs (perceived usefulness and perceived ease of use) with 10 items and the experience measurement questionnaire consisted of all six constructs (PU, PEOU, PS, BI, PE and RT) with 24 items. Each item used a five-point Likert agreement scale with the end-points of Strongly disagree (1) to Strongly agree (5). Although all the constructs had been validated by previous studies, the author also evaluated them to ensure the validity and reliability was within an acceptable range.

Reliability measures the degree to which a tool produces consistent results during multiple measurements (Hair et al., 2016). This internal consistency was checked

using a Cronbach's alpha value ranging from 0 to 1. Individual items greater than score of 0.7 are considered acceptable (Fornell & Larcker, 1981).

#### *Expectation Confirmation/Disagreement Questionnaire*

According to Brown et al.'s (2014) technology acceptance model (TAM), expectation confirmation was a strong predictor of satisfaction and perceived usefulness; positive expectation disagreement was a predictor of the level of use as well as being a strong predictor of perceived usefulness.

Within this study, items from Brown et al.'s (2014) questionnaire were adapted. These had been rigorously validated in Brown et al.'s previous technology acceptance studies. Three to six item scales were used to measure PU, PEOU, PS and BI. Perceived usefulness (PU) refers to the belief that a user believes that their job performance can be improved by using a specific tool or system (Chen et al., 2007; Aizen, 1991). This presumption also positively affects the user's intention to use this system. In the current study, PU is defined as the overall assessment and perception clinical practitioners hold on the usefulness of the MSTS in the assessment and measurement of human posture and back shape. The PU scale used in the current study had six items that had previously demonstrated high reliability (Cronbach's alpha ranges from 0.88 to 0.92) and validity across multiple studies (for a review, see Hess et al., 2014).

The items used to measure the expectation of perceived usefulness were as follows.

*Q1 I expect that the new method of capturing and analysing 3D back shape using Structure Sensor<sup>TM</sup> and Netfabb basic software will enable me to accomplish tasks more quickly.*

*Q2 I expect that the new method of capturing and analysing 3D back shape using Structure Sensor<sup>TM</sup> and Netfabb basic software will improve the quality of the work I do.*

*Q3 I expect that the new method of capturing and analysing 3D back shape using Structure Sensor<sup>TM</sup> and Netfabb basic software will make it easier to do my job.*

*Q4 I expect that the new method of capturing and analysing 3D back shape using Structure Sensor<sup>TM</sup> and Netfabb basic software will enhance my effectiveness on the job.*

*Q5 I expect that the new method of capturing and analysing 3D back shape using Structure Sensor<sup>TM</sup> and Netfabb basic software will give me greater control over my job.*

*Q6 I expect that the new method of capturing and analysing 3D back shape using Structure Sensor<sup>TM</sup> and Netfabb basic software will improve my productivity.*

According to Revels et al. (2010), PEOU has been identified as a major component in evaluating a user's acceptance of a particular technology. PEOU refers to the users' perception of performing a particular task that requires the amount of mental effort (Rouibah et al., 2011). In the current study, PEOU is defined as the overall perception of clinical practitioners believing their system that would be free from effort to use within their clinical practice. The PEOU scale used in the current study had four items that demonstrated high reliability (Cronbach's alpha ranged from 0.86 to 0.90) across multiple studies (for a review, see Hess et al., 2014).

Items used to measure the expectation of perceived ease of use were as follows.

*Q7 I expect that it will be easy to get the new method of capturing and analysing 3D back shape using Structure Sensor<sup>TM</sup> and Netfabb basic software to do what I want it to do.*

*Q8 I expect that overall, the new method of capturing and analysing 3D back shape using Structure Sensor<sup>TM</sup> and Netfabb basic software will be easy to use.*

*Q9 I expect that learning to operate the new method of capturing and analysing 3D back shape using Structure Sensor™ and Netfabb basic software will be easy for me.*

*Q10 I expect that interacting with the new method of capturing and analysing 3D back shape using Structure Sensor™ and Netfabb basic software will not require a lot of my mental effort.*

Two separate studies by Davis (1989) and Adams et al. (1992) demonstrated good convergent and discriminant validity ( $r = 0.54$  to  $0.93$ ) of both PU and PEOU scales with the help of a multitrait, multimethod evaluation technique. The PU is highly correlated with self-reported current usage and self-predicted future usage. Whereas the PEOU was highly correlated with current usage and future usage (Davis, 1989). This reflects favourably on the convergent, discriminant and factorial validity of the usefulness and ease of use scales.

The items in both PU and PEOU were worded appropriately in order to measure expectations immediately after training (pre-use response) and experiences after using (post-use response) the MSTs in clinical practice (see Appendix 2 and 3).

Consistent with prior research, the actual use was operationalized using system log data (recorded manually) of the duration of use (in hours) minus idle time (e.g., Venkatesh et al., 2003). This measure provided the advantage of eliminating the common method bias and limited the potential for social desirability biases given the elimination of idle time.

#### *Perceived Satisfaction (PS)*

Perceived user satisfaction (PS) is defined as the feeling of positive experience resulting from a tool/system's performance of initial expectations (Cho et al., 2011;



Amin et al., 2014). The questionnaire used in this study was adapted from Brown et al.'s (2014). Perceived satisfaction in this study was assessed by asking each clinical practitioner to respond to the following four statements.

*Q11. I am an enthusiastic user of the new method of capturing and analysing 3D back shape using Structure SensorTM and Netfabb basic software to measure back shape and posture*

*Q12. All things considered, my continuing to use the new method of capturing and analysing 3D back shape using Structure SensorTM and Netfabb basic software in my job is (Extremely Negative to Extremely Positive).*

*Q13. All things considered, my continuing to use the new method of capturing and analysing 3D back shape using Structure SensorTM and Netfabb basic software in my job is (Extremely Bad to Extremely Good).*

*Q14. All things considered, my continuing to use the new method of capturing and analysing 3D back shape using Structure SensorTM and Netfabb basic software in my job is (Extremely Harmful to Extremely Beneficial).*

Previous studies that used similar PS items within their studies (Wixom & Todd, 2005; Kim & Chang 2007; Konradt et al., 2007; Hess et al., 2014) demonstrated good reliability (Cronbach's alpha > 0.82) and construct validity.

### *Behaviour Intention*

Oliver et al. (1997) suggests that behavioural intention refers to the user's likelihood to engage in a certain behaviour. Based on this definition, behavioural intention as used within this study was described as the clinical practitioners' likelihood of engaging with and using the MSTS in their regular clinical practice. Behavioural intention was assessed by asking each clinical practitioner who participated in this study to answer the three statements below.

*Q15. I intend to continue using the new method of capturing and analysing 3D back shape using Structure SensorTM and Netfabb basic software.*

*Q16. I predict I would continue using the new method of capturing and analysing 3D back shape using Structure SensorTM and Netfabb basic software.*

*Q17. I plan to continue using the new method of capturing and analysing 3D back shape using Structure SensorTM and Netfabb basic software.*

Previous studies have used similar behavioural intention items within their studies (Ryu et al., 2008; Barua, 2012; Hess et al., 2014; Joo et al., 2014) and demonstrated good reliability (Cronbach's alpha 0.87 to 0.89) and construct validity.

### *Perceived Enjoyment (PE)*

In this study, 'perceived enjoyment' was conceptualised as an intrinsic-motivation variable. Intrinsic motivation is defined as the doing of an activity for its inherent satisfaction rather than for some separable consequence (Ryan & Deci, 2000). In contrast, 'extrinsic motivation', such as perceived usefulness (discussed above under expectation agreement), is a construct that pertains to whenever an activity is done to attain some external outcome. The three items for perceived enjoyment were adapted from previous published work by Sun and Zhang (2008) and developed and validated by Agarwal and Karahanna (2000), Liu and Li (2011), Teo and Noyes (2011) and Al-Debei (2014). The results of their studies demonstrate high reliability with cronbach's alpha ranging from 0.86 to 0.92. Perceived enjoyment was assessed by asking each clinical practitioner who participated in this study to answer the three statements below.

*Q18. I find using Structure SensorTM and Netfabb basic software to capture and analyse 3D back shape to be enjoyable.*

*Q19. The actual process of using Structure SensorTM and Netfabb basic software to capture and analyse 3D back shape is pleasant.*

Q20. *I have fun using Structure Sensor™ and Netfabb basic software to capture and analyse 3D back shape.*

### *User Resistance to the Technology*

User resistance or the opposition of users to perceived change to adopt to new technology has been conceptualized as an adverse reaction to the implementation of new technology in clinical practice. Klaus and Blanton (2010) refers to user resistance as the behavioural expression of a user's opposition to the implementation of a system. The attribution then leads to outcome and efficacy expectancies; negative expectancies lead to user resistance. Within the current study, Kim and Kankanhalli (2009) scales based on Bovey and Hede's (2001) framework were adapted to measure user resistance.

This classification distinguishes between overt (open and expressive) and covert (concealed or hidden) resistance as well as between active (originating action) and passive (inert or not acting) resistance. The degree of resistance is considered to increase from covert passive (e.g., ignoring or indifference) to overt active (e.g., obstructing) behaviours. Following the framework, the author adapted four items representing resistance behaviour, with each item corresponding to a category of the framework: "not comply with" (passive and covert), "not cooperate" (active and covert), "do not agree" (passive and overt), and "oppose" (active and overt). All items in this tool were adapted from the previous published work by Kim and Kankanhalli (2009), which demonstrated a good reliability with cronbach's alpha of 0.94 (Hsieh,

2015). The resistance to technology were assessed by asking the clinical practitioner to answer the four statements below.

Q21. *I will not comply with the change to the new way of capturing and analysing 3D back shape using Structure SensorTM and Netfabb basic software.*

Q22. *I will not cooperate with the change to the new way of capturing and analysing 3D back shape using Structure SensorTM and Netfabb basic software*

Q23. *I oppose the change to the new way of capturing and analysing 3D back shape using Structure SensorTM and Netfabb basic software*

Q24. *I do not agree with the change to the new way of capturing and analysing 3D back shape using Structure SensorTM and Netfabb basic software*

### *Interview*

A further approach used in this study to evaluate the use of the MSTS was through recorded semi-structured interviews. An interview guide was developed to make sure that no questions were omitted during each interview (see Appendix 4). Yet, in keeping with the exploratory nature of the interviews, questions were kept as open as possible. Each interview lasted forty-five minutes to an hour and was held at the clinical practitioner's site. The purpose of the project and the reason for the interview were explained to the interviewees beforehand. All the participants were interviewed regarding their impression of the system, expectation confirmation, any aspect they liked or disliked in the system and anything missing in this system. More in-depth questions were asked about the functionality of the system and duration to capture and analyse patients' three-dimensional data. Participants were also asked whether they would be able to use the system in their own clinical practice. The questions were derived and adopted from the technology acceptance literature, in particular the *Unified Theory of Acceptance and Use of Technology* (Venkatesh et al., 2003) and

the *Technology Acceptance Model* (Davis, 1985). Together with each participant, the interviewer also reviewed video data, giving the participant the opportunity to clarify their queries on the use of MSTS.

#### *5.3.5 Protocol*

All participants filled in a background questionnaire (Appendix 1). This included their age, gender, highest educational level attained, day-to-day digital technology and Internet usage (for personal and work-related activities), discipline, scope of practice and years of experience as a practitioner.

There were four stages within this research project (please see Figure 5.1).

Stage 1 (demonstration and training). All the participants in this study were trained and familiarised to use the MSTS to capture and analyse back shape through a one-day workshop.

Stage 2 (expectation measurement). At the end of the training-and-familiarisation session, all the participants in this study were given a questionnaire (Appendix 2) to capture their expectations of using the MSTS to assess back shape.

Stage 3 (system use). Within their clinical practice, all the participants were asked to use the MSTS to capture and measure 3D back and body shape for at least 10 patients who had spinal pain of whom at least two had acute low back pain and another two had chronic low back pain. One of their patients' data capture and measurement was videoed by the author or by the practitioner for further qualitative analysis. All the

participants were also asked to log the time taken to capture, measure and analyse their patients' data.

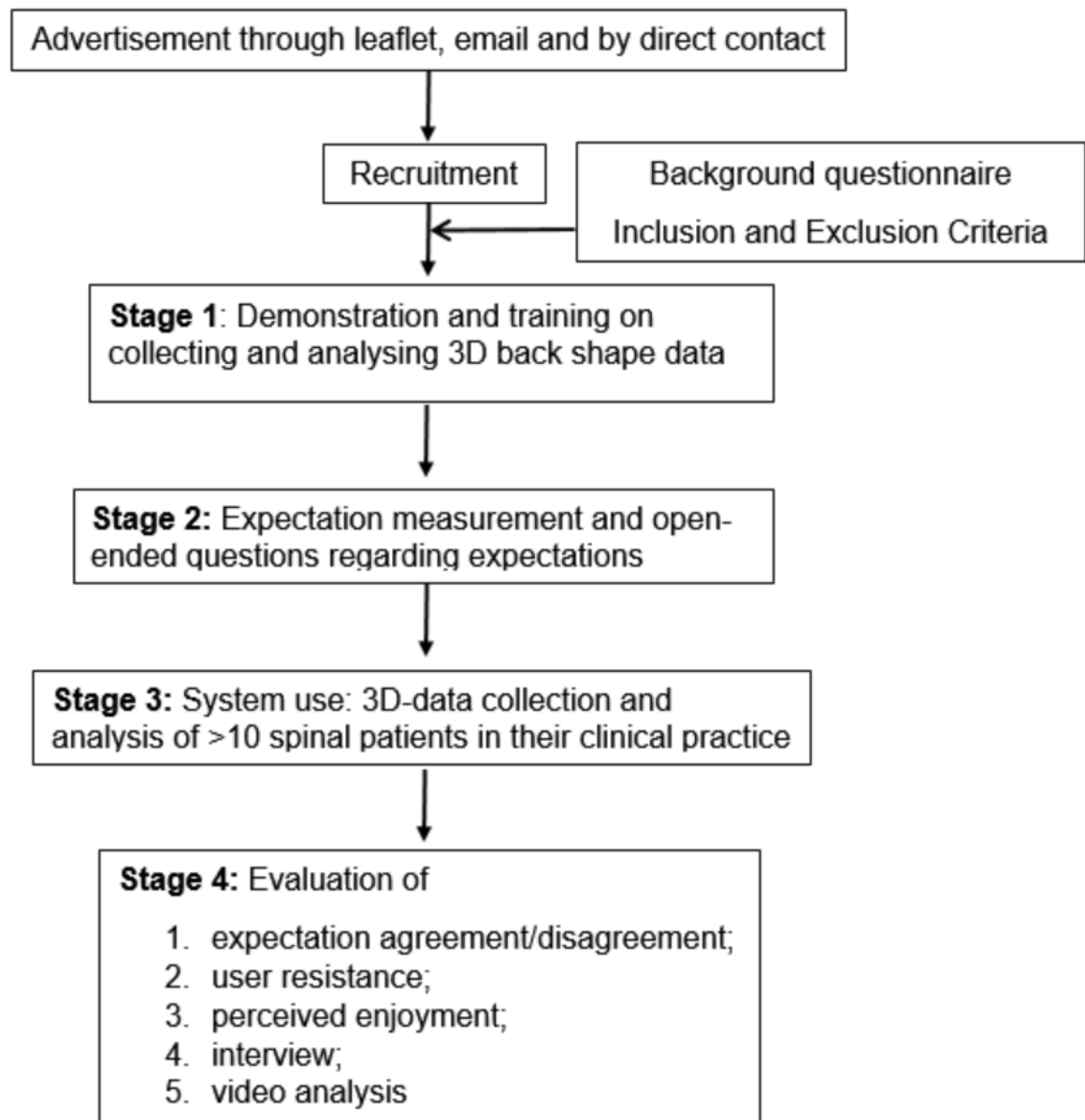


Figure 5.1 Protocol of clinical-acceptance study design

Stage 4 (evaluation). After they had completed using the tool on a sufficient number of patients in Stage 3, each participant was assessed for their technology acceptance.

Feedback on the MSTS together with its design features was obtained using an expectation confirmation/disconfirmation questionnaire and open-ended questions. Interviews were also conducted to capture advantages and disadvantages of the MSTS together with the use of the system and factors that would facilitate participants using the tool. Participants were also asked questions regarding the possible applications of the system and its affordability.

#### *5.3.6 Procedure*

All potential participants who met the inclusion criteria were given a participant information sheet. This included a summary of the background of the study, what taking part involved, what the practitioner could expect if they took part, the risks and potential benefits of taking part, together with the details of the research team. Participants were given time to read the information sheet as well as the opportunity to ask questions about the study before making their decision as to whether to participate or not. Participants were informed that the decision to take part in the study was completely voluntary, and that taking part would not change the treatment they provide to their patients. Those who made a decision to take part in the study were asked to give their written consent by signing a consent form and fill in the background questionnaire.

After a minimum of 15 participants (health-care practitioners) had been recruited, a one-day hands-on training session was conducted in order to train the participants on using the MSTS to capture and measure 3D back shape. Therefore, a total two days of training were provided with fifteen participants on one day and ten on the second

day. In this training session, each participant had to collect and analyse 3D back data on at least one human model. The data were collected using a commercially available iPad camera and Structure Sensor™ (see section 5.3.4).

In order to capture the data, the clinical practitioner walked around with the camera pointing towards the patient in a 360 degrees circle at three different heights (patient's shoulder, pelvis and knee). Throughout the data collection, the distance between the camera and the model was between 0.5 to 1 metres. In order to limit the variability associated with participants' positions and standardizing the data collection, two reference lines for the placement of feet were drawn on the floor towards X and Y axis (see Figure 3.5).

The collected data (3D model) were then realigned and processed in the open-source software called Netfabb Basic™. The variables were then measured and reported these included lumbar lordosis angle, cervical lordosis angle, thoracic kyphosis angle, shoulder elevation angle, lateral pelvic tilt angle, frontal knee angle and scapular prominence angle (in degrees).

Along with the hands-on training, all the participants were also provided with a digital handbook with illustrations of a step-by-step guide and video guide on using the MSTS within their clinical practice. Following the demonstration and training, each participant's expectations of using this MSTS were measured using the expectation measurement questionnaire. After using the MSTS in their clinical practice, all the



participants were evaluated their clinical acceptance of the MSTs using expectation agreement/disagreement questionnaire.

#### **5.4 Data Analysis**

According to Hair et al. (2010), establishing the presence of normal distribution of data is fundamental to parametric analysis. This degree of normality of a distribution may influence the validity and reliability of the results. Tests of skewness-kurtosis tests were employed to establish the degree of deviation from a normal distribution.

The questionnaire data included expectation (after training and before use of the system) and experience (after use in clinical practice) measures. Experience measures were compared with expectation measures using a paired t-test and effect size using Cohen's D. Correlations were also calculated between expectation measures, experience and resistance to technology measures. The mean scores of the different components (usefulness, EOU, satisfaction and BI) were compared to expectation and experience measures. All the quantitative data were analysed with the IBM Statistical Package for the Social Sciences (SPSS Version 23.0) software.

In the current study, all the interview data were transcribed manually, followed by the thematic analysis of data. Thematic analysis is a type of qualitative analysis which aims at noticing, analysing and reporting repeated themes across a data set that has been collected through the interview (Guest et al., 2012). Braun and Clarke (2012) suggest that thematic analysis is compatible with theoretical approaches to analysing qualitative data. Additionally, along with Braun and Clarke (2012), Patton (1990),

(2005), identifies thematic content analysis as having the advantages of flexibility and simplicity, together with the ability to capture the dynamic and evolving nature of events.

NVivo (Version 11), a piece of computer-assisted qualitative data analysis software, was used to code the qualitative data according to the domains that were identified. NVivo is a powerful tool that is capable to do sophisticated data-coding. It supports several approaches to building themes of either local or more global (Bazeley & Jackson, 2013). Within the data analysis software, the data were coded to identify sub-themes for each of the themes. The author reviewed the data to identify issues that were consistently raised by participants or appeared to be very important to a participant. The author then conducted a taxonomic analysis by identifying sub-themes within each theme. During the analysis process, the author looked for negative cases that contradicted the sub-domains. When negative cases were identified, the author adjusted the themes by either merging or forming new categories, so as to include distinctly different data (in terms of content). After a final list of domains and sub-domains was created, the data were re-coded a final time through a cross-comparison of the quotes included in each category.

## **5.5 Results**

This section presents an in-depth presentation of the results from the questionnaire and semi-structured interviews. The current study investigated the clinical acceptance, perceived user experience and perceived satisfaction by health-care practitioners of

the MSTS to capture and measure 3D back shape. Twenty-five health-care professionals were recruited in the study; two of them withdrew after the initial training due to personal reasons.

#### *5.5.1 Reliability Analysis of pre- and post-use questionnaires*

According to Brown et al.'s (2014) technology acceptance model, expectation confirmation is a strong predictor of perceived usefulness and perceived satisfaction.

##### *5.5.1.1 Perceived Usefulness*

Participants' perceived usefulness of the MSTS to measure posture and back shape was assessed (before and after) using the questionnaire that contained the six items. The overall mean score for this scale was high for both before and after use of the tool with 4.09 (SD = 0.06) and 4.17 (SD = 0.09) respectively. The 95%-confidence interval was ranged as high as 3.95 and 4.37. The pre-use interaction experience of these items in the questionnaire demonstrated moderate reliability with Cronbach's alpha of 0.57, but this score improved to 0.72 by removing Items Q4, Q5 and Q6. The post-use interaction of six items demonstrated good reliability with Cronbach's alpha of 0.77 (see Table 5.3 and 5.4).

##### *5.5.1.2 Perceived Ease of Use*

Participants' perceived ease of use of the MSTS to measure posture and back shape was assessed (before and after use) using the questionnaire with four items. The overall mean score for this scale was high for both before and after use of the tool with 4.01 (SD = 0.08) and 4.29 (SD = 0.07) respectively. The 95%-confidence interval

ranged between 3.83 and 4.45. The pre-use interaction experience of the items in this questionnaire demonstrated moderate reliability with Cronbach's alpha of 0.66 but this score improved to 0.76 by removing item Q10. The after-use interaction items demonstrated good reliability with Cronbach's alpha of 0.70 (see Table 5.3 and 5.4).

#### *5.5.1.3 Perceived Satisfaction*

After using the tool, participants' perceived satisfaction mean score of was high with 4.23 (SD = 0.07). The 95%-confidence interval ranged between 4.08 to 4.39. The after-use interaction experience of this questionnaire items demonstrated moderate reliability with Cronbach's alpha of 0.61. This score improved to 0.65 by removing Item Q21 (see Table 5.3 and 5.4).

#### *5.5.1.4 Behavioural Intention*

The participants' behavioural intention item's mean score was high after-use of the tool with 4.08 (SD = 0.08). The 95%-confidence interval ranged between 3.91 and 4.25. The items demonstrated moderate reliability with Cronbach's alpha of 0.65 (see Table 5.3 and 5.4).

#### *5.5.1.5 Perceived Enjoyment*

Participants' perceived enjoyment after use of the MSTs to measure posture and back shape was assessed using the questionnaire with three items (see Appendix 3). Overall mean score for this item was high for after-use of the tool with 4.23 (SD = 0.48). The 95%-confidence interval ranged between 4.02 and 4.43. The items demonstrated moderate reliability with Cronbach's alpha of 0.68 (see Table 5.3 and 5.4).

#### *5.5.1.6 Resistance to Technology*

Participants' resistance to technology after use of the MSTS to measure posture and back shape was assessed using the questionnaire with four items (see Appendix 3). The overall mean score for this item was high for after use of the tool with 1.60 (SD = 0.09). The 95% confidence interval ranged between 1.42 and 1.79. The items of these scale demonstrated good reliability with Cronbach's alpha of 0.69 (see Table 5.3 and 5.4).

#### *5.5.2 Comparison of Expectation and Experience*

In order to evaluate clinical acceptance, the perceived usefulness and ease-of-use score were compared between before and after use of the MSTS. The differences between expectation and experience scores were investigated using paired *t* tests to assess the (dis)confirmation of (initial) expectations. The results are summarised here and fully presented in Table 5.5. In comparing the expectation to the experience score for perceived usefulness, there was a small increase in mean value,  $d = 0.21$ . The difference in means over time was statistically non-significant. The above result indicates that their expectations have been met after using the tool in their clinical environment (see Table 5.5).

The change in mean scores for perceived ease of use from expectation to experience was large ( $d = 0.72$ ) and statistically significant ( $p = 0.01$ ) (see Table 5.5). The change over time indicated that regular usage of the tool for a longer period, gets easier for practitioners to use it in their clinical environment.

Table 5.3

Descriptive statistics for individual outcome measures measured before and after-use of the MSTs.

	PEOU (Expectation)	PEOU (Experience)	PU (Expectation)	PU (Experience)	Perceived Satisfaction	BI	PE	Resistance
Mean	4.01	4.29	4.09	4.17	4.23	4.08	4.23	1.60
Median	4.00	4.25	4.16	4.16	4.25	4.00	4.33	1.50
Mode	4.00	4.00	4.33	4.50	4.25	4.00	4.33	2.00
Std. Dev	0.40	0.38	0.33	0.45	0.36	0.39	0.48	0.43
Variance	0.16	0.14	0.11	0.2	0.13	0.15	0.23	0.18
Skewness	-0.14	0.01	-0.23	-0.22	-0.78	0.54	-0.13	0.06
SE(Skewness)	0.48	0.48	0.48	0.48	0.48	0.48	0.48	0.48
Z Skew	-0.29	0.03	-0.49	-0.46	-1.62	1.13	-0.27	0.13
Kurtosis	-0.85	-0.62	-0.84	-0.64	0.97	0.31	-0.34	-0.99
SE (Kurtosis)	0.93	0.93	0.93	0.93	0.93	0.93	0.93	0.93
Z Kurtosis	-0.91	-0.66	-0.9	-0.68	1.04	0.33	-0.36	-1.06
95% CI (LL)	3.83	4.12	3.95	3.97	4.08	3.91	4.02	1.42
95% CI (UL)	4.18	4.45	4.23	4.37	4.39	4.25	4.43	1.79

*Note: LL – Lower limit; UL - Upper limit; PEOU – Perceived Ease of Use; PU – Perceived Usefulness; BI – Behavioural Intention; PE – Perceived Enjoyment; Resistance – Resistance to Technology*

Table 5.4  
Reliability analysis

Categories	Mean	SD	No. of items	Overall Cronbach's Alpha	Cronbach's Alpha after items deleted	Items deleted
Perceived Usefulness (expectation)	4.09	0.07	6.00	0.57	0.73	Q4, Q5 and Q6
Perceived Usefulness (experience/after use)	4.17	0.10	6.00	0.77	0.53	Q14, Q15 and Q16
Perceived EoU (expectation)	4.01	0.09	4.00	0.66	0.76	Q10
Perceived EoU (experience/after use)	4.29	0.08	4.00	0.70	-	-
Perceived Satisfaction (after use)	4.23	0.08	4.00	0.62	0.65	Q21
Behavioural Intention (after use)	4.08	0.08	3.00	0.66	-	-
Perceived Enjoyment (after use)	4.23	0.10	3.00	0.69	-	-
Resistance to Technology (after use)	1.60	0.09	4.00	0.69	-	-

Note: EOU – Ease of Use

Table 5.5  
Comparison between expectation and experience (paired t test)

	Mean (SD)		Cohen's <i>d</i>	<i>T</i>	<i>p</i>	CI (95%)	
	Expectation	Experience				Lower Limit	Upper Limit
Usefulness Score	4.09 (0.33)	4.17 (0.45)	-0.21	-0.72	0.47	-0.30	0.14
Ease of use Score	4.01 (0.40)	4.29 (0.38)	-0.72	-2.83	0.01*	-0.48	-0.07

Note: CI – Confidence Interval; \* Significant difference in *p* value ( $p < 0.05$ )

### 5.5.3 Correlations between variables

In order to explore the relationship between the measures of both expectation and experience, correlation coefficients were calculated for baseline measures and the questionnaire scales.

The results presented in Table 5.6 shows that, for most of the variables related to participants' background data and their digital expertise showed no significant correlation (Pearson's correlation coefficients ranging from -0.16 to 0.30) with clinical acceptance variables (perceived usefulness, ease of use (EoU), satisfaction, behavioural intention, perceived enjoyment and resistance to technology). After using the equipment, age and years of experience were negatively correlated with perceived ease of use,  $r = -0.32$  and  $r = -0.41$ , respectively. Therefore, older and more experienced professionals perceived the system as less easy to use. From the results, it is also apparent that more experienced professionals were more resistant ( $r = -0.48$ )



to using the system. Physiotherapists showed greater perceived enjoyment ( $r = -0.44$ ) than other health-care professionals.

To explore the relationships between the clinical acceptance measures, correlation coefficients were calculated between the scales (see Table 5.7, Figure 5.3). Except for perceived usefulness and behavioural intention, most of the variables related to clinical acceptance measures showed no significant correlation (Pearson's correlation coefficients ranging from -0.00 to 0.37). However, perceived usefulness was substantially correlated with ease of use and behavioural intention ( $r = 0.42$  and  $r = 0.46$  respectively). This indicated that if practitioners see the benefits of the MSTS their interest in using the system increases and consequently find the system easier to use.

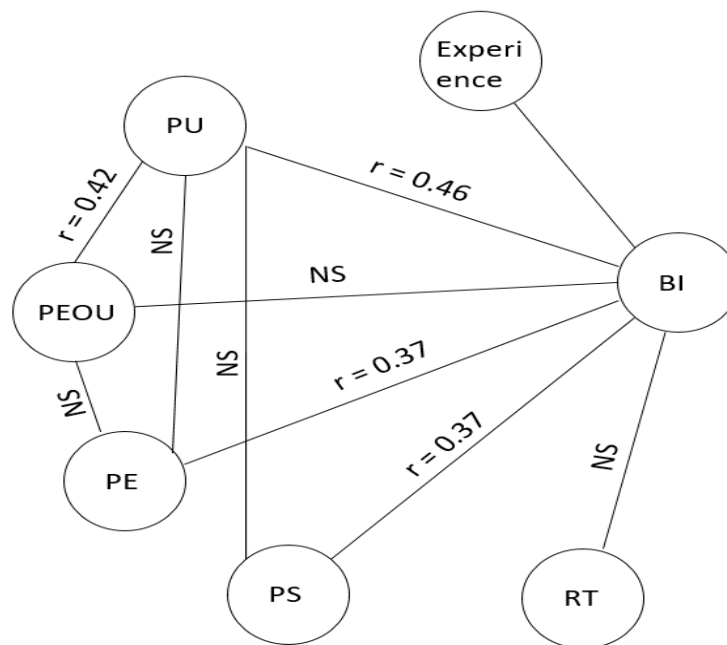


Figure 5.3 Inter-relationship between clinical acceptance variables. (Note: NS – non-significant; PU – perceived usefulness; PEOU – perceived ease of use; PE- perceived enjoyment; PS – perceived satisfaction; RT – resistance to technology; BI – behavioural intention)

Table 5.6  
Correlations between demographics and clinical acceptance measures

	Usefulness Expectation	Usefulness Experience	EoU Expectation	EoU Experience	Satisfaction	Behavioural Intention	Perceived Enjoyment	Resistance to Technology
Age	.21	.00	.08	-.32	.09	-.09	-.13	-.29
Gender	.09	-.15	-.09	.15	-.08	-.36	.08	.31
Profession <sup>a</sup>	-.03	-.03	-.01	-.16	.06	-.07	-.44*	-.07
Qualification	.30	.08	.19	-.22	.16	-.07	.10	-.08
Average use of digital technology	-.15	.09	.10	.20	-.06	.06	.07	.10
Years of experience	.07	.00	.30	-.41*	.08	-.10	-.00	-.48*
Use of technology rating	.32	.24	.13	.17	.03	.06	-.14	-.26

\* Significant difference in *p* value ( $p < 0.05$ ); <sup>a</sup> – Physiotherapist, Sports therapist and Osteopaths

Table 5.7  
Correlations between clinical acceptance variables

	PUsefulness (Expectation)	PEOU (Experience)	PUsefulness (Experience)	PSatisfaction	BI	PResistance	PEnjoyment
PEOU (Expectation)	.34	.27	.04	.21	-.00	.00	.14
PUsefulness (Expectation)	-	.11	.14	-.02	-.02	.12	.11
PEOU (Experience/after use)	-	-	.42*	.26	.25	.16	.21
PUsefulness (Experience//after use)	-	-	-	.26	.46*	.15	.29
PSatisfaction (after use)	-	-	-	-	.37	-.26	.29
BI (after use)	-	-	-	-	-	-.08	.37
PResistance (after use)	-	-	-	-	-	-	-.07

\* Significant difference in p value ( $p < 0.05$ )

#### *5.5.4 Qualitative data*

##### *5.5.4.1 Analysis of interviews*

All interview data were imported into NVivo 11. As recommended by Riffe et al. (2014) all the interview data were transcribed word for word. The transcribed data were coded into broad codes (impression, expectation, use, duration, practical implications and affordability), linked to the primary aim of this clinical acceptability study. The broad codes were further distinguished by perspective (positive, negative, neutral, like, dislike, suggestions, yes and no). As a result, 175 units of thought were identified. Units of thought were defined as expressions of participants' opinion or judgement about using the MSTs in clinical use (e.g., duration, presentation, affordability and usability or expressions of their experience).

The collected units of thought are regarded as genuine and meaningful. Units are regarded as genuine in the sense that the author did not intentionally bias the participants' report of their experiences. The participants only commented on aspects of their experience that caught their attention and elicited an expression of opinion. All transcribed units including time codes were used to identify the pages from which the units of thought were derived.

Using tree nodes in NVivo 11, the codes were organised for conceptual clarity, explanatory, identifying patterns and meaningful analysis (Bazeley & Jackson, 2013). The codes were arranged into three main themes: facilitating factors, inhibiting factors and potential application of the system. The facilitating factors are further subcategorised into 'ease of use', 'affordability' and 'clinical use' as discussed below.

### *Clinical Use*

Usefulness in the clinical environment was the category with the highest number of answers (32), followed by the quality of practice (22), duration (19), visualization (15), and training/skills (5). Please refer to Figure 5.4 for the word tree (feature-based text visualization) of the relationship between usefulness, ease of use, duration, feasibility, future intention to use and clinical applicability through sub-trees. A common view amongst interviewees was that they were impressed with the quality of the data (for example, ability to view the three-dimensional nature of human posture) together with its accuracy; the time taken for data collection; the system's simplicity and its portability. The following extracts illustrate the usefulness of the MSTS within participating therapists' clinical environment.

*“Excellent tool for 3-dimensional posture screening, but I struggled with the analysis of the data, but after using it in couple of Patient’s I got used to the system. As using it for a longer time it got better” (P3).*

One of the participants in the study mentioned about the minor technical faults during data collection.

*“Brilliant tool for measuring and analysing back shape. Occasionally there were some technical faults during the data capture, which we should expect in any technology. These technical faults caused some delay in data capture but by reloading the app it worked fine” (P4).*

Few participants also mentioned on the duration of data capture and the quality of data from MSTs.

*“Best thing about this tool is that this can capture accurately even the skin folds and measurable. It will be useful to have both the assessment and measurement part as one app, so that will be less time consuming” (P10).*

*“The captured model has got great high definition details, easy to pick up differences in any posture abnormalities” (P16).*

#### *Ease of Use*

Ease of use (44) was the most frequent answer in the interviews, followed by the portability of the tool (27), human-computer interaction (22) and the space it took to collect data (18). In the interview, one of the clinical practitioner’s commented on the ‘ease of use’ as shown below.

*“I really enjoyed using the tool to analyse patients with low back pain and for posture screening. The one thing I like about this tool is its usability it is easy to use as well as the fact that is less time consuming” (P2).*

#### *Affordability*

Most of the participants (n = 20) who responded believed that the new tool was very much affordable, small proportion of participants had either no opinion (n = 2) or believed that it would not be affordable (n = 1).

#### *Inhibiting factors*

A minority reported minor technical errors such as iPad freezes up during data collection, either the mobile APP was slow or shuts down or the connecting to the internet service was difficult. Additionally, few participants raised that analysing data took longer duration about 15 – 20 minutes per patient.

Most of the participants agreed that the MSTS improved the quality of their practice by providing high-quality personal feedback to their patients. Issues related to resistance for using the MSTS were not mentioned or highlighted in the interview data. A few suggestions were also made by the participants on the broader and potential applicability of the MSTS besides postural assessment, for instance its use in the field of research and education. As one interviewee said; *“I wish it had an additional feature to measure dynamic movements or the range of motion of the spine”* (P17). Another interviewee mentioned; *“it will be great if it can be used in many mobiles across platforms like androids and windows”* (P20)

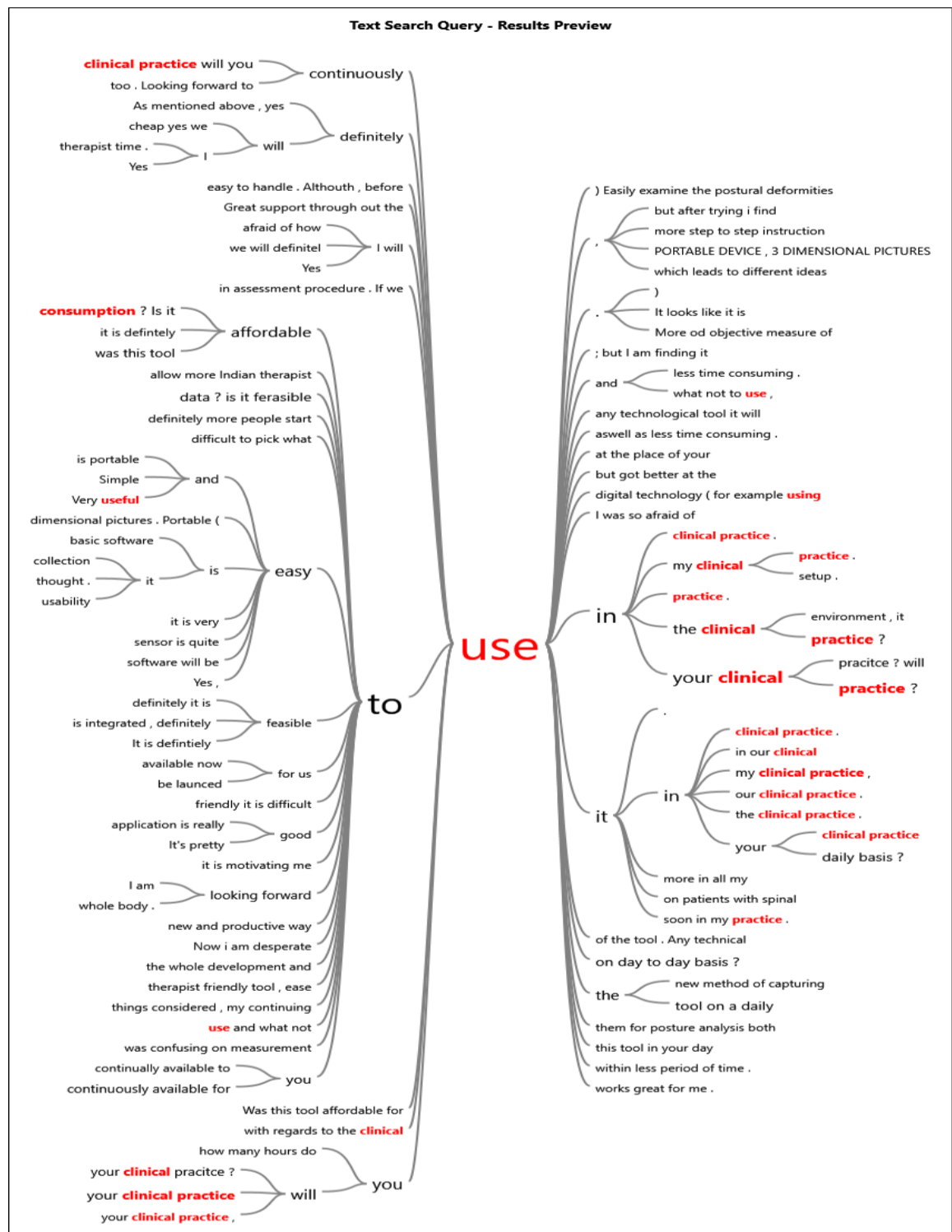


Figure 5.4 Mapping of clinical use. The visual representation of interview data through 'word tree'



## 5.6 Discussion

The aim of the current clinical acceptance study was to investigate factors that enhanced clinical acceptance within healthcare professionals when using the MSTS to capture and measure three-dimensional back shape and posture. Additionally, the current study examined the relationship between the clinical acceptance variables: perceived usefulness, perceived ease of use, perceived enjoyment, perceived satisfaction and behavioural intention. With regards to Brown et al's. (2014) TAM variables, the current study adopted two more additional variables, perceived enjoyment and user resistance to technology, which are considered as essential measures for any clinical acceptance study (Venkatesh, 2000; Adner & Kapoor., 2010; Van Schaik & Ling, 2011).

Based on Venkatesh and Davis (2000) TAM was hypothesised that there would be a relationship between perceived usefulness and perceived ease of use for behavioural intention. The overall results of the current study partially or fully support hypotheses H1 and H2. Each hypotheses will be discussed in detail in the forthcoming sections.

### *5.6.1 Measurement of Acceptance*

The scales used in the current study tested for its reliability, despite its good reliability has been proven by earlier studies (Taylor & Todd, 1995; Wixom & Todd, 2005; Davis & Venkatesh, 2004; Konradt et al., 2007; Kim & Chang 2007; Ryu et al., 2008; Barua, 2012; Joo et al., 2014; Hess et al., 2014). The Cronbach's alpha reliability coefficients for all the measurement scales in the present study indicated moderate to good internal

consistency. The Cronbach's alpha reliability coefficient score is marginally lower than minimum value necessary to prove reliability (0.7) (Nunnally & Bernstein, 1994).

#### *5.6.2 Level of Acceptance*

In addition to the quantitative results, the qualitative results further supported the current study's clinical acceptance variables. In the thematic analysis, the usefulness within the clinical environment was the category with the highest number of answers, followed by the quality of practice. Ease of use was the most frequent answer in the interview. The above mixed method study results indicated that the majority of clinical practitioners who participated in this study perceived that the MSTS was useful, easy to use, satisfied and keen to continue using the system for measuring posture and back shape within their clinical practice.

The results of the current study are consistent with those reported in previous studies that have evaluated on healthcare professionals' adoption of technology (Van Schaik et al., 2002; Chismar et al., 2003; Liu & Ma 2006; 2005; Barker et al., 2005; Yi et al., 2006; Orruno, 2011; Lim et al., 2011; Pynoo et al., 2012; Kuo et al., 2013). The results of these studies will be discussed in detail in the following sections.

#### *5.6.3 Expectation Confirmation*

The current clinical acceptance study investigated clinical practitioners' expectations together with their experience of using the MSTS to assess posture and back shape.

The results from the paired *t* test and qualitative data confirmed that the MSTS to

measure back shape and posture either met or exceeded clinical practitioners' expectations.

In concordance with the current study, several studies reported expectation confirmation. Most of these studies were either in education or business settings, involving students, customers and managers. Only a few studies (Van Schaik et al., 2002; Chismar et al., 2003; Barker et al., 2005; Liu & Ma 2005; 2006; Yi et al., 2006; Lim et al., 2011; Pynoo et al., 2012; Kuo et al., 2013) reported the acceptance of technology within health-care professionals.

The results of the current clinical acceptance study are consistent with the previous study by Van Schaik et al., (2002) when evaluating the clinical acceptance for a postural assessment system the Microscibe digitizer among forty-nine physiotherapists. The quantitative results on the relationship between perceived ease of use and perceived usefulness were similar in both studies. Although this is the only study, directly related to the current study, Van Schaik et al's acceptance result was based on the participants' perceptions without hands-on experience of using the system.

Further, Bhattacharjee (2001a, 2001b) identified expectation confirmation as a strong determinant of perceived usefulness, perceived enjoyment, and satisfaction. The clinical acceptance result of the current study was also supported by positive expectation disconfirmation, with a high perceived level of use and positive perceived usefulness. The majority of the previous evidence from Venkatesh et al. (2003), Kim

and Malhotra (2005) and Limayem et al. (2007) demonstrated that PU is the strongest determinant of intention to use. However, a small number of studies by Igbaria et al. (1997) and Agarwal and Prasad (1998) demonstrated that ease of use has a non-significant direct impact on intention to use.

As reported by Van Schaik et al. (2002), Barker et al. (2005) and Hanif et al. (2011), the facilitating factors influencing the satisfaction and acceptance of the system by the clinical practitioners were system's ease of use together with its perceived usefulness. In support, the qualitative results on the ease of use, clinical use and affordability of the MSTS supported the findings of the quantitative results for perceived usefulness and perceived ease of use. According to the participants, they perceive that the three-dimensional visualisation of posture and back shape together with its clinical applicability of the system for both the diagnosis and evaluation of treatment outcomes, not only will improve the quality of clinical practice but also it will improve the user experience.

Therefore, as stated by Hadji and Degoulet (2016) and Kabra et al. (2017), it is important to observe that the initial acceptance of the MSTS by clinicians was regarded as the first step to the successful deployment of the tool. Subsequently, the overall system's success depends on the continuous use of the system within practice.

#### *5.6.4 Associations between TAM variables*

##### *Relationship of PEOU and PU on Behavioural Intention*

Luxton et al. (2011) and Connor and O'Reilly (2016), state that PU and PEOU were identified as the most important positive predictors of healthcare professionals' intention to use technology. Similarly, in the past decade, several TAM studies by Lee et al. (2003), Luxton et al. (2011) and Connor and O'Reilly (2016) explained the important effect that PEOU (as a facilitator) has on behavioral intention to use technology within a clinical environment. The quantitative and qualitative results of the current study confirmed two main findings which were consistent with the results of Venkatesh and Davis (2000). Firstly, after using the system, PU and PEOU demonstrated a significant correlation. Secondly, PU correlated with BI (please see Figure 5.3). These relationships were consistent with other healthcare studies related to the use of TAM (Rawstorne et al., 2000; Wilson & Murrell, 2004; Yi et al., 2006; Chen et al., 2008; Wu et al., 2008; Xue et al., 2009; 2012; Aggelidis & Chatzoglou, 2009; Holden et al., 2012; Aldosari, 2012).

In contrast, the relationship between PEOU and PU was not supported by Chau and Hu (2001), (2002) and Chismar and Wiley Paton (2003). A possible explanation for this is that most healthcare professionals may place a higher value on PU than on PEOU. For instance, clinical practitioners regularly use specific complex medical technologies within their clinical practice, without prior hands-on experience. Thus, the ease of use does not affect the intention to use a system if the usefulness is given.

In the current study, during the training sessions, the healthcare professionals got an opportunity to familiarize themselves with using the MSTS for the measurement and analyses of their patients' back shape. The prior training with the MSTS may have influenced their expectations and experiences of the PEOU scores. Furthermore, participants reported limited technical issues or dissatisfaction when using the MSTS.

The current practice of posture and back shape assessment by physiotherapists, osteopaths and sports therapists within a clinical environment is subjective and either through visual observation (eye balling) or by the analyses of 2D pictures. Due to the complexity and cost of existing tools (like Integrated Shape Imaging System (ISIS-2)), most therapists do not use them within clinical practice (Sohn & Yeo, 2016). Furthermore, clinical practitioners are not willing to spend extra time on lengthy trivial computer recording jobs during busy patient caring period (Kirkley & Stein, 2004). Thus, designing a tool that captures posture and back shape data, one that is objective and easy to use is critical for the acceptance of the MSTS by spinal healthcare professionals.

#### *Relationship of PS and PE on PU*

Venkatesh (2000) identifies perceived enjoyment and perceived satisfaction as valuable predictors additional to perceived ease of use and usefulness within clinical acceptance model. In describing the relationship between clinical acceptance variables, Venkatesh and Bala (2008), identify that the determinants of perceived enjoyment alone influence PEOU and not PU. Although the results of the present study demonstrate non-significant correlations between PU, PS and PE, the mean PE and

PS scores were high. The quantitative result for PS and PE of the current study is endorsed by the qualitative results where most practitioners perceived that the three-dimensional visualization of patients' data using the MSTS not only improves the clinicians perceived satisfaction score but also improves their perception of the quality of clinical practice.

The results of the current study are in agreement with previous studies (Getty et al., 1999; Boshoff & Gray 2004; Petter et al., 2008; Kim & Park, 2012). There are several possible explanations for the high PE and PS scores achieved. Firstly, in the present study, according to the author's belief that the comprehensive training undertaken before the start of the study together with the technical assistance during the use of the MSTS in clinical practice may have influenced the results for the PE and PS scores. This is supported by Getty et al. (1999) and Boshoff and Gray, (2004) who advocate that by providing technical support before as well as during the implementation of technology results in satisfaction and increased positive enjoyment. Secondly, Rathert et al. (2012) state that, a tool or a system which addresses therapists' needs and provides high quality patient-centred care is perceived to have a positive satisfaction score among clinical practitioners.

As explained in the previous section, the user experience, visualisation of three-dimensional posture together with its clinical applications might perhaps positively contribute to PS. Thirdly, in accordance with Petter et al. (2008), a positive experience with the use of technology (MSTS) contributes to the enhancement of satisfaction that subsequently leads to greater intention to use. Furthermore, Palm et al. (2010) suggest

that adoption and integration of advanced health-care technology into clinical practice is essential to improve the quality of clinical practice and enhance patients' experience.

#### *Additional Supporting Variables Influencing Clinical Acceptance*

In addition to the clinical acceptance variables, the results of this study also demonstrated minimal resistance to the use of the MSTS in clinical practice. Offenbeek et al. (2013) suggest that clinical acceptance stresses mainly an individual's cognition, but the resistance emphasizes on factors like social and power relationships within in the organization. A limitation of resistance research is, however, that it tends to focus on explaining resistive behaviours and largely ignores the opposite end of the dimension, which is a supportive behaviour. As suggested by Rivard and Lapointe's (2012) work on the implementation of new technology, this study provided technical support not just during the system use in initial training, but also during their clinical practice; this could have resulted in low resistance.

With reference to affordability, the perception of the participants (physiotherapists, sports therapist and osteopaths) was that the MSTS was reasonably economical for regular clinical use. The qualitative results of the current study indicated that eighty-seven percent of participants believed that the MSTS was very affordable. Equipment that is currently in use for posture screening (Photogrammetry method) exceeds £60,000 (Formetric 4D) while the projected costs (£500) of the new low-cost MSTS. The demand from practitioners is that the system needs to provide objective and accurate results in the form of quantitative measures and visual representations within an affordable range.



The overall results of this mixed-methods study confirm the clinical acceptance of the MSTs in terms of (a) perceived usefulness through expectation confirmation and (b) perceived ease of use within a clinical environment.

#### *5.6.5 Association of Demographics with TAM variables*

The study also revealed that the age and digital expertise of the clinician are strongly associated with PU and PEOU. The positive relationship between age, digital expertise and professional qualification on PEOU were consistent with previous research (Kwon et al., 2007; Ng T.W & Feldman, 2008). Three studies (Quinzio et al., 2003; Ammenwerth et al., 2003; Moody et al., 2004;) suggested that previous computer experience together with the quality of training program were related to the acceptance of new technology.

Furthermore, Walczuch et al. (2007) and Kuo et al. (2013) suggested that people who have digital expertise (or any early adopters of innovative technology) generally use technology in their clinical practice even when the potential benefits are still not explicit. Ng T.W and Feldman, (2008) detail that, people with high levels of education and digital skills are more likely to try new technologies and are more inclined to understand any new features and usefulness of a new tool. Nowadays, most people, including healthcare professionals, are familiar with new technologies as well as their advanced features. In the last decade, there significant increase in research reporting the use of advanced features to capture patients' data (for e.g. heart rate, blood pressure, calories burnt, and measuring of range of motion) in smart phones, tablets as well as computers (Standing & Standing, 2008; Meankaew et al., 2010; Luxton et al., 2011;

Sultan, 2015; Connor & O'Reilly, 2016). Technically proficient adults may not only be more concerned innovation, but also try to incorporate new technology within their own clinical practice. A previous study by Agarwal and Prasad (1998) also confirmed that individuals with higher technological competence, had a greater effect on PEOU.

#### *5.6.6 Practical Implications*

This research has provided four practical implications. Firstly, the results suggest that before implementing new technology it is necessary to set realistic expectations and strive to achieve them. Secondly, before beginning any tool implementation, it is necessary to provide a comprehensive explanation and training of the tool. Communication, providing support and monitoring during early implementation has demonstrated very good and positive ease of use together with less resistance to using the tool. Thirdly a portable, less complex interface or software increases the intention to use of the MSTS in the clinical environment. Finally, the usefulness of the system plays a vital role for using it within a larger population of clinicians.

#### *5.6.7 Limitations and future studies*

Future research should attempt to gather data from a larger and broader sample size. For example, the acceptance of the MSTS needs to be explored in a wide range of practitioners varying from spinal nurses to spinal consultants/surgeons. Additionally, there is a need for a longitudinal study to look at the long-term acceptance of the MSTS within a clinical environment.

## 5.7 Conclusions

The present study evaluated various factors contributing to the clinical acceptance of a new MSTS in a private clinical set-up. The 3D MSTS provided objective results in the form of quantitative measures and high-spec three-dimensional visual images. Clinicians saw these images as a baseline measurement as useful to monitor both progression or deterioration of their patients' clinical condition.

Even though the current study was for a short span of time (a week), the results affirm that variables that contributed to the acceptance of a mobile-based the MSTS together with its application within the clinical practice. Smartphones and tablets are capable of changing how healthcare is delivered principally because they merge and integrate multiple and varied technological functions into a single device that is both versatile and portable.

The current acceptance study suggests that the innovation characteristics of the MSTS as a screening tool in conjunction with three-dimensional visualisation of patient posture data and its ability to quantitatively measure were greatly embraced by healthcare professionals. Even though the quantitative and qualitative results presented in this chapter have broadened and strengthened previous clinical-acceptance research, healthcare professionals' intention towards the acceptance of technology demands a deeper understanding to further facilitate the creation of innovative products and thereby enhance the delivery and quality of clinical care.

# **Chapter 6. Can a Personalised Educational (E-Booklet) Intervention Change Behaviour and Reduce Pain in Adult Patients with Low Back Pain? A RCT.**

## **6.1 Chapter aim**

The main theme of the previous chapter was evaluating clinicians' acceptance of using the posture-screening tool within a clinical environment. The benefits of the novel MSTS also include the improvement of treatment of patients with spinal disorders by providing personalised educational booklet. The aim of this chapter is to evaluate the effectiveness of a personalised interactive education booklet for patients with low-back pain and their fear of movement behaviour during their activities of daily living (ADL).

## **6.2 Introduction and Literature Review**

Low-back pain is defined as 'pain and discomfort, localised below the costal margin and above the inferior gluteal folds with or without leg pain' (European guidelines of low back pain; Burton et al., 2004). However, there is another, more common form of back pain that arises through unknown pathological processes, otherwise known as non-specific LBP. This type of LBP is defined as 'low back pain not attributed to recognisable, known specific pathology (e.g infection, tumour, osteoporosis, ankylosing spondylitis, fracture, inflammatory process, radicular syndrome or cauda equina syndrome) (European guidelines of low back pain, 2004). Low-back pain (LBP) is one of the most common symptoms prompting patients to seek care (Deyo et al., 2006; Hoy et al., 2010). Low-back pain is increasingly recognised as highly prevalent condition. In the young and adult population, LBP is a leading cause of long-term disability with functional impairment more than any other musculoskeletal

condition (Vos et al., 2010). Lifetime prevalence estimates of LBP exceed 50% in the adult population (Deyo et al., 2001). This disabling disorder that greatly effects society is both a burden for individual patients and a cost for society because of the loss of work (Luo et al., 2004; Steenstra et al., 2005; Kent & Keating, 2005; Thelin et al., 2008).

Whilst efforts to identify the characteristics of LBP are being attempted (Manek & MacGregor, 2005; Lorusso et al., 2010; Mitchell et al., 2010), the type of LBP also needs to be addressed to enable a correct diagnosis and subsequent treatment. There are three types of LBP, which can be categorised as acute, sub-acute and chronic. Acute low-back pain is the pain that resolves within 12 weeks of onset. Acute low back pain is then contrasted with chronic low back pain, which is the pain that has endured for longer than 12 weeks (Koes & van Tulder, 2006). Some researchers subdivide the initial 12-week period into acute low back pain that resolves within a six (sometimes four) week period and sub-acute low back pain for pain that lasts between six (or four) and 12 weeks. Chronic LBP is defined as “repeated episodes of back or neck pain continuing for longer than three months” (Van Tulder et al., 1997, p2129; 2000). Due to pain and impaired function, people with chronic low-back pain often suffer with anxiety and depression, which affects their social, recreational and work life (Koes, 2006).

### *6.2.1 Approaches in the management of LBP*

Review studies (Koes et al., 2010; Staal et al., 2013) based on a combination of evidence and experts' opinion, shown limited evidence and could not draw firm conclusions on health outcomes in the management of LBP.

However, the recent guidelines on LBP agree that reassurance, advice to stay active and early return to work have favourable outcomes in people with acute and sub-acute LBP. Recently published updated guidelines for LBP in the Netherlands recommend that a clinician's decision on interventions offered depend on the presence or absence of psychosocial factors. Three subgroups are specified; 'normal course of LBP', 'abnormal course with absence of psychosocial factors' and 'abnormal course in the presence of psychosocial factors'. Physiotherapy is indicated in all three subgroups, with the focus on education, graded activity and return to work. For the third subgroup an additional time-contingent exercise program (3–6 weeks) is recommended, the patient's progress to be closely monitored by the referring physician (Staal et al., 2013).

With regards to the prevention of LBP, primary prevention refers to interventions designed to divert the onset of new back pain among those who are and have always been back pain-free. Secondary prevention refers to an intervention to reduce the likelihood of repeated low back pain in the future. In the last decade, many studies encompassing both primary and secondary prevention interventions have been undertaken. Many of these have been criticised on methodological grounds, particularly limited power to detect intervention effects because of small sample sizes,

short follow-up periods and low, or unreported, intervention adherence by participants (Linton & van Tulder, 2001).

Twenty-seven randomised controlled trials of heterogeneous, prevention interventions for low-back pain were included in a systematic review by Linton and van Tulder (2001). Their findings support the effectiveness of exercising as a preventative measure along with strong evidence that both lumbar supports and back schools were ineffective. In contrast, Malmivaara et al. (2000) identified four randomised controlled trials in their Cochrane systematic review where they found back schools were effective. There are various back schools and they broadly vary in their programmes. Common findings in all of their programmes are providing education about the back's anatomy and function, self-management and the teaching isometric (involving muscular contraction against resistance) exercises.

#### *6.2.2 Importance of Psychosocial intervention*

In recent years, there have been extensive studies on understanding the key psychological variables and barriers in the management of chronic LBP (Grotle et al., 2004). According to Grotle et al. (2004), the mechanical causes are not always the origin of chronic LBP, there is a greater psychological association. Picavet et al. (2002) identify the key psychological barriers in the management of chronic LBP are (1) negative orientation to pain (2) fear of movement and (3) fear of re-injury.

The most influential Fear-Avoidance (FA) model to explain the above fear factors in chronic LBP was originally formulated by Vlaeyen et al. in 1995 and recently updated



in 2007 (Leeuw et al., 2007). The FA model describes how individuals experiencing acute pain may lead to chronic disability (as seen in Figure 6.1) (Leeuw et al., 2007).

According to this FA cycle (Figure 6.1) if the pain is misinterpreted in a negative manner this could lead to pain-related fear and associated safety-seeking behaviours, such as avoidance (Vlaeyen & Linton, 2000). On the other hand, psychosocial factors could also cause the pain to become worse and enter a chronic phase due to the disuse and disability (Abbott et al., 2010). This in turn can lower the threshold at which the person will experience pain.

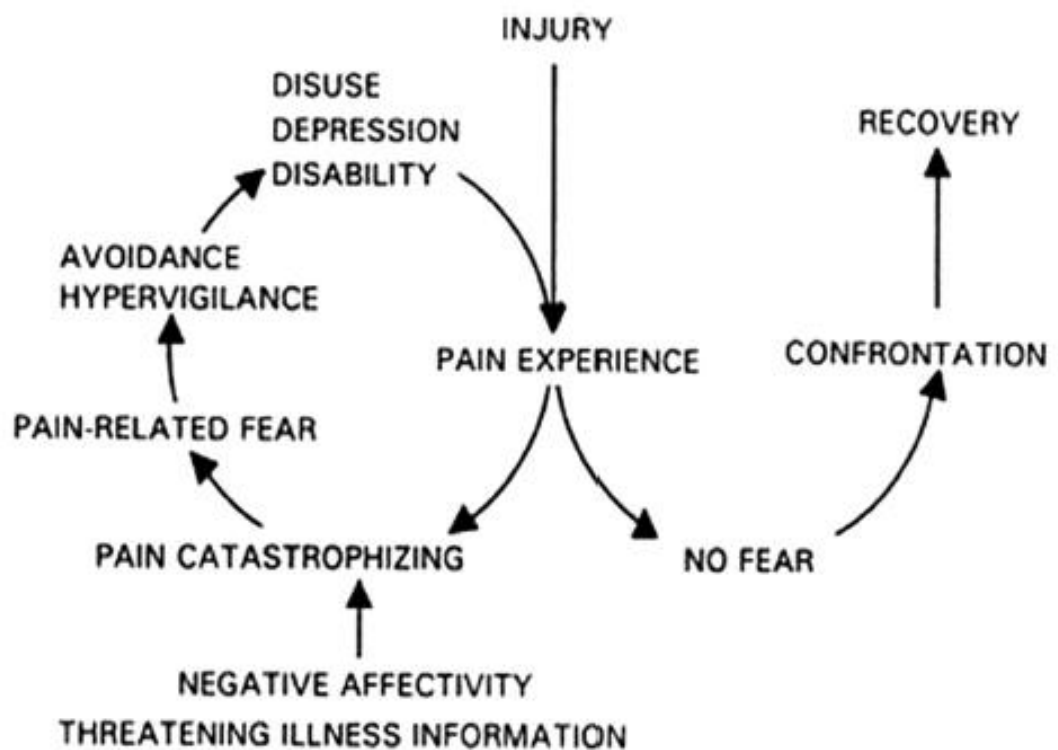


Figure 6.1 Fear Avoidance Model (Reproduced from Vlaeyen & Linton, 2000)

Historically, the bio-medical theory was regarded as the 'golden' theory (fundamental), but in recent years the biopsychosocial interventions have been more popular. Cognitive Behavioural Therapy (CBT) refers to an intervention programme based on psychological treatment that uses cognitive and behavioural techniques for managing symptoms in a positive manner. The main aim of this model is to enhance the self-management of patients with chronic LBP, by changing the way they would think and behave (Beck., 1995)

There are variable factors such as pain perception, fear avoidance behaviour and perceived disability that may influence the prognosis of both acute and chronic low back pain (Hancock et al., 2007; Vos, 2015; Traeger et al., 2015). There is a consensus among research studies (Brox et al., 2003; Fairbank et al., 2005; Abbott et al., 2010; Hoffman et al., 2007) that the patients showed good prognosis on the intensity of pain levels, disability and quality of life, in application of CBT to patients who have undergone surgical management. However, the National Institute for Health and Care Excellence (NICE) guideline insists that there is inconclusive evidence regarding the effectiveness of CBT in the management of persistent non-specific LBP (NICE, 2009). Results from studies by Koes et al. (2010), Lamb et al. (2010), Hill et al. (2011) and Vibe Fersum et al. (2013) shown increasing empirical evidence supporting the use of CBT strategies. Therefore, the current study intends to evaluate the clinical effectiveness of part of CBT when it is delivered through E-booklet using mobile technologies.

### 6.2.3 *The Back Book*

The 'Back Book' is an evidence-based educational booklet written by a multidisciplinary team of researchers. This educational booklet helps to deliver psychosocial interventions. It advocates active coping, maintaining activities and either staying at work or an early return to work after an episode of LBP. It is also designed to encourage self-management by patients (Burton et al., 2002).

A double-blind, randomised controlled trial investigated the effectiveness of 'The Back Book' on back pain beliefs, fear avoidance beliefs, self-reported functional disability and pain intensity among 162 individuals. The results demonstrated that those who had received the booklet showed greater, early improvement in their beliefs in managing back pain actively. In addition, these statistically significant ( $p < 0.001$ ) improvements were maintained at one-year follow up. Additionally, early reductions of initial high fear avoidance beliefs among the experimental group were significantly reduced in self-reported functional disability at three months (Burton et al., 1999).

A recent systematic review by Traeger et al. (2015) on evaluating the effectiveness of patient information materials for non-specific low back pain included 14 randomized controlled trials. The reviewers concluded that patient information booklets improved both knowledge and back pain-related beliefs. Additionally, the authors reported moderate – to high quality evidence that patient education in primary care can provide long-term support through reassurance for patients with acute or subacute LBP. Taken together, these findings indicate there can be a role for early education and advice that can help challenge unhelpful beliefs and behaviours with regard to non-specific low-

back pain. Furthermore, Henrotin et al. (2006) and Waddell et al. (2007) suggest that the improved clinical outcomes extend to reduce absenteeism at work and costs associated with sick leave and disability.

In contrast, evidence for improved outcomes from preventative, education-based interventions in the workplace is still less compelling. A systematic review of 10 controlled trials in various occupational settings found no evidence of effect of educational booklet on back pain related absenteeism or of economic savings for employers (Tveito et al., 2004). In addition, the reviewers reported weak evidence or no effect on future episodes of low-back pain. However, the occupational interventions included in the review were education in back schools, which have variable programmes and may often give more emphasis to physical factors and to teaching lifting techniques rather than to psychosocial factors.

As booklet are easy to deliver and inexpensive they have become common practice in the self-care management of LBP (Coudeyre et al., 2006; Henrotin et al., 2006; Liddle et al., 2007). Along with educational booklets, personalised face-to-face advice is believed to have many advantages. For example, patients often become more aware of other treatment options and able to understand their source of pain (Burton et al., 1999).

#### *6.2.4 Personalised management*

Successful management of LBP requires patients' active participation in care. Seeking accurate advice from health-care professionals also enhances patients' active

participation. Any intervention which has poor patient engagement is more likely lead to poor outcome in their clinical care (Sundararajan et al., 2004; Sen et al., 2005). Previous studies on management of LBP have reported high levels of patient dissatisfaction due to poor engagement (Verbeek et al., 2004; Snelgrove et al., 2009).

A recent systematic review of 43 studies identified three key areas of patients' perceived need: (1) patients wanted health-care practitioners to provide information including the cause of their LBP together with the legitimisation of their symptoms. (2) patients needed good and effective communication and shared decision-making and (3) patients valued both holistic individualised care as well as continuity of care (Chou et al., 2018).

To address patients' dissatisfaction, health-care practitioners were advised to adopt a patient-centred model of care (Koes et al., 2006; Montori et al., 2013; Constand et al., 2014). Yet, very little is known on the effectiveness of self-care management of personalised educational booklets in LBP patients. No previous study has investigated the effectiveness of a standard educational booklet in comparison with a personalised educational booklet which contains 3D interactive material. There is a relative dearth of studies and complete lack of support in the existing studies on the efficacy of personalised education in improving patients' psychosocial variables in LBP.

#### *6.2.5 Objectives and Hypothesis*

The first objective of this study was to determine the effect of a personalised educational intervention (E-booklet) in comparison to standard booklet on the

perceptions of pain, disability and fear of movement in people with both acute and chronic low-back pain. The second objective was to compare the effectiveness of personalised educational booklet between acute and chronic low-back pain patients.

Therefore, the following hypotheses are tested in this research.

Null hypothesis 1: There is no difference between the standard and the experimental groups in pain, fear of movement and disability in four weeks of intervention time.

Hypothesis 1: For personalised patient education, the mean scores of pain, disability and fear of movement are lower than for non-personalised patient education.

Hypothesis 2: Compared to the chronic low-back pain patients, patients with acute low-back pain show greater improvements in their perceived disability and fear avoidance to movement.

### **6.3 Method**

This section describes the recruitment strategies for the trial, the participants and the randomisation process, the intervention materials, outcome measures and procedures that were followed as well as statistical analyses that were employed.

The design of the study was a randomized clinical trial (RCT) to investigate the effect of a personalised educational (E-booklet) for patients with a low-back pain ( $N = 40$ ) with a four-week follow-up. The independent variables were time (Week1 and Week 4), personalisation of treatment (standard/non-personalised education or

experimental/personalised education) and back condition (acute back pain or chronic back pain).

### *6.3.1 Design*

According to the hierarchy of evidence, randomised clinical trials (RCTs) are generally used to evaluate new interventions and constitute level II evidence (NHMRC, 2000). RCTs are considered as the gold standard method in experimental research. Sibbald and Roland (1998) and Stolberg et al. (2004) describe RCT's as the most rigorous way of identifying whether or not a cause-and-effect relation exists between the intervention and the outcome.

In the current experimental study design, a study population was selected and randomisation was done in selecting participants to minimise bias (Polit & Beck, 2010). According to Creswell (2017), the randomisation of sample reduces allocation bias by randomly allocating participants to an experimental or control group. All the participants in the study would have the same opportunity to be assigned to the experimental group(s) or to the control group.

In the current study, RCT was used to investigate the efficacy of personalised educational intervention in low back pain patients. This provide the most rigorous way to determine whether a cause-and-effect relationship exists between intervention and outcome (Sibbald & Roland, 1998).

### *6.3.2 Ethics*

This project was submitted to and approved by Teesside University's Research Ethics Committee, Middlesbrough, UK.

### *6.3.3 Informed consent*

Participants were informed of all information relevant to participation in this study via an information sheet for them to keep and were offered a discussion with the author, giving the chance to clarify any questions and concerns. Informed consent was gained and the signed consent form was copied twice: one to keep for study records and consequently was stored at Teesside University. The other was made available for the participants to keep as a record.

### *6.3.4 Right to withdraw*

It was made clear to participants that they could withdraw from the study at any time throughout the study period, by contacting the researcher and their supervisor without any consequence for their care.

### *6.3.5 Confidentiality*

This project was conducted in accordance with the Data Protection Act (1998): participants was allocated a code by which data was collected and stored confidentially. iPad and Laptop used for data storage was password encrypted.

### *6.3.6 Recruitment*

The author contacted potential participants in person, email and/or by telephone, using the contact details they had given to the respective clinical practitioners. Clinical



practitioners act as advocates for recruitment. Based on an advertisement through posters and leaflets in the private clinics, the potential recruits were given an option to contact the author. To all the potential recruits, full details of the study and a consent form was given prior to the study. Additional enquiries about their back-pain symptoms and general health confirmed their eligibility for a trial concerned with non-specific back pain. Between May 2017 to November 2017, a total number of  $N = 40$  patients participated in this study from five different private physiotherapy departments.

#### *6.3.7 Participants*

Participants were patients with acute ( $n = 21$ ) and chronic low back pain ( $n = 19$ ) with an overall mean age group of 41.65 (SD = 13.32) years. Patients were categorised as having acute LBP group if the symptoms are less than 4 weeks and as chronic if symptoms last more than 12 weeks.

#### *Inclusion Criteria*

Participants were eligible to participate if they were aged 18 years and over, experiencing non-specific LBP for a minimum of 2 - 12 weeks and reported at least a moderate level of pain recorded as 3 or above on a numeric pain rating scale (Ferraz et al., 1990) (Appendix 6). The symptoms could be new or part of a recurrent episode. Participants had to be able to read and write English and have access to PC or any mobile device to access the personalised E-booklet.

## Exclusion Criteria

Exclusion criteria included the following: non-English speaking participants, lumbar surgery in the past 12 months; painful chronic illness; current diagnosis of clinical depression or severe depressive symptoms on screening; dementia; symptoms due to direct traumatic or evidence of serious spinal pathology; an unrelated condition that might impact movement and substantial visual impairment. Participants were also excluded if they had previously participated in any back-pain management programme, for example physiotherapy management with a CBT component.

A qualified health-care practitioner carried out screening for eligibility. If the practitioner found any signs of abnormal or danger from their screening, which indicated evidence of serious or sinister pathology, were directed to seek medical advice and they were not included in the study.

### *6.3.8 Sample Size*

Although researchers are generally interested in drawing conclusions about their hypotheses, statistical analyses of study results provide conclusions about the null hypotheses. Hypothesis testing gives the probability of finding the result that was observed if the null hypothesis were true or the probability of a Type 1 error. If the probability of a Type 1 error is less than a specified value ( $\alpha$ ), the null hypothesis is rejected (and the researcher's hypothesis is supported).  $\alpha$  is commonly set at .05, although it is set at this level by convention. Beta is the probability of a Type 2 error, that is, of accepting a false null hypothesis. The power of a study is defined as the probability of correctly rejecting the null hypothesis and is given by  $1 - \beta$ . Again,

by convention, a power of 80% is normally considered acceptable (Cohen, 1988; Kraemer & Blasey, 2015). The sample size needed to detect a true difference between groups, depending on the magnitude of the effect, can be calculated using alpha, the study power and the estimated effect size based on, for example, clinical knowledge, previous research findings or conventions for small, medium or large effect sizes for different types of statistical test (Cohen, 1988).

For this study, a priori sample size calculation was carried out using G\*Power software (Faul et al., 2007). The power calculation required a sample size of 52 patients with an alpha level of 0.05 and a power of 80%, based on an expected clinical change of 2 points for the main outcome measure. When the recruitment process started it soon became obvious that it would not be possible to include that number of people within a reason-able time. The trial was designed to be exploratory, investigating the effectiveness of new intervention materials for which there are no previously published data to indicate an expected effect size.

#### *6.3.9 Instrumentation*

##### *Pain Intensity (Numeric Pain Rating Scale) (NPRS) (Appendix 6)*

The NPRS is a segmented numeric version of the visual analog scale (VAS) in which a participant selects a whole number (0–10 integers) that best reflects the intensity of his/her pain. The common format is a horizontal bar or line. Similar to the VAS, the NPRS is anchored by terms describing pain severity extremes (Hawker, 2011). This pain scale has shown high test-retest reliability in both literate and illiterate patients ( $r = 0.96$  and  $0.95$  respectively) (Ferraz et al., 1990). The validity of this tool is high in

terms of correlation with the VAS in patients with chronic conditions ( $r = 0.86$  to  $0.95$ ; Ferraz et al., 1990).

In the current study, patients were given anatomically simple pictures that show the front and back of the human body. They had to identify the location(s) of their pain in the picture. Patients were asked to rate their present pain intensity using a 0 to 10 ordinal scale located at the bottom of the page. A “0” rating corresponded with no pain and a “10” rating corresponded with maximum pain intensity.

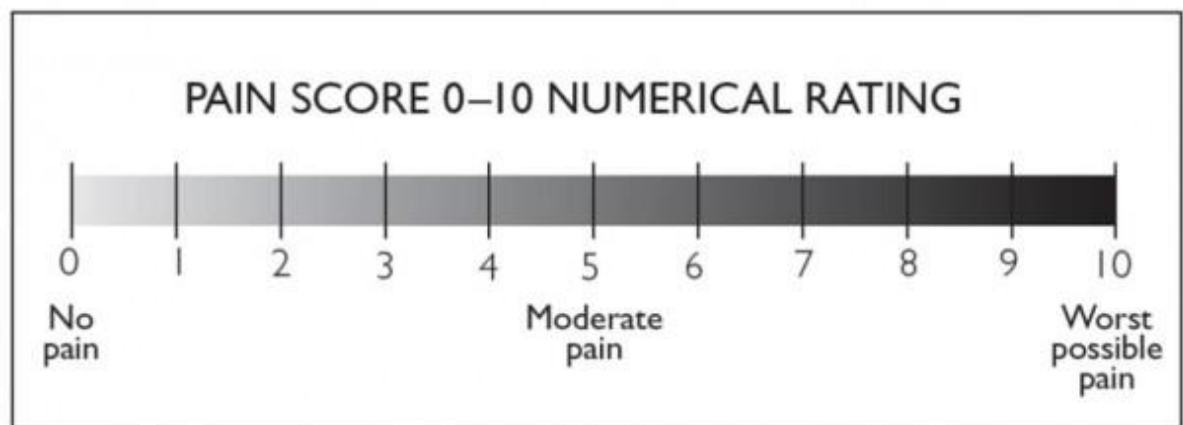


Figure 6.11 Numerical Pain Rating Scale

#### *Fear Avoidance Belief Questionnaire (FABQ)*

The second instrument used was the Fear Avoidance Belief Questionnaire (FABQ) to measure fear-avoidance beliefs about physical activity. The FABQ is a 16-item questionnaire and each item is scored from 0 to 6 (see Figure 6.12). Higher numbers on the FABQ indicate increased levels of fear-avoidance beliefs related to low back pain. Two subscales within the FABQ have been identified: a four-item scale measuring fear-avoidance belief about physical activity (FABQ-pa) and a seven-item scale measuring fear-avoidance belief about work (FABQ-W). The FABQ has

demonstrated high levels of reliability in previous studies of patients with low-back pain (Crombez et al., 1999; Grotle et al., 2005).

The FABQ (total) has shown high test-retest reliability with ICC = 0.97 (Kovacs et al., 2006). The subscale, FABQ physical activity has shown moderate to good reliability with ICC = 0.72 to 0.90 (Pfingsten et al., 2000; Chaory et al., 2004). The FABQ work subscale has also shown moderate to good reliability, with ICC = 0.80 to 0.91 (Holm et al., 2003; Williamson, 2006). In terms of construct validity, the FABQ is moderately correlated with the Roland and Morris Disability Questionnaire. The correlation coefficients for the FABQ scale, the FABQ Work subscale and the FABQ Physical Activity subscale are 0.52, 0.63, and 0.51, respectively. The FABQ was also shown to be correlated with the Tampa Scale of Kinesiophobia (Swinkels-Meewisse et al., 2003), another measure of fear avoidance. The correlation coefficients for the FABQ Work subscale and the FABQ Physical Activity subscale are 0.53 and 0.76, respectively (Williamson, 2006).

**Fear-Avoidance Beliefs Questionnaire (FABQ)**  
**Waddell et al (1993) Pain , 52 (1993) 157 - 168**

Here are some of the things which other patients have told us about their pain. For each statement please circle any number from 0 to 6 to say how much physical activities such as bending, lifting, walking or driving affect or would affect *your* back pain.

	Completely disagree	1	2	3	4	5	Completely agree
1. My pain was caused by physical activity.....	0	1	2	3	4	5	6
2. Physical activity makes my pain worse.....	0	1	2	3	4	5	6
3. Physical activity might harm my back.....	0	1	2	3	4	5	6
4. I should not do physical activities which (might) make my pain worse	0	1	2	3	4	5	6
5. I cannot do physical activities which (might) make my pain worse.....	0	1	2	3	4	5	6

The following statements are about how your normal work affects or would affect your back pain

	Completely disagree	1	2	3	4	5	Completely agree
6. My pain was caused by my work or by an accident at work.....	0	1	2	3	4	5	6
7. My work aggravated my pain.....	0	1	2	3	4	5	6
8. I have a claim for compensation for my pain.....	0	1	2	3	4	5	6
9. My work is too heavy for me.....	0	1	2	3	4	5	6
10. My work makes or would make my pain worse.....	0	1	2	3	4	5	6
11. My work might harm my back.....	0	1	2	3	4	5	6
12. I should not do my normal work with my present pain.....	0	1	2	3	4	5	6
13. I cannot do my normal work with my present pain.....	0	1	2	3	4	5	6
14. I cannot do my normal work till my pain is treated.....	0	1	2	3	4	5	6
15. I do not think that I will be back to my normal work within 3 months.	0	1	2	3	4	5	6
16. I do not think that I will ever be able to go back to that work.....	0	1	2	3	4	5	6

**Scoring**

Scale 1: fear-avoidance beliefs about work – items 6, 7, 9, 10, 11, 12, 15.

Scale 2: fear-avoidance beliefs about physical activity – items 2, 3, 4, 5.

Source: Gordon Waddell, Mary Newton, Iain Henderson, Douglas Somerville and Chris J. Main, A Fear-Avoidance Beliefs Questionnaire (FABQ) and the role of fear-avoidance beliefs in chronic low back pain and disability, *Pain*, 52 (1993) 157 – 168, 166.

Figure 6.12 Fear Avoidance Belief Questionnaire (FABQ)

**Oswestry Disability Questionnaire (ODQ)**

The third instrument used in this clinical trial was the disability from low-back pain, which was measured by the Oswestry Disability Questionnaire (ODQ). The ODQ is a disease-specific measure of functional disability in patients with low-back pain. This

patient-completed questionnaire gives a subjective percentage score of the level of function

## Oswestry Low Back Pain Disability Questionnaire

### Instructions

This questionnaire has been designed to give us information as to how your back or leg pain is affecting your ability to manage in everyday life. Please answer by checking ONE box in each section for the statement which best applies to you. We realise you may consider that two or more statements in any one section apply but please just shade out the spot that indicates the statement which most clearly describes your problem.

#### Section 1 – Pain intensity

- ☐ I have no pain at the moment
- ☐ The pain is very mild at the moment
- ☐ The pain is moderate at the moment
- ☐ The pain is fairly severe at the moment
- ☐ The pain is very severe at the moment
- ☐ The pain is the worst imaginable at the moment

#### Section 2 – Personal care (washing, dressing etc)

- ☐ I can look after myself normally without causing extra pain
- ☐ I can look after myself normally but it causes extra pain
- ☐ It is painful to look after myself and I am slow and careful
- ☐ I need some help but manage most of my personal care
- ☐ I need help every day in most aspects of self-care
- ☐ I do not get dressed, I wash with difficulty and stay in bed

#### Section 3 – Lifting

- ☐ I can lift heavy weights without extra pain
- ☐ I can lift heavy weights but it gives extra pain
- ☐ Pain prevents me from lifting heavy weights off the floor, but I can manage if they are conveniently placed eg. on a table
- ☐ Pain prevents me from lifting heavy weights, but I can manage light to medium weights if they are conveniently positioned
- ☐ I can lift very light weights
- ☐ I cannot lift or carry anything at all

#### Section 4 – Walking\*

- ☐ Pain does not prevent me walking any distance
- ☐ Pain prevents me from walking more than 1 mile
- ☐ Pain prevents me from walking more than 1/2 mile
- ☐ Pain prevents me from walking more than 100 yards
- ☐ I can only walk using a stick or crutches
- ☐ I am in bed most of the time

Figure 6.13. Oswestry Disability Questionnaire (ODQ)

(disability) in activities of daily living. This questionnaire consists of 10 different functional items. The subject scores each functional item by rating the difficulty from 0

to 5. The final score is typically expressed as a percentage, with higher percentages indicating higher amounts of disability (see Figure 6.13). The ODQ has demonstrated high levels of test-retest reliability (such as ICC 0.93,  $p < 0.00$ ; Bayar et al., 2003) and is highly recommended for its use as an outcome measure in studies of LBP (Gronblad & Hupli, 1993). Furthermore, Fisher and Johnston (1997), demonstrates the concurrent validity of the ODQ scale for measuring the change in disability following treatment.

#### *Perceived User Satisfaction Questionnaire*

Participants' perceived satisfaction after use of the educational booklet was assessed using a six-item end-user satisfaction survey (Marshall and Hays, 1994). The items included in this survey evaluates, general impression, information, presentation, ease of use and satisfaction of using the educational booklet. All these items used five-point Likert scales with endpoints strongly disagree (1) and strongly agree (5) or Very bad (1) and very good (5) (see Figure 6.14 and Appendix 9).



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### Perceived User Satisfaction

1. What is your general impression of the booklet  
Very Bad      Bad      Neutral      Good      Very good
2. Quantity of information in the booklet is useful to understand and the advice is beneficial in managing my self-care.  
Strongly Disagree      Disagree      Neutral      Agree      Strongly Agree
3. Photos or videos added value  
Strongly Disagree      Disagree      Neutral      Agree      Strongly Agree
4. I found that the booklet was easy to use  
Strongly Disagree      Disagree      Neutral      Agree      Strongly Agree
5. All this considered are you satisfied with the provided booklet  
Strongly Disagree      Disagree      Neutral      Agree      Strongly Agree
6. Will you continue to use for the self-care management?  
Strongly Disagree      Disagree      Neutral      Agree      Strongly Agree
7. What is your preferred format to receive back care programme?  
  
Electronic  
or  
Booklet
8. Any other comments  

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Figure 6.14. Perceived User Satisfaction Questionnaire

### 6.3.10 Procedure

Before and after a four-week of educational intervention, pain, fear avoidance behaviour and disability were measured using NPRS scale, FABQ, ODQ and user satisfaction survey respectively.

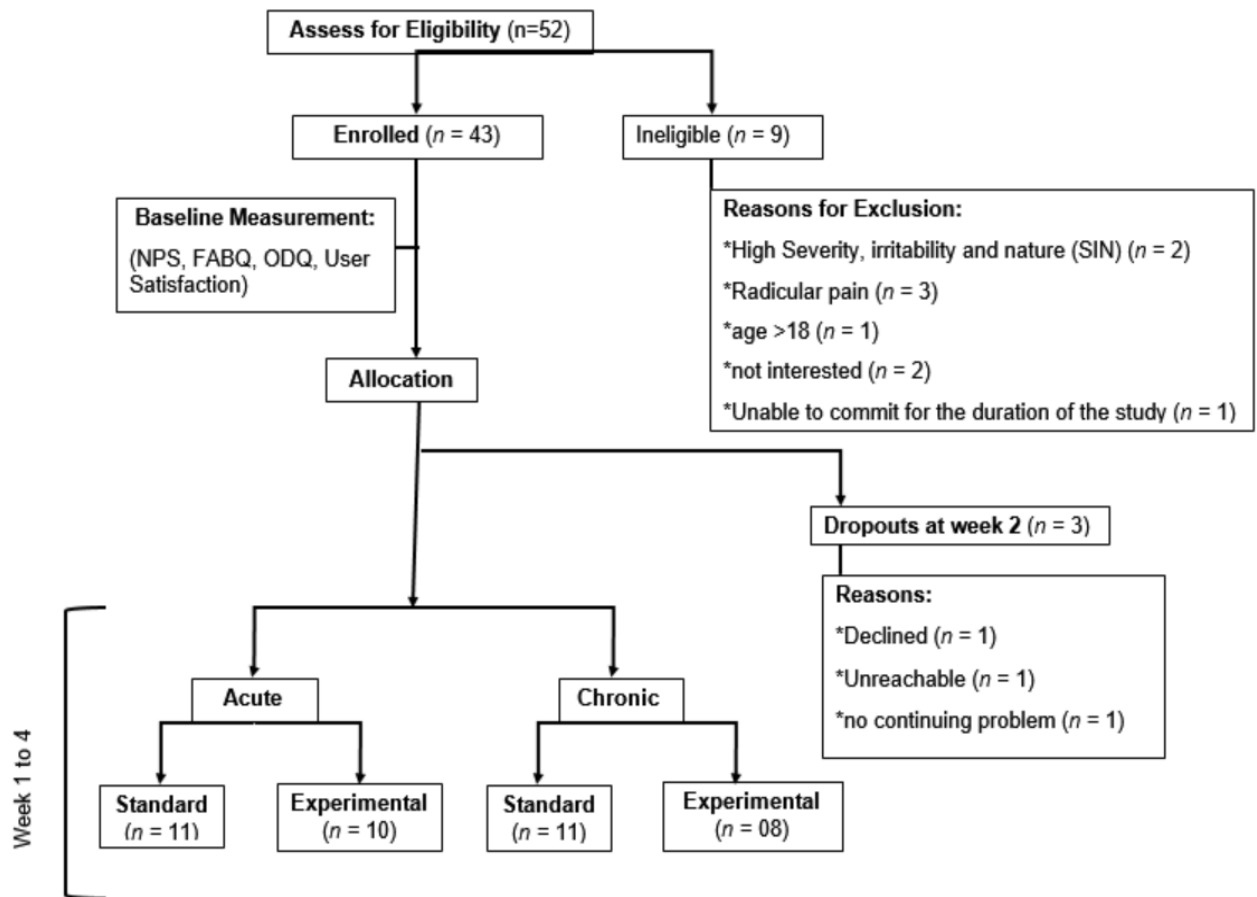


Figure 6.2 Flow diagram of the study course showing the number of participants in different groups.

The present study involved participants having a diagnosis non-specific LBP only, that was not due to any other pathologies as previously mentioned in the exclusion criteria. There were two groups in this study (acute and chronic LBP). Based on the signs and

symptoms of LBP together with physical examination by a clinical practitioner, all participants were categorised as either acute or chronic. Patients were categorised as having acute LBP group if the symptoms are less than 4 weeks and as chronic if symptoms last more than 12 weeks. Within each group, the participants were randomly allocated to standard or experimental intervention, as explained below.

### *Randomisation*

Enrolled participants meeting the inclusion criteria were randomly allocated to either the experimental (e-booklet (personalised)) or control group (standard (non-personalised) care) using computer-generated sequences of random numbers (<http://graphpad.com/quickcalcs/randomize1.cfm>). The author generated the allocation sequence, enrolled the participants and assigned participants to their group. Neither the author nor the participants were blinded to the acute or chronic condition allocations.

### *Intervention*

Along with the standard physical therapy treatment, all the patients received either a standard (non-personalised) booklet or a personalised educational e-booklet as described below. Each patient was instructed to read the booklet as part of a home program and self-management of symptoms.

### *Standard Educational Booklet*

Patients received standard care treatment using the standard 'Back Care' educational booklet (see Appendix 7). A small booklet was used as a supplement to active patient

management. This traditional approach to patient education emphasises a general overview of spine anatomy, anatomic sources of pain, explanations of various (established and unestablished) treatment mechanism, recommendations on avoidance of pain, bed rest, the use of exercise for aerobic benefit or to strengthen trunk musculature. This booklet also focusses on patients' beliefs and attitudes by teaching the advantages of remaining active and avoiding bed rest, combined with reassurance that there is likely nothing seriously wrong.

#### *Personalised Educational E-Booklet*

An individualised biomechanical book contains the same information as the standard educational booklet. However, the personalised booklet contained a 3D model of their own back and body (see Appendix 8). The 3D model used in this study was captured through a commercially available iPad based 3D mobile scanning tool Structure Sensor™. The system has been explained in the previous chapters. This high-quality 3D standing and sitting posture image enables participants to visualise (bio-feedback) their own posture in all planes through the personalised educational E-booklet. Hoffman et al., (2007) and Sielski et al., (2017) found that biofeedback was more effective than cognitive behavioral approaches in reducing symptoms in Chronic LBP patients. The personalised booklet used in the current study aims to educate patients' in a specific manner with specific do's and don'ts and uses an intervention that appropriately addresses their own limitations with completing their activities of daily living. This E-booklet was presented to patients in two different formats (video and PDF).

All the participants in both the groups were asked to keep a diary to record their use of self-help booklets and to rate their satisfaction with it (Appendix 9). The outcome measures (i.e. NPRS, FABQ, ODI User Satisfaction) were taken before and after intervention in all the four groups.

#### **6. 4 Data Analysis**

Analysis of covariance (ANCOVA) was conducted to analyse the effects of education booklet (personalised or non-personalised) and back condition (acute or chronic) as well as their interaction effect at Week 4, while holding constant the measurement at Week 1. Outcome measure data were also analysed in a mixed analysis of variance (also known as a split-plot ANOVA, SPANOVA). Within group analysis was done using paired *t* test. The aim was to establish whether the change over time differs between the two educational conditions and between the two back conditions, and whether an interaction effect with time existed. In addition, the Pearson's correlation between the measures (pain, fear avoidance, disability and user satisfaction) was analysed at week 1 and week 4.

#### **6.5 Results**

This part of the chapter presents the findings which emerged from the statistical analysis presented in the previous section.

##### *Participant flow*

A flow chart presented in the Figure 6.2, provides a graphic representation of the participant flow in this study. A total of 43 participants started the trial, three withdrew

in the first two weeks of trial due to personal reasons. Out of three, two of them were experimental group and one from standard booklet group. Therefore only data from 40 participants were considered for data analysis. There were total of 21 participants in the acute LBP group, with 11 participants in the standard educational booklet and 10 participants in the personalised E-booklet group. In the chronic LBP group, there were total of 19 participants, 11 in the standard and 8 in the personalised E-booklet group.

Table 6.1 Descriptive statistics of participants

	Acute (Standard)	Acute (E-Booklet)	Chronic (Standard)	Chronic (E-Booklet)	All Groups
Total No. of participants (n)	11	10	11	08	40
Gender (n) (%)					
Male	7 (63.6%)	4 (40%)	8 (72.7%)	3 (37.5%)	22 (55%)
Female	4 (36.4%)	6 (60%)	3 (27.3%)	5 (62.5%)	18 (45%)
Age					
Mean (SD)	43.09 (16.6)	44.10 (11.30)	34.18 (12.52)	46.87 (8.72)	41.65 (13.32)
Std Error(SE)	5.00	3.57	3.77	3.08	2.10
Variance	275.69	127.87	156.96	76.12	177.56
Skewness	.035	-.209	1.31	0.32	0.13
Std. Error of Skewness	0.66	0.68	0.66	0.75	0.37
Kurtosis	-1.18	-1.32	1.32	-0.77	-0.99
Std. Error of Kurtosis	1.27	1.33	1.27	1.48	0.73

### *Baseline Characteristics and Descriptive Statistics*

The study sample had a mean age group of 41.65 (SD = 3.32) years, with standard chronic group is youngest with mean age of 34.18 (SD = 12.52) years. Gender wise, 55% ( $n = 22$ ) being male participants and 45% ( $n = 18$ ) female participants. The summary of the descriptive statistics of participants in each group is seen in Table 6.1. All the participants were randomly allocated to the intervention or control group. It can be seen from the Table 6.1 that the groups were broadly similar with regards to baseline characteristics.

### *Descriptive statistics of the Dependent Variables*

The outcome measures of patients' physical functioning (pain, fear, disability and satisfaction) was measured by means of the NPRS, FABQw, FABQpa, ODQ and the user satisfaction questionnaires.

### *Pain*

Back pain was measured using 11-point numerical pain rating scale (NPRS). In acute LBP group, the mean score of NPRS at baseline was 6.20 (SD = 1.75) (95% CI, 4.94 – 7.45) for the intervention group and 6.18 (SD = 1.40) (95% CI, 5.24 – 7.12) for the control group. In the chronic LBP group, the mean score of NPRS at baseline was 4.75 (SD = 1.03) (95% CI, 3.88 – 5.61) for the intervention group and 5.54 (SD = 1.36) (95% CI, 4.62 – 6.46) for the control group. The summary of this data is reported in Table 6.2. The results indicate that in terms specific to back pain, the groups were

comparable and no statistical significant difference between the two groups were found.

#### *Fear of movement*

In acute LBP group, the mean score of FABQw at baseline was 15.90 ( $SD = 4.33$ ) (95%  $CI$ , 12.80 – 18.99) for the intervention group and 18.90 ( $SD = 4.65$ ) (95%  $CI$ , 15.78 – 22.03) for the control group. In chronic LBP group, the mean score of FABQw at baseline was 11.12 ( $SD = 5.16$ ) (95%  $CI$ , 6.80 – 15.44) for the intervention group and 13.54 ( $SD = 3.38$ ) (95%  $CI$ , 11.27 – 15.82) for the control group. The summary of this data is reported in Table 6.3. The results indicate that in terms specific to back pain, the groups were comparable and no statistical significant difference between the two groups were found in FABQw score.

The Fear avoidance belief during physical activity (FABQpa) scale was measured using a 4-item scale. In the acute LBP group, the mean score of FABQpa at baseline was 28.30 ( $SD = 3.86$ ) (95%  $CI$ , 25.53 – 31.06) for the intervention group and 30.72 ( $SD = 4.22$ ) (95%  $CI$ , 27.89 – 33.56) for the control group. In the chronic LBP group, the mean score of FABQpa at baseline was 23.25 ( $SD = 5.52$ ) (95%  $CI$ , 18.63 – 27.86) for the intervention group and 26.00 ( $SD = 5.63$ ) (95%  $CI$ , 22.21 – 29.78) for the control group. The summary of this data is reported in Table 6.4. The results indicated that during physical activity, both the intervention and control groups were comparable and no significant differences in FABQpa scores between the groups was found.



### *Disability*

In the acute LBP group, the mean score of ODQ at baseline was 51.33 ( $SD = 3.94$ ) (95%  $CI$ , 48.50 – 54.15) for the intervention group and 55.55 ( $SD = 4.58$ ) (95%  $CI$ , 52.47 – 58.63) for the control group. In the chronic LBP group, the mean score of the ODQ at baseline was 32.22 ( $SD = 4.60$ ) (95%  $CI$ , 28.37 – 36.06) for the intervention group and 34.24 ( $SD = 6.24$ ) (95%  $CI$ , 30.04 – 38.43) for the control group. The summary of this data is reported in Table 6.5. The results indicated that in terms of functional disability, the groups were comparable and no significant differences in ODQ scores between the groups was found.

Table 6.2 Descriptive statistics of pain for both acute and chronic groups

		Before				After			
		Acute (Standard Booklet)	Acute (E- Booklet)	Chronic (Standard Booklet)	Chronic (E- Booklet)	Acute (Standard Booklet)	Acute (E- Booklet)	Chronic (Standard Booklet)	Chronic (E- Booklet)
Mean		6.18	6.20	5.54	4.75	2.36	2.80	1.81	1.25
Std.Error		0.42	0.55	0.41	0.36	0.47	0.53	0.29	0.25
95% Confidence Interval for Mean	Lower Bound	5.24	4.94	4.62	3.88	1.31	1.59	1.15	.65
	Upper Bound	7.12	7.45	6.46	5.61	3.41	4.00	2.47	1.84
Variance		1.96	3.06	1.87	1.07	2.45	2.84	.96	.50
Std. Deviation		1.40	1.75	1.36	1.035	1.56	1.68	.98	.70
Minimum		4.0	3.0	3.0	3.0	.0	1.0	1.0	.0
Maximum		8.0	9.0	8.0	6.0	5.0	5.0	4.0	2.0
Range		4.0	6.0	5.0	3.0	5.0	4.0	3.0	2.0
Interquartile Range		2.0	2.3	1.0	1.8	3.0	3.3	1.0	1.0
Skewness		-.39	-.22	-.11	-.38	.21	.04	1.20	-.40
Skewness Std. Error		0.66	0.68	0.66	0.75	0.66	0.68	0.66	0.75
Kurtosis		-.81	-.063	.48	-.44	-.98	-1.83	1.13	-.22
Kurtosis Std. Error		1.27	1.33	1.27	1.48	1.27	1.33	1.27	1.48

Table 6.3 Descriptive statistics of fear of movement (work) variable for both acute and chronic groups

		Before				After			
		Acute (Standard Booklet)	Acute (E- Booklet)	Chronic (Standard Booklet)	Chronic (E- Booklet)	Acute (Standard Booklet)	Acute (E- Booklet)	Chronic (Standard Booklet)	Chronic (E- Booklet)
Mean		18.90	15.90	13.54	11.12	10.00	5.60	5.81	3.62
Std.Error		1.40	1.36	1.02	1.82	1.15	1.10	0.76	1.13
95% Confidence Interval	Lower Bound	15.78	12.80	11.27	6.80	7.41	3.09	4.12	.94
for Mean	Upper Bound	22.03	18.99	15.82	15.44	12.58	8.10	7.51	6.30
Variance		21.69	18.76	11.47	26.69	14.80	12.26	6.36	10.26
Std. Deviation		4.65	4.33	3.38	5.16	3.84	3.50	2.52	3.20
Minimum		9.0	8.0	6.0	3.0	4.0	1.0	2.0	.0
Maximum		24.0	21.0	18.0	18.0	15.0	14.0	10.0	10.0
Range		15.0	13.0	12.0	15.0	11.0	13.0	8.0	10.0
Interquartile Range		7.0	7.0	3.0	8.5	6.0	3.3	4.0	3.8
Skewness		-.82	-.80	-.99	-.029	-.21	1.60	-.16	1.21
Skewness Std. Error		0.66	0.68	0.66	0.75	0.66	0.68	0.66	0.75
Kurtosis		.479	-.45	1.41	-.94	-1.28	3.62	-.58	1.23
Kurtosis Std. Error		1.27	1.33	1.27	1.48	1.27	1.33	1.27	1.48

Table 6.4 Descriptive statistics of fear of movement (physical activity) variable for both acute and chronic groups

		Before				After			
		Acute (Standard Booklet)	Acute (E- Booklet)	Chronic (Standard Booklet)	Chronic (E- Booklet)	Acute (Standard Booklet)	Acute (E- Booklet)	Chronic (Standard Booklet)	Chronic (E- Booklet)
Mean		30.72	28.30	26.00	23.25	18.90	17.70	16.90	16.25
Std.Error		1.27	1.22	1.70	1.95	1.41	0.78	1.26	1.84
95% Confidence Interval for Mean	Lower Bound	27.89	25.53	22.21	18.63	15.75	15.91	14.08	11.87
	Upper Bound	33.56	31.06	29.78	27.86	22.06	19.48	19.73	20.62
Variance		17.81	14.90	31.80	30.50	22.09	6.23	17.69	27.35
Std. Deviation		4.22	3.86	5.63	5.52	4.70	2.49	4.20	5.23
Minimum		20.0	24.0	14.0	16.0	10.0	13.0	11.0	9.0
Maximum		36.0	36.0	34.0	30.0	26.0	21.0	22.0	23.0
Range		16.0	12.0	20.0	14.0	16.0	8.0	11.0	14.0
Interquartile Range		3.0	7.0	7.0	11.3	4.0	4.3	8.0	9.5
Skewness		-1.78	.94	-.78	.13	-.62	-.59	-.01	-.35
Skewness Std. Error		0.66	0.68	0.66	0.75	0.66	0.68	0.66	0.75
Kurtosis		4.08	.085	.88	-1.76	.285	-.25	-1.88	-1.62
Kurtosis Std. Error		1.27	1.33	1.27	1.48	1.27	1.33	1.27	1.48

Table 6.5 Descriptive statistics of disability for both acute and chronic groups

		Before				After			
		Acute (Standard Booklet)	Acute (E- Booklet)	Chronic (Standard Booklet)	Chronic (E- Booklet)	Acute (Standard Booklet)	Acute (E- Booklet)	Chronic (Standard Booklet)	Chronic (E- Booklet)
Mean		55.55	51.33	34.24	32.22	31.11	27.77	29.49	21.38
Std.Error		1.38	1.24	1.88	1.62	1.16	2.50	2.05	1.10
95% Confidence Interval for Mean	Lower Bound	52.47	48.50	30.04	28.37	28.52	22.10	24.91	18.77
	Upper Bound	58.63	54.15	38.43	36.06	33.69	33.44	34.07	24.00
Variance		20.98	15.58	38.96	21.16	14.81	62.82	46.51	9.78
Std. Deviation		4.58	3.94	6.24	4.60	3.84	7.92	6.81	3.12
Minimum		50.0	45.6	25.6	25.6	22.2	15.6	20.0	15.6
Maximum		61.1	56.7	45.6	36.7	35.6	44.4	40.0	24.4
Range		11.1	11.1	20.0	11.1	13.3	28.9	20.0	8.9
Interquartile Range		11.1	7.2	8.9	8.9	2.2	10.0	8.9	4.4
Skewness		.00	.018	.51	-.386	-1.27	.66	.14	-.74
Skewness Std. Error		0.66	0.68	0.66	0.75	0.66	0.68	0.66	0.75
Kurtosis		-1.68	-1.36	-.24	-1.876	2.06	1.47	-1.10	.22
Kurtosis Std. Error		1.27	1.33	1.27	1.48	1.27	1.33	1.27	1.48

### *User Satisfaction*

Participants' perceived satisfaction of the educational booklet was assessed using a six-item end-user satisfaction survey. The interaction of these items showed moderate reliability with Cronbach's alpha of 0.69. the summary of the reliability tests is presented in the Table 6.6.

The mean scores of the acute LBP group showed that the mean level of satisfaction was 3.33 (SD = 0.22) (95% CI, 3.18 – 3.48) in the control group and 4.28 (SD = 0.28) (95 % CI, 4.08 – 4.48) in the experimental group. In the chronic LBP group, the mean level of satisfaction was 3.25 (SD = 0.31) (95% CI, 3.04 – 3.47) in the control group and 4.16 (SD = 0.19) (95 % CI, 4.00 – 4.33) in the experimental group. The mean scores in both acute and chronic LBP groups are high or above average, which indicates that the educational booklet (standard and personalised) was provided, useful, easy to use and supported their back-care management (see Table 6.7).

### *Three-way interactions between time, condition and groups*

A mixed methods analysis of variance was performed to analyse all the outcome measures. This section reports the main effects for each independent variable (condition, group and time), associated effect sizes, and interaction effects.

A mixed (3 x 3) methods analysis of variance was conducted to compare pain, fear of movement and disability on patients with acute and chronic LBP (condition) measured at week 1 (baseline) and at week 4 (4 weeks, follow up) and the impact of study groups

(standard versus E-booklet). The means and standard deviations are presented in Table 6.8.

There was a statistical significant effect for time ( $p < 0.05$ ) in all dependent variables (see Table 6.9). The pain, fear avoidance behaviour at work and physical activity and disability all showed significant improvement over time. This is illustrated in Figures 6.5.1 to 6.5.4.

Table 6.6 Reliability of user satisfaction questionnaire

	Scale mean if item deleted	Scale variance if item deleted	Corrected item-total correlation	Squared multiple correlation	Cronbach's alpha if item deleted
1. General impression of the Booklet	18.10	6.32	.45	.40	.64
2. Information in the booklet is useful to understand and the advice is beneficial	18.05	6.49	.61	.45	.59
3. Photos or videos added value	17.94	6.16	.58	.36	.59
4. Booklet was easy to use	17.94	8.16	.23	.11	.70
5. Are you satisfied with the booklet	18.10	7.09	.36	.25	.67

Table 6.7 Descriptive statistics of user satisfaction for both acute and chronic groups

		After			
		Acute (Standard Booklet)	Acute (E- Booklet)	Chronic (Standard Booklet)	Chronic (E- Booklet)
Mean		3.33	4.28	3.25	4.16
Std.Error		0.06	0.08	0.09	0.07
95% Confidence Interval for Mean	Lower Bound	3.18	4.08	3.04	4.00
	Upper Bound	3.48	4.48	3.47	4.33
Variance		.05	.08	.10	.04
Std. Deviation		.22	.28	.319	.19
Minimum		3.0	3.7	2.8	3.8
Maximum		3.7	4.7	3.8	4.5
Range		.7	1.0	1.0	.7
Interquartile Range		.3	.4	.7	.2
Skewness		.00	-1.10	-.03	.00
Skewness Std. Error		0.66	0.68	0.66	0.75
Kurtosis		-.43	1.62	-.39	.81
Kurtosis Std. Error		1.27	1.33	1.27	1.48



### *Numerical Pain Rating Scale (NPRS)*

There was a statistical significant main effect for the pain scores ( $p = 0.00$ ), with a small effect size (partial eta squared = 0.18) (see Table 6.9). This indicates that there was significant improvement in pain before and after intervention in both the standard and E-booklet group. In the acute LBP condition, the mean difference in NPRS scores in a standard booklet group, before and after the intervention was 3.8 and 3.4 in E-booklet group. In chronic LBP condition, the mean difference of NPRS score in standard booklet group, before and after intervention was 3.7 and 3.5 in E-booklet group. The result of ANCOVA of NPRS score shows no statistical difference between standard and e-booklet group ( $p = 0.83$ ) (see Table 6.11). This result supports null hypothesis 1 on perceived pain.

### *Fear Avoidance Behaviour at Work (FABQw)*

In the acute LBP condition, the mean difference in FABQw score between the standard booklet group, before and after intervention was 8.9 and 10.3 in E-booklet group. In chronic LBP condition, the mean difference in FABQw score in standard booklet group, before and after intervention was 7.69 and 7.48 in E-booklet group. The two-way interaction effect, indicating the changes in the FABQw scores over time and in conditions (acute and chronic LBP groups) shows statistical significant difference ( $p=0.09$ ) with good effect size (partial eta squared = 0.74). In addition, there was a statistical significant main effect for the study group in FABQw scores ( $p < 0.05$ ) with small effect size (partial eta squared = 0.17) (see Table 6.9).

Further analysis showed there was statistical significant improvement in FABQw score ( $p = 0.03$ ) between standard and experimental group in acute LBP conditions (see Table 6.10 and 6.12; Figure 6.5.5). Although the magnitude of the effect is small, the result partially supports the hypothesis 1 that there would be significant improvements in FABQ scores over time in the experimental group compared to the control group.

#### *Fear Avoidance Behaviour in Physical Activity (FABQpa)*

In acute LBP condition, the mean difference of FABQpa score in standard booklet group, before and after intervention was 11.8 and 10.6 in E-booklet group. In chronic LBP condition, the mean difference of FABQpa score in standard booklet group, before and after intervention was 9.1 and 7 in E-booklet group. Additionally, significant difference between acute and chronic LBP condition, patients in acute LBP group perceived more fear avoidance behaviour compared to chronic group. Fear avoidance behaviour in physical activity score shows non-significant difference in three-way, two-way and main effect interactions ( $p < 0.05$ ) with effect size (small partial eta squared = 0.00 to 0.16) (see Table 6.9). The result of ANCOVA of FABQpa score also confirms the above result (see Table 6.13 and Figure 6.5.6). This result supports null hypothesis 1 on fear avoidance behaviour in physical activity.

#### *Oswestry Disability Questionnaire (ODQ)*

In acute LBP condition, the mean difference of ODQ score in the standard booklet group, before and after intervention was 24.4 and 23.6 in E-booklet group. In chronic LBP condition, the mean difference of ODQ score in standard booklet group, before

and after intervention was 4.8 and 10.9 in E-booklet group. The two-way interaction effect, indicating the changes in the ODQ scores over time and in conditions (acute and chronic LBP groups) was significant ( $p = 0.00$ ) with moderate effect size (partial eta squared = 0.52). In addition, there was a statistical significant main effect for study group in ODQ scores ( $p < 0.05$ ) with small effect size (partial eta squared = 0.28) (see Table 6.9).

Further between group (standard Vs experimental) analysis showed there is a statistical significant improvement in ODQ score ( $p = 0.01$ ) in both acute and chronic LBP conditions (see Tables 6.10 and 6.14; Figure 6.5.4 and 6.5.7). Within group analysis (before vs after) using paired 't' test showed that participants using E-booklet in chronic LBP group, there is a significant improvement in ODQ score ( $t = 6.67$ ;  $p = 0.00$ ; 95% CI 6.99 -14.67) (see Table 6.15). Although the magnitude of the effect is small, the above result supports the hypothesis 1 and reject hypothesis 2. There is a larger significant improvement in ODQ scores in the chronic LBP condition over time in the experimental group compared to the control group.

#### *User Satisfaction Questionnaire*

The results of the Mixed ANOVA of US questionnaire showed that there was no statistical significant difference between conditions (Acute vs Chronic) ( $p = 0.26$ ; effect size = 0.03). In contrast, the comparison between control (standard educational booklet) and experimental (personalised e-booklet) group in both acute and chronic condition showed a statistically significant difference ( $p = 0.00$ ; effect size = 0.77). This

indicates that most of the participants prefer the personalised E-booklet in place of the standard educational booklet (see Tables 6.8 and 6.9).

Table 6.8 Comparison of mean and SD between groups

Variables		Scores Mean (SD)			
		Acute		Chronic	
		Standard (n = 11)	E-Booklet (n = 10)	Standard (n = 11)	E-booklet (n = 8)
NPRS					
	Before	6.1 (1.4)	6.2 (1.7)	5.5 (1.3)	4.7 (1.0)
	After	2.3 (1.5)	2.8 (1.6)	1.8 (0.9)	1.2 (0.7)
FABQw					
	Before	18.9 (4.6)	15.9 (4.3)	13.5 (3.3)	11.1 (5.1)
	After	10.0 (3.8)	05.6 (3.5)	5.81 (2.5)	3.62 (3.2)
FABQpa					
	Before	30.7 (4.2)	28.3 (3.8)	26.0 (5.6)	23.2 (5.5)
	After	18.9 (4.7)	17.7 (2.4)	16.9 (4.2)	16.2 (5.2)
ODQ					
	Before	55.5 (4.5)	51.3 (3.9)	34.2 (6.2)	32.2 (4.6)
	After	31.1 (3.8)	27.7 (7.9)	29.4 (6.8)	21.3 (3.1)
US	After	3.3 (0.2)	4.2 (0.2)	3.2 (0.3)	4.1 (0.1)

*Note: LL – Lower limit; UL - Upper limit; PEOU – Perceived Ease of Use; PU – Perceived Usefulness; NPRS – Numerical pain rating scale; FABQw – Fear avoidance behaviour at work; FABQpa – Fear avoidance behaviour at physical activity; ODQ- Oswestry disability questionnaire; US – User satisfaction*

Table 6.9 Comparison of 2-way and 3-way interactions of variables through mixed ANOVA

Variables	F value (Effect Size) F (1, 36) ( $\eta_p^2$ )						
	Main effects			2-way interactions			3-way interactions (Time, Condition, Group)
	Time	Group	Condition	(Time, Condition)	(Time, Group)	(Condition, Group)	
NPRS	230.1 (0.86)***	0.37 (0.01)	8.00 (0.18)***	0.00 (0.00)	0.46 (0.13)	1.51 (0.40)	0.04 (0.00)
FABQw	214.51 (0.85)***	7.64 (0.17)***	14.04 (0.28)***	2.86 (0.74)	0.24 (0.00)	0.41 (0.01)	0.47 (0.01)
FABQpa	165.07 (0.82)***	2.01 (0.05)	7.09 (0.16)	4.45 (0.11)	1.21 (0.03)	0.00 (0.00)	0.08 (0.00)
ODQ	155.51 (0.81)***	14.04 (0.28)***	105.35 (0.74)***	40.43 (0.52)***	1.03 (0.02)	0.29 (0.00)	1.87 (0.04)
User Satisfaction	-	121.2 (0.77)***	0.26 (0.03)	-	-	0.05 (0.00)	-

*Time = Before vs After; Group = Standard vs E-booklet; Condition = Acute Vs Chronic; \* Significant difference in p value ( $p < 0.05$ ); \*\*  $p < 0.01$ ; \*\*\*  $p < 0.001$*

Table 6.10 Further Analysis of FABQw and ODQ scores by 2x2 ANOVA

<i>p</i> Value (Effect Size)								
FABQw					ODQ			
	F value	Time* Group	Time	Group	F value	Time* Group	Time	Group
Acute	0.73	0.40 (0.03)	0.00 (0.88)	0.03* (0.21)	0.59	0.81 (0.00)	0.00 (0.90)	0.01** (0.27)
Chronic	0.18	0.89 (0.00)	0.00 (0.82)	0.12 (0.13)	3.03	0.09 (0.15)	0.00 (0.53)	0.01** (0.28)

\* Significant difference in *p* value ( $p < 0.05$ );  $p < 0.01$ ; \*\*\*  $p < 0.001$

Table 6.11 ANCOVA of dependent variable: Post NPRS

Source	df	SS	MS	F	<i>p</i> value	Partial eta squared
PreNPRS	1	10.87	10.87	7.26	.01**	.17
Condition	1	3.58	3.58	2.39	.13	.06
Group	1	.06	.06	.04	.83	.00
Condition, Group	1	1.15	1.15	.76	.38	.02
Error	35	52.40	1.49			

Note: SS – Sum of Squares; MS – Mean of Squares; \* Significant difference in *p* value ( $p < 0.05$ ); \*\* $p < 0.01$ ; \*\*\*  $p < 0.001$

Table 6.12 ANCOVA of dependent variable: post FABQw

Source	df	SS	MS	F	<i>p</i>	Partial eta squared
PreFABQw	1	127.51	127.51	16.75	.00***	.32
Condition	1	5.76	5.76	.75	.39	.02
Group	1	40.25	40.25	5.28	.02**	.13
Condition, Group	1	9.36	9.36	1.23	.27	.03
Error	35	266.39	7.61			

*Note: SS – Sum of Squares; MS – Mean of Squares; \* Significant difference in p value ( $p < 0.05$ ); \*\* $p < 0.01$ ; \*\*\*  $p < 0.001$*

Table 6.13 ANCOVA of dependent variable: post FABQpa

Source	df	SS	MS	F	<i>p</i>	Partial eta squared
PreFABQpa	1	142.80	142.80	9.94	.00***	.22
Condition	1	.63	.63	.04	.83	.00
Group	1	.15	.15	.01	.91	.00
Condition, Group2	1	1.14	1.14	.08	.77	.00
Error	35	502.61	14.36			

*Note: SS – Sum of Squares; MS – Mean of Squares; \* Significant difference in p value ( $p < 0.05$ ) \*\* $p < 0.01$ ; \*\*\*  $p < 0.001$*

Table 6.14 ANCOVA of dependent variable: post ODQ

Source	df	SS	MS	F	<i>p</i>	Partial eta squared
PreODQ	1.00	7.68	7.68	0.22	0.64	0.01
Condition	1.00	61.60	61.60	1.74	0.20	0.05
Group	1.00	320.57	320.57	9.05	0.00***	0.21
Condition, Group	1.00	50.61	50.61	1.43	0.24	0.04
Error	35.00	1239.51	35.41			

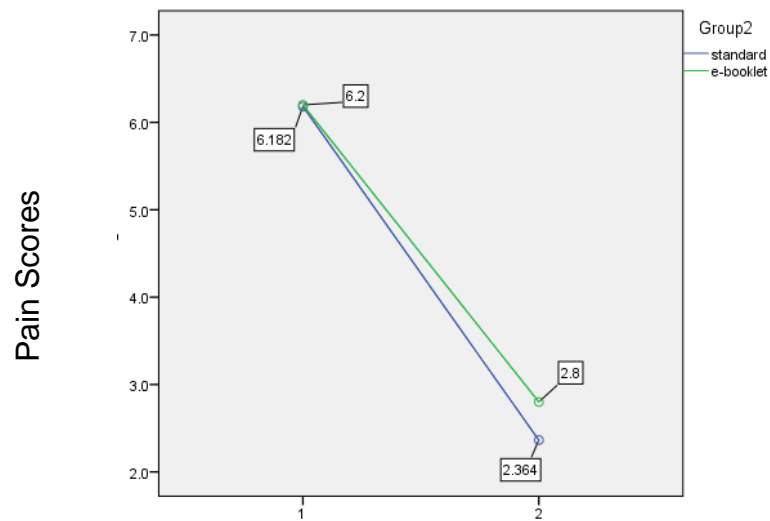
*Note: SS – Sum of Squares; MS – Mean of Squares; \* Significant difference in *p* value ( $p < 0.05$ ); \*\* $p < 0.01$ ; \*\*\*  $p < 0.001$*

Table 6.15 ODQ paired 't' test for chronic LBP group

Before Vs After	Mean	SD	Std Error Mean	95% Confidence Interval of the difference		't'	Sig (2-tailed)
				Lower	Upper		
Standard Booklet	4.74	9.01	2.71	-1.30	10.80	1.74	0.11
E-Booklet	10.834	4.59	1.62	6.99	14.67	6.67	0.00***

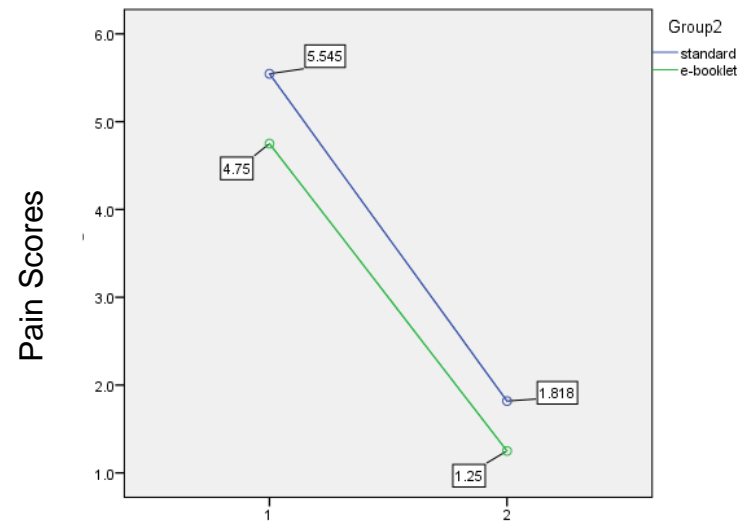
*\* Significant difference in *p* value ( $p < 0.05$ ); \*\* $p < 0.01$ ; \*\*\*  $p < 0.001$*





Weeks. 1 – Week 1 (Before); 2- Week 4 (After)

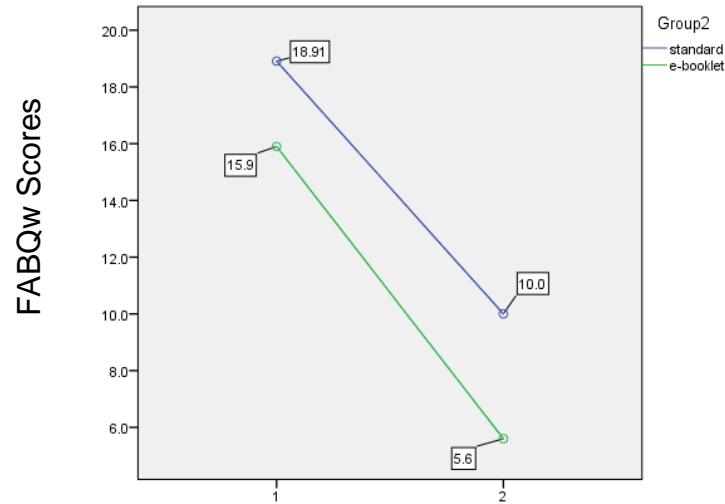
a) Acute LBP Condition



Weeks. 1 – Week 1 (Before); 2- Week 4 (After)

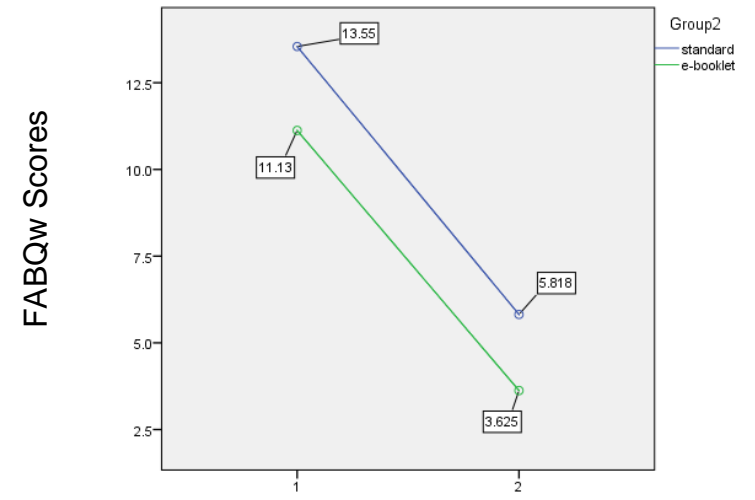
b) Chronic LBP Condition

Figure 6.5.1 Comparison of numerical pain scale between standard and personalised e-booklet. In both acute (a) and chronic (b) LBP condition, the pain variable demonstrates significant improvement over time in both standard and e-booklet group.



Weeks. 1 – Week 1 (Before); 2- Week 4 (After)

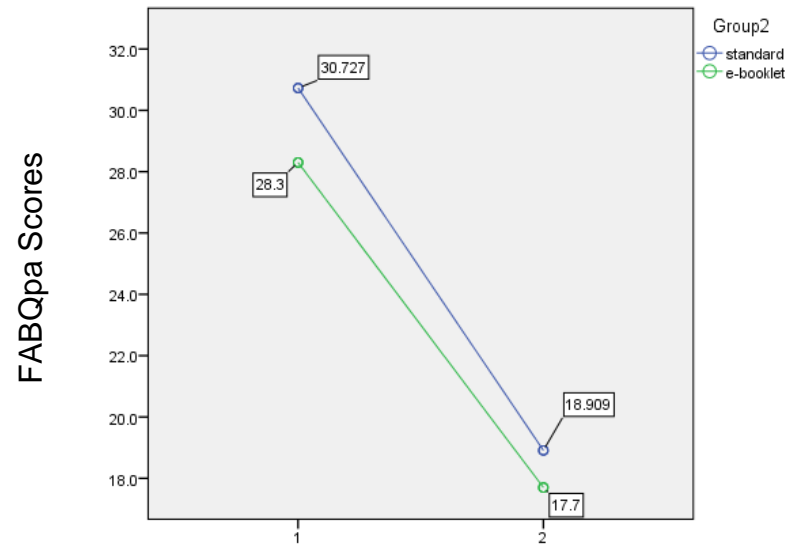
a) Acute LBP Condition



Weeks. 1 – Week 1 (Before); 2- Week 4 (After)

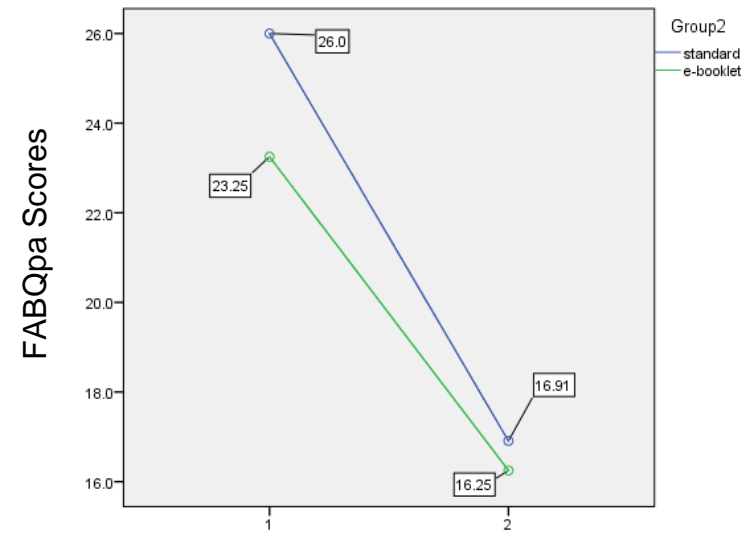
b) Chronic LBP Condition

Figure 6.5.2 Comparison of FABQw score between standard and personalised e-booklet. In both acute (a) and chronic (b) LBP condition, the fear avoidance behaviour at work demonstrates significant improvement over time in both standard and e-booklet group.



Weeks. 1 – Week 1 (Before); 2- Week 4 (After)

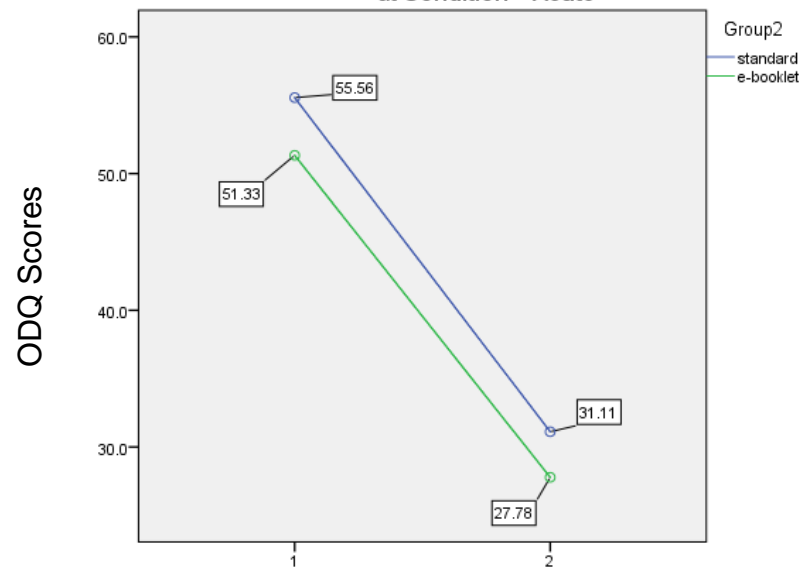
a) Acute LBP Condition



Weeks. 1 – Week 1 (Before); 2- Week 4 (After)

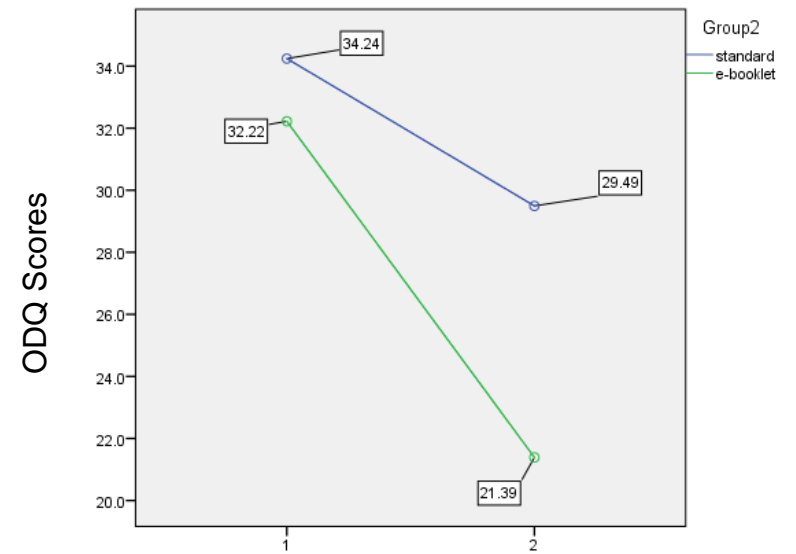
b) Chronic LBP Condition

Figure 6.5.3 Comparison of FABQpa between standard and personalised e-booklet. In both acute (a) and chronic (b) LBP condition, the fear avoidance behaviour at physical activity demonstrates significant improvement over time in both standard and e-booklet group.



Weeks. 1 – Week 1 (Before); 2- Week 4 (After)

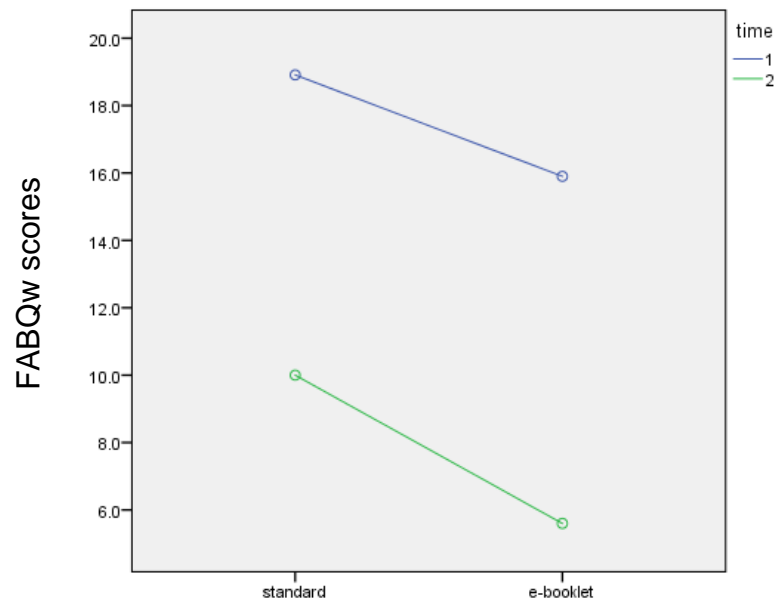
a) Acute LBP Condition



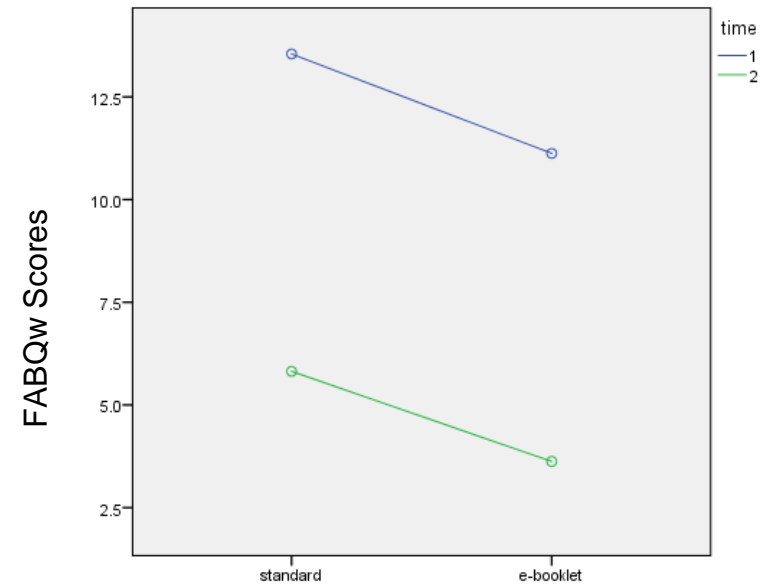
Weeks. 1 – Week 1 (Before); 2- Week 4 (After)

b) Chronic LBP Condition

Figure 6.5.4 Comparison of ODQ scores between standard and personalised e-booklet. In acute (a) LBP condition, the disability variable demonstrates significant improvement over time in both standard and e-booklet group. Whereas in chronic (b) LBP condition, the personalised e-booklet group demonstrate greater improvement in comparison to standard booklet group.



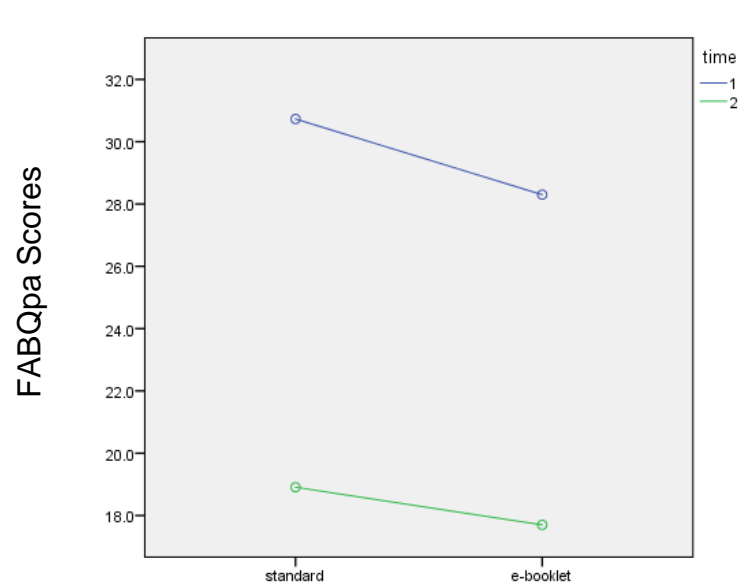
a) Acute LBP Condition



b) Chronic LBP Condition

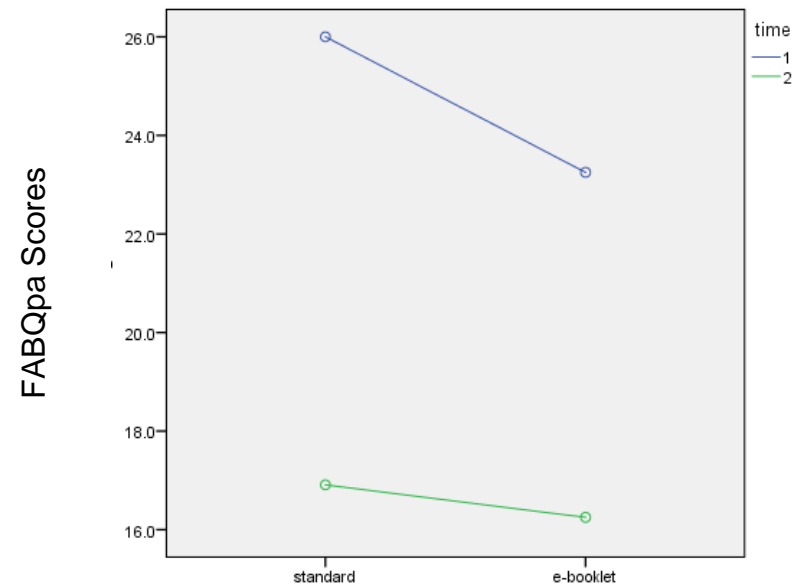
Time: 1 – Week 1 (Before); 2- Week 4 (After)

Figure 6.5.5 Comparison of pre- and post FABQw score between standard and personalised e-booklet. In comparison to chronic LBP condition (b), acute LBP condition (a) demonstrate significant improvement in FABQw score between standard and experimental group.



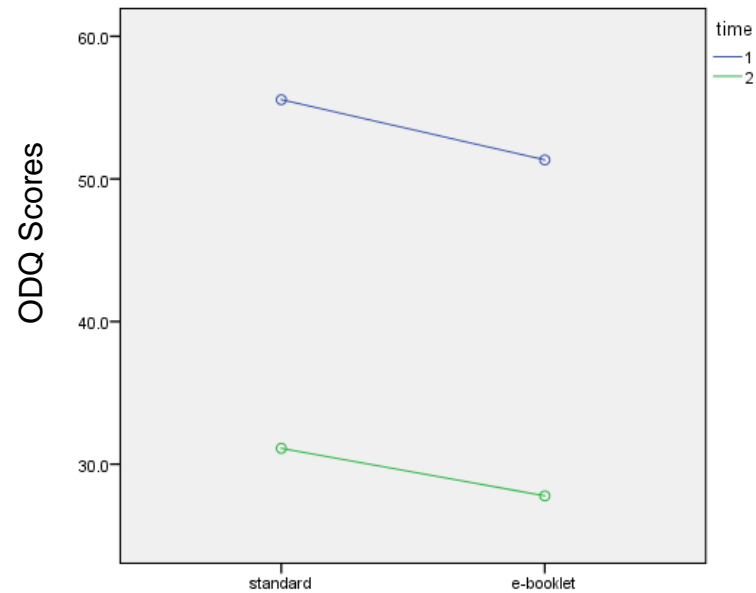
a) Acute LBP Condition

Time: 1 – Week 1 (Before); 2- Week 4 (After)



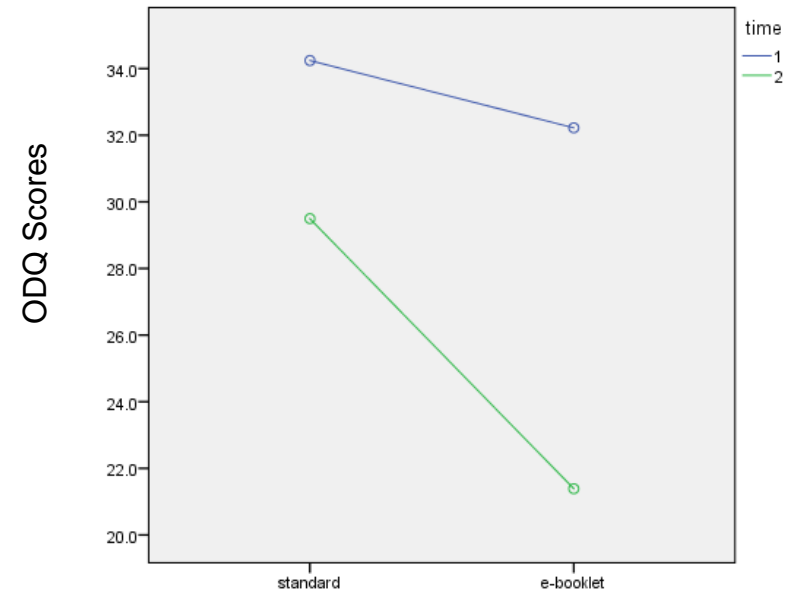
b) Chronic LBP Condition

Figure 6.5.6 Comparison of pre- and post FABQpa score between standard and personalised e-booklet. Both acute LBP condition (a) and chronic LBP condition (b) demonstrate non-significant improvement in FABQpa score between standard and experimental group.



a) Acute LBP Condition

Time: 1 – Week 1 (Before); 2- Week 4 (After)



b) Chronic LBP Condition

Figure 6.5.7 Comparison of pre- and post ODQ score between standard and personalised e-booklet. In comparison to acute LBP condition (a), chronic LBP condition (b) demonstrate significant improvement in ODQ score between standard and experimental group.

### Preferences

Within the User satisfaction survey, all the participants were asked whether they prefer standard or electronic personalised booklet. Most of the participants including people in the standard booklet group chose the electronic version (E-booklet) for the self-management of both acute and chronic LBP (see Table 6.16).

Table 6.16 Participants preferred choice of booklet (Standard vs Personalised E-Booklet).

		Frequencies		Total
		Standard Booklet	E-Booklet	
Acute (Standard Booklet)				
	Count	5	6	11
	% within Groups	45.5%	54.5%	100.0%
Acute (E-Booklet)				
	Count	0	10	10
	% within Groups	0.0%	100.0%	100.0%
Chronic (Standard Booklet)				
	Count	3	8	11
	% within Groups	27.3%	72.7%	100.0%
Chronic (E-Booklet)				
	Count	0	8	8
	% within Groups	0.0%	100.0%	100.0%
Total				
	Count	8	32	40
	% of Total	20.0%	80.0%	100.0%



### *Correlations between dependent variables*

In order to explore the relationship between the measures of interaction experience, correlation coefficients were calculated between the dependent variables on both pre-intervention and post-intervention scores. Most of the variables related to fear, disability and user satisfaction showed no significant correlation (Pearson's correlation coefficients ranging from -0.01 to 0.18) after the intervention. These results suggest that the after use of the educational booklet, there is no relation between pain and fear of movement and perceived disability by the patients with LBP. In contrast, the fear avoidance behaviour at work (FABQw) was negatively correlated ( $r = -0.38$ ) to satisfaction. This indicates that whenever the FABQw score decreases, the perceived user experience of the booklet increases.

Another finding in the current study was the relationship between pain, fear avoidance behaviour and disability. Before any intervention the current study finds a significant positive relationship between pain, fear avoidance behaviour ( $r = 0.34$ ;  $p < 0.05$ ) and disability ( $r = 0.33$ ;  $p < 0.05$ ) (see Table 6.17). However, after the intervention and also at four weeks follow-up, pain was not found to correlate with fear avoidance behaviour ( $r = -0.01$ ,  $p > 0.05$ ) and disability ( $r = 0.29$ ,  $p > 0.05$ ). The summary of the correlation coefficients is presented in the Table 6.17.

Table 6.17 Correlations between variables

	Pre FABQw	Pre FABQpa	Pre ODQ	Post NPRS	Post FABQw	Post FABQpa	Post ODQ	USMean
Pre NPRS	.18	.34*	.33*	.49**	.18	.03	.17	-.15
Pre FABQw		.39*	.56**	-.00	.68**	.16	.29	-.24
Pre FABQpa			.46**	.04	.35*	.51**	.32*	-.12
Pre ODQ				.27	.48**	.11	.25	.01
Post NPRS					.12	-.01	.18	.01
Post FABQw						.13	.29	-.38*
Post FABQpa							.15	.03
Post ODQ								-.30

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

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

### *Qualitative Data Analysis*

At the end of the four-week trial, all the participants were encouraged to give their feedback about their booklet through written comments. They were asked to provide information on how they used the booklet at home. They were also asked how satisfied they felt with the programme and whether they had encountered any problems. Finally, they were asked if they had any other comments or suggestions for improvements to the booklet.

The results showed that a common view amongst participants within both the standard and the experimental group was that they found the e-booklets helped them cope with symptoms and follow the exercises. Most of them also commented that it was simple, easy to use, straightforward to follow and understandable.

A couple of participants from the standard booklet group commented that they would prefer the booklet in the electronic form or as a mobile application. The extract of these comments is shown below.

*“The information on the booklet was good and informative. It is quite good to follow the exercises in a picture as the description was below. Really appreciate if this is provided in an electronic or in the mobile application format....so it’s with me all the time” (P1)*

The majority of the participants in the personalised educational e-booklet group expressed their satisfaction as seen below.

*“I have used the video booklet many times in the last 4 weeks. It’s really given me the chance to look at my posture in all directions. Importantly this video reminded and helped me in choosing my best sitting posture at my work. This made a huge difference and I feel a lot better within a couple of weeks.” (P6)*

One of the patient commented on the benefits of biofeedback.

*“I really like the format and information given in the educational material. It was quite good to see my own back shape and try to understand where the pain is coming from. I am much more relaxed and relieved after knowing what the source of pain is. It is always happy to know that not to worry.” (P24)*

Another patient commented on the adaptation of posture after using the E-booklet.

*“Seeing my 3D view of my sitting model, made me to think about my posture and how I work. I have started doing things differently now, I do not stay sitting for long period. I make sure I get up and walk around and it’s helping me.” (P33)*

In summary, both the quantitative and qualitative results of this RCT study indicate that the personalised educational booklet helped the patients’ (both acute and chronic LBP conditions) to improve their disability and fear avoidance behaviour at work.

## **6.6 Discussion**

### **6.6.1 Summary**

The purpose of the current randomised clinical trial study was to compare and evaluate the effect of a personalised educational intervention on the self-care management of

acute and chronic LBP patients. The current study investigated the short-term effects of the personalised educational booklet on the perception of pain, disability and the fear avoidance behaviour of movement.

Overall the results from this study indicate that the personalised educational e-booklet is effective in treating pain, disability and fear avoidance behaviour at work in acute and chronic LBP patients. The results partially reject the null hypothesis 1 and partially accept hypothesis 2 on movement behaviour and disability.

Patient education on self-help, fear-avoidance behaviour and exercise has been a prominent part of LBP management (Coudeyre et al., 2006; Cooper et al., 2009). For the last two decades, the common medium of patient education was through a standard 'back book' educational material (Cohen et al., 1994). The large part of the educational material currently available is focussed on patients' beliefs and attitudes by teaching them the advantages of remaining active and avoiding bed rest, combined with the reassurance that there is nothing seriously wrong with their backs. In the current study, along with the above content, the personalised interactive educational material contained information about the patients' posture (biofeedback), an overview of their spinal anatomy, explanations of sources of pain and exercises for aerobic benefit and exercises to strengthen trunk musculature.

#### *6.6.2 The Perceived Pain Intensity*

The results of this study in both acute and chronic LBP demonstrated significant improvements in the NPRS mean average score (see Table 6.2) at the one-month

follow-up in both the standard and experimental groups. Even though there was a decrease in the intensity of pain over time, pain scores show no statistical differences between the two groups and LBP (acute and chronic) condition.

The findings of the current study on the duration of recovery of symptoms (pain and disability) was similar to the study by Hazard et al. (2000), Pengel et al. (2003), Dunn and Croft (2006) and Axen et al. (2011). In these studies, twelve to eighty-four percentage of patients with back pain was generally expected to show improvements and resolved their symptoms spontaneously over the four-week follow-up period of the study (Croft et al., 1998; Andersson 1999; Pengel et al., 2003; Kongsted et al., 2015; Silva et al., 2017). The duration it takes to decrease symptoms, particularly the pain is possibly the most important or understandable outcome to many patients with low back pain.

Although in general, acute LBP is widely considered to have a good prognosis (Indahl et al., 1995; Schiottz-Christensen et al., 1999), there are a number of substantial variable factors that may influence the prognosis of both acute and chronic LBP patients. Few authors have attempted to develop prediction rules to assist clinicians in identifying patients with low-back pain with different types of prognosis (Bekkering et al., 2005; Pransky et al., 2006; Jellema et al., 2007). According to Hancock et al. (2007), a decrease in pain intensity, duration of current episode, and number of previous episodes are key predictors for faster recovery rates and prognosis. There is a possibility that the intensity of pain may have an influence on the recovery of other

psychosocial outcome measures (fear, disability and user experience) in the current study.

A finding in the sample of the current study was the relationship between pain, fear avoidance behaviour and disability. Same as previous studies (McCracken et al., 1992; 1998), before any intervention the current study found a significant positive relationship between pain, fear avoidance behaviour and disability (see Table 6.17). However, after the intervention and also at four weeks follow-up, pain was not found to correlate with fear avoidance behaviour and disability. A possible explanation of this result is that before any intervention, pain score measured by NPS scale is believed to be high in individuals with high levels of fear of pain and movement in their normal activities of daily living and at work (Zvolensky et al., 2001; McCracken et al., 1993). Individuals with a high fear of pain overpredict the pain intensity that will be experienced during a given activity (McCracken et al., 1993). This phenomenon was demonstrated in a study that assessed the effect of performing a painful physical examination test (straight leg raise test) on patients with low back pain radiating into the lower extremity (McCracken et al., 1993). Patients with higher levels of fear of pain had a greater tendency to overpredict pain intensity that they would experience from performing the straight leg raise test; however, their estimations became more accurate with subsequent tests (McCracken, 1998).

During the rehabilitation process, patients were exposed to exercises that were likely to cause low-back pain and patients with a high fear of pain could standardise their pain perception. The pain perception at the end of rehabilitation, combined with the

overprediction of pain perception at the beginning of rehabilitation, resulted in a larger perceived improvement in pain and disability for patients with a higher pain perception. This study suggests that along with the intensity of pain, in-depth future studies evaluating role of fear of pain and its significant interactions with fear avoidance behaviour and disability are needed. Additional longitudinal experimental research is needed to define the relationship between fear of pain and fear avoidance in patients with acute and chronic LBP. Due to the limitations in sample size, this study did not consider these complex associations between fear of pain, fear-avoidance, and disability.

The results of this RCT study, have helped to gain an understanding of different variables that may have influenced the prognosis of patients with LBP. Greater understanding of these variables can help practitioners provide an accurate prognosis and assist in both designing and choosing 'choice of interventions' in LBP patients.

#### *6.6.3 Fear Avoidance Behaviour*

The complexity of spinal clinical presentations suggests that general information alone not sufficient in managing and preventing LBP and improving the rates of patients return to work. The results of the current randomized clinical trial suggest that when personalised fear avoidance education (with biofeedback) together with an individualised exercise programme is delivered alongside routine physiotherapy management this results in decreasing disability for patients with chronic LBP.



The current study found significant improvements in FABQw scores over time in the experimental group compared to the control group (see Table 6.9 and 6.12; Figure 6.5.2). However, FABQ in physical activity score showed a non-significant difference in two-way interactions between the acute and chronic LBP conditions and groups. The results suggest that, personalised interactive educational materials, containing patients own 3D posture images as biofeedback, helps patients (1) appreciate their posture in space (2) understand how to correct their posture themselves (self-manage) and (3) consequently decrease their fear of movement at work. This implies that the type of information presented to patients can influence their beliefs about low back-pain (Burton et al., 1999; Linton et al., 2000; Buchbinder et al., 2001; Traeger et al., 2015; Valenzuela-Pascual et al., 2015).

The present findings are consistent with a recently published randomized control trial (Amorim et al., 2016), evaluating the use of a mobile-web app to self-manage LBP in a larger sample (n = 199). Although their intervention was not a personalised tool, the improvements in patients physical and behaviour outcomes translated into significant improvement in worker productivity and presentism at 4-month follow-up. A possible explanation of these results is that patients easily adopts to a new behaviour when their knowledge of the condition improves (Irvine et al., 2015). A recent systematic review by Shorthouse et al. (2016) also suggests that educational materials are useful medium to engage workers and provide information regarding practical modifications to their work environment, activities and potentially reduce psychological distress regarding ill-health at work. Additionally, there is some support for changing posture

and beliefs about LBP, alongside evidence that educational approaches specifically designed to address psychosocial issues can aid self-management (Waddell & Burton 2001).

The personalised educational materials used in the current study not only lower a patient's physiological pain perception, but also alter his or her cognitive and psychosocial perception (fear avoidance behaviour) which, in turn, influence physical and work-related activities by inhibiting fear beliefs about activities that patients once avoided.

#### *6.6.4 Perceived Disability*

Low-back pain causes more disability globally than any other condition (Hoy et al., 2014; Vos, 2015). Recent evidence suggests that multidimensional care (biofeedback, psychological, social and knowledge) is effective in reducing disability in the management of LBP (Campello et al., 2012). The aim of the current RCT study was to evaluate the effectiveness of personalised interactive educational material in the management of LBP.

The results of the current study show that participants using a personalised patient information report significantly lowered perceived disability than those using standard patient information. At the enrolment of the study, the baseline scores were the same in both the acute and the chronic group. After intervention at the four-week follow-up point, the perceived disability decreased in the acute LBP condition and in the chronic LBP condition (see Table 6.8 and Figure 6.5.4). With regards to the perceived

disability, the current study is a successful experiment in clinical practice. Patients in the chronic-LBP condition, showed a statistically significantly greater improvement in the perception of disability compared to the acute group. This finding is important, as increased perceived disability has been linked with long-term outcomes such as delayed recovery, work status and work retention (Fritz et al., 2001; Campello et al., 2006;).

This finding complements the fear-avoidance model put forward by Vlaeyen and Linton (2000). It provides evidence that the LBP patients expected less disability when education and exercise prescription encourage study participants to engage in activities. For example, a study participant with high fear-avoidance beliefs who received the fear-avoidance educational booklet was twice more likely to show an improvement in disability (Fritz & George, 2002).

These results are consistent with those of other studies by Loisel et al. (1997), Karjalainen et al. (2003) and Campello et al. (2012). Their results show that a multidisciplinary biopsychosocial rehabilitation programme was more effective than usual care for disability in the short term (4 weeks follow-up). A possible reason for this finding is that the use of a personalised education material included in the intervention group better approximates the pain and fear of movement in LBP patients and easier to visualise because its in 3D. The optimal personalised exercise programme is most likely to de-emphasize pain associated with exercise and thus results in patients have greater tolerance. Additionally, this also indicates that the intervention was effective in modifying maladaptive beliefs (Campello et al., 2012; Marin et al., 2017).

In contrast to the earlier findings, inconclusive results were found in providing a multidisciplinary biopsychosocial rehabilitation programme for LBP patients in the management of intermediate and long-term disability (Karjalainen et al., 2003; Anema et al., 2007; Bultmann et al., 2009; Whitfill., et al 2010). Further research is required on evaluating the effectiveness of personalised education material and its longer-term effects.

In summary, it is clear from the results that implementing an early and effective intervention in the management of patients with acute LBP, can improve outcome measures like chronic pain and disability (van Tulder et al., 2006).

#### *6.6.5 Perceived User Satisfaction*

A previous study by Bettany-Saltikov et al. (2011), on the information needs of spinal patients, acknowledged that most patients prefer written information alongside verbal advice. This finding is supported by Treweek et al. (2002), who highlighted that people forget half of what they are told within five minutes of leaving the consultation room. Van Schaik et al. (2007) also reported on patients' self-reported 'poor' knowledge about their condition. To address this issue, providing a standard educational booklet become common practice in the self-care management of LBP (Coudeyre et al., 2006; Henrotin et al., 2006; Liddle et al., 2007). The major strength of the standard educational booklet is that it is cheap and simple to produce and is even less time-consuming to deliver. It does not require complex training by a physiotherapist to issue it, but merely requires active support and reinforcement by the physiotherapist to the patient.

The aim of the current RCT study was to evaluate a personalised educational booklet, which contained a 3D model of patients' own backs and bodies. High-quality interactive 3D standing and sitting postures enabled participants to visualise (biofeedback) their own posture in all planes. This booklet also educated patients in a specific personalised manner on do's and don'ts and to use an intervention that appropriately addressed their specific and individualised limitations on activities of daily living.

The results show that the patients' satisfaction with personalised e-booklet was significantly higher in the experimental group than in the control group. The findings were similar in both the acute and the chronic LBP conditions. The results from the user satisfaction questionnaire indicate that the educational booklet was satisfying, useful, easy to use and benefitted in patients understanding of their back problem and their self-management.

A possible explanation for these results is that the personalised educational booklet addresses the patients' information needs on LBP. In support of this, Bush et al. (1993) have suggested that patients with LBP have both practical and realistic desires to learn about their problem, what to expect and what can they do about it.

According to Mead and Bower (2002), the concept of patient-centredness is complex. Positive associations about patient-centred care and their satisfaction were reported in six studies (Roter, Hall, & Katz, 1987; Street, 1992; et al., 1996; Cecil & Killeen, 1997; Langewitz, Phillipp, Kiss, & Wossmer, 1998; Kinnersley et al., 1999), but null findings were reported in another six (Stewart, 1984; Henbest & Stewart, 1990; Butow,

Dunn, Tattersall & Jones, 1995; Cape, 1996; Winefield et al., 1996; Wissow et al., 1998). It is generally seen as an approach to a health professional's attention to patients' psychosocial (as well as physical) needs and the use of psychotherapeutic behaviours to convey a sense of partnership and positive regard, together with the active facilitation of patients' involvement in decision-making about their care.

Another finding in the current study is that whenever the FABQw score decreases, the perceived user satisfaction score of the booklet increases. The evidence suggests that there is a congruence between patient satisfaction and patient's perception of the problem, prognosis and its long-term management of low-back pain (Cedraschi et al., 1996).

## **6.7 Limitations and Future studies**

Various limitations of this study are listed below. This also opens up large potential for further studies. First, the current study did not quantify the frequency of use of the booklet and the time spent on reading the material each time. This may influence the results and the effectiveness of the educational material. Second, in both the control and experimental group, the author finds it difficult to control physiotherapy management, for example passive mobilisation, manipulation and other administration of therapeutic modalities. Third, most of the participants in this study were middle-aged, well-educated, and from the private health-care sector. In order to generalise the results, it is important to conduct future studies with samples of a greater selection of variety of population. It is difficult to provide a comparison of the results of this study

with other research, due to heterogeneity (diverse of character) of the sample size and a lack of consistency in the content and structure of existing educational leaflets (Shorthouse et al., 2016). Fourth, no baseline measure was taken of the number of previous back pain episodes and patients understanding or knowledge of LBP condition.

Furthermore, the sample size was modest and no measurement was made of patients' engagement with the e-booklet. Moreover, the frequency of participation in exercise was not measured. The results of this study are limited in their wider applicability of patients with chronic LBP who have disability for more than a year (external validity).

In the current study, the duration of the intervention was for 4 weeks. There is a need for a larger longitudinal study to evaluate the effectiveness and sustainability of the personalised e-booklet in LBP patients.

## **6.8 Conclusion**

The conclusion of this study is that users of the personalised interactive educational booklet showed greater improvement compared to the control group in most of the outcome measures (physical, behavioural and at work) at 4-week follow-up. In addition, the users of the intervention (e-booklet) group showed greater satisfaction and scored better on both perceived pain and disability.

## **Chapter 7. General Discussion**



## **7.1 Chapter Aim**

The aim of this chapter is to present a general discussion of the empirical work presented in the preceding chapters of the current thesis. Furthermore, this section highlights the originality of the work together with its limitations and recommendations for future work.

## **7.2 Discussion of findings**

The overall aim of the research presented in this thesis was to develop and evaluate the low-cost 3D imaging mobile surface topography system for the measurement of 3D posture and back shape within a clinical setting. The hypothesis was that the MSTS would be a reliable, valid tool and one that would be readily accepted by clinicians and patients for the assessment and management of patients with spinal disorders.

Kimberlin and Winterstein (2008) identify that the reliability and validity are the two key indicators of the quality of any measuring instrument. Therefore, the first main objectives of the research presented in the current thesis were to evaluate the reliability and validate the use of the 3D imaging MSTS to quantify posture using an optoelectronic system (Vicon) as the gold-standard reference tool.

To the best of the author's knowledge, this is the first study to report the intra- and inter-rater reliability and validity of the MSTS that captures the 3D surface of the back and the whole body.

As presented in the Chapter 3, the reliability results indicated good to excellent intra-rater reliability and good to moderate inter-rater reliability for measuring 78% (7 out of

9; lumbar lordosis, thoracic kyphosis, cervical lordosis, shoulder elevation, left frontal knee angle and right and left scapular prominence) of postural variables with an ICC ranging from 0.70 to 0.98. The remaining 22% of variables (2 out of 9; lateral pelvic tilt and right frontal knee angle) showed moderate to low inter and intra-rater reliability with ICC's ranging from 0.26 to 0.79.

The intra- and inter-rater reliability were as good as previous studies using photography, radiography and Moiré topography methods with a mean intra-class correlation coefficient of (ICC) > 0.98 ( Grivas et al., 1997; Dunk et al., 2004; McAlpine et al., 2009; Fortin et al., 2012; Frerich et al., 2012). Furthermore, the absolute changes in the mean angle (3.4°) across trials with 90% confidence limits for all the posture variable was very similar to the surface topography method with a difference between trials was 2.1° (Frerich et al., 2012). Good intra-rater reliability for most of the postural variables makes the presented device an acceptable device to use within the clinical environment, one that is comparable to both photogrammetry and radiography. It is also important to note that the frontal plane variables like LPT and FKA produced poor reliability. This indicates that the MSTS is not a good system to measure frontal plane postural variables in the clinical environment.

With regards to the validity of the instrument, several studies have reported the validity of sagittal plane postural variables measured by both radiographic and non-radiographic instruments. The non-radiographic instruments range widely from the flexi-ruler (Dunleavy et al., 2010; Greendale et al., 2011; Letafatkar et al., 2011; MacIntyre et al., 2011; Oliveira et al., 2012), photogrammetry (Van Niekerk et al., 2008;

Fortin et al., 2010; Saad et al., 2012), inclinometer (Lewis et al., 2010; Czaprowski, 2012) to surface topography (Kovac & Pecina, 1999; Fortin et al., 2010).

As highlighted in Chapter 4, the results from the estimation of measuring sagittal and frontal plane postural variables (lumbar lordosis, thoracic kyphosis, shoulder elevation, lateral pelvic tilt and front knee angle) by the MSTS was as good as the Vicon system on healthy young adults. The mean difference between Vicon and MSTS for all the above variables ranged from 0.06 to 3.99 degrees. The novel tool (MSTS) is not only advantageous in its portability and low-cost, but it also demonstrates moderate reliability and validity for the measurement of posture variables within clinical practice. The reliability and validity of the tool is critically important for improving evidence-based practice of posture by clinicians.

Furthermore, as highlighted in Figure 7.1, the clinical acceptance of the tool by clinical practitioners is of critical importance for the effective use of the MSTS within clinical practice. Based on Venkatesh and Davis's (2000) Technology Acceptance Model (TAM), it was hypothesised at the start of the study that there would be positive relationship of perceived usefulness (PU) and perceived ease of use (PEOU) to behavioural intention (BI) to use the MSTS within clinical practice.

In order to evaluate the above, the clinical acceptance study presented in Chapter 5 investigated clinical practitioners' expectations together with their experience of using the MSTS to assess posture and back shape. The quantitative and qualitative results

of the clinical acceptance study confirmed that the MSTS to either meets (PU,  $p = 0.47$ ) or exceeds (PEOU,  $p = 0.01$ ) clinical practitioners' expectations.

The current practice for posture and back shape assessment by physiotherapists, osteopaths and sports therapists within a clinical environment is subjective and generally conducted through visual observation. Sohn and Yeo (2016) suggest that due to the complexity and expensiveness of existing tools (like the Integrated Shape Imaging System (ISIS-2)), most therapists cannot afford to buy these. Furthermore, Kirkley and Stein (2004) reported that clinical practitioners do not appreciate wasting time on lengthy and trivial computer recording jobs when their time could be better spent looking after patients in their busy clinics. Thus, designing a tool that captures posture and back shape data, a tool that is both objective as well as easy to use is crucial for it to be accepted by healthcare professionals specialising in the treatment patients with spinal pain or deformity. The significant positive correlation between the MSTS's ease of use and intention to use the tool provides some support for the conjecture that may be indispensable for its usefulness.

In addition, Venkatesh (2000), identifies perceived enjoyment and perceived satisfaction to be valuable additional predictors of intention to use the tool within the clinical acceptance model. The quantitative results of the clinical acceptance study which was endorsed by the qualitative results revealed that practitioners perceived that the three-dimensional visualisation of a patient's posture and back shape in both the diagnosis and evaluation of treatment outcomes not only improve the quality of clinical practice but also improves user experience. In support of this, Van Schaik et al. (2002),

Barker et al. (2003) and Hanif et al. (2011) reported that possible facilitating factors influence both clinical practitioners' satisfaction as well as their acceptance of the system, were the system's ease of use together with the perceived usefulness of the tool.

The quantitative and qualitative results of the clinical acceptance study indicate that the majority of clinical practitioners who participated in this study perceived that the MSTS was useful and easy to use. Most were satisfied, enjoyed using it and were keen to continue to use the system within their clinical practice. As stated by Hadji and Degoulet (2016) as well as Kabra et al. (2017), it is important to note that the initial acceptance of any system is regarded as the first step to successful deployment. Subsequently, the overall system's success will depend on the continuous use of the system.

The key factors that contributed to the clinical acceptance of the system can be summed up as follows. Firstly, it is very important to provide adequate training before any practitioner starts using it. Secondly it is also vital to provide technical assistance to clinical practitioners while they are using of MSTS in clinical practice. thirdly, according to Rathert et al. (2012), a tool or a system which addresses therapists' needs and provides high quality patient-centred care are perceived to have a better satisfaction score among clinical practitioners. As explained above, user experience and visualisation of three-dimensional posture together with its clinical applications may have contributed to a higher "perceived satisfaction" score. Fourthly, in accordance with Petter et al. (2008), positive experiences through the use of

technology (MSTS) contribute to the enhancement of satisfaction, that subsequently leads to greater intention to use. Furthermore, Palm et al. (2010) suggest that the adoption and integration of advanced health-care technology into clinical practice is essential to improve both the quality of clinical practice as well as significantly enhancing patients' experience.

In addition to clinical practitioners' acceptance, the benefits of the novel MSTS also include the improvement of treatment for patients with spinal disorders through personalised care. In the current thesis, the purpose of the randomised control clinical trial presented in Chapter 6 was to compare and evaluate the effect of personalised educational intervention on the self-care management of acute and chronic LBP patients. A personalised educational booklet, which contained a 3D model of the patients' own backs and bodies was provided to personalise the home exercise program. The high-quality interactive 3D standing and sitting postures provided within the booklet enabled participants to visualise (through visual feedback) their own posture in all three planes. This booklet also educated patients' in a specific personalised way on the do's and don'ts that were appropriate for their own backs and full-body postures. The personalised booklet also provided an educational intervention that appropriately addressed patients' specific and individualised limitations of their activities of daily living. The study investigated found that the short-term effects of the personalised intervention on the perceptions of pain, disability and fear avoidance behaviour of movement at work were greater as compared to routine non-personalised care.

Patient education on self-help, fear-avoidance behaviour and exercise comprise a significant component of the LBP management of patients by physiotherapists (Coudeyre et al., 2006). For the last two decades, the common medium of patient education was through a standard 'back book' that is now nearly 25 years old (Cohen et al., 1994). The large part of the educational material within it that is currently available is based on the biopsychosocial model. It is focussed on patients' beliefs and attitudes by teaching them the advantages of remaining active and avoiding bed rest, combined with the reassurance that there is nothing seriously wrong with their backs. In the current study, along with the above content, the personalised interactive educational material contained information about the patients' posture (visual-feedback), together with an overview of their spinal anatomy, explanations of the sources of pain and exercises both for aerobic benefit as well as exercises to strengthen the trunk musculature.

The personalised interactive educational materials, containing the individual patients own 3D posture images as visual feedback, helped patients appreciate their posture and understand how to correct their posture themselves i.e self-manage their condition. This enabled them to decrease their perception of fear of movement at work. The result of this study also demonstrates that the type of information presented to patients on educating patients' in a specific manner with specific do's and don'ts influenced and alter patients' beliefs regarding their low back pain (Linton et al., 2000; Burton et al., 1999; Traeger et al., 2015; Buchbinder et al., 2001; Valenzuela-Pascual et al., 2015).

The present findings are consistent with a recently published randomized control trial (Irvine et al., 2015), that evaluated the use of a mobile-web app to self-manage LBP in a large sample (n = 199). In this, study Irvine et al. (2015) introduced the application called FitBack, which is a responsive web application delivering self-management for non-specific LBP. Although their intervention using a mobile application was not a personalised tool, the improvements in patients' physical and behavioural outcomes translated into significant improvements in both worker productivity and presentism at the 4-month follow-up. A possible explanation for these results is that patients easily adopt new behaviour when their knowledge of the condition improves (Irvine et al., 2015). A recent systematic review by Shorthouse et al. (2016) supports these results by also reporting that educational materials for the management of LBP were a useful medium to engage workers and provide information regarding practical modifications to their work environment and activities. Consequently, psychological distress regarding ill health at work will potentially reduce.

As reported in Chapter 6, the personalised educational materials used in the current study not only lowered patients' physiological pain perception, but also suggest that it altered their cognitive and psychosocial perceptions on the fear of movement. This, in turn, potentially could influence their physical and work-related activities by inhibiting fear beliefs about doing activities that patients once avoided.

As presented in Chapter 6, the RCT results of the current research are consistent with those of other studies by Loisel et al. (1997), Karjalainen et al. (2003), Campello et al. (2012). Campello's results show that a multidisciplinary biopsychosocial rehabilitation



programme in patients with LBP was more effective than traditional care for disability in the short term (4 weeks follow-up). An optimal personalised education exercise programme is most likely to de-emphasize the pain associated with movement and exercise and this may then result in patients have greater exercise tolerance. Furthermore, the results of the current RCT study also suggest that the personalised educational intervention was effective in modifying maladaptive beliefs about posture and movement in patients with LBP (Campello et al., 2012; Marin et al., 2017).

Mead and Bower (2000) and Mead et al. (2002) state that the concept of patient-centredness is complex and regarded as crucial for the delivery of high-quality care by healthcare practitioners. Patient-centredness is generally described as providing attention to patients' personalised biopsychosocial needs. Furthermore, it helps with active facilitation of patients' involvement in decision-making about their care (Kinnersley et al., 1999).

The results of previous studies conducted on patient-centredness have been inconsistent. Positive associations about patient-centred care together with patients satisfaction, have been reported in six research studies (Roter, Hall & Katz, 1987; Street, 1992; Winefield et al., 1996; Cecil & Killeen, 1997; Langewitz, Phillipp, Kiss, & Wossmer, 1998; Kinnersley et al., 1999), whilst negative findings have been described in a further six studies (Stewart, 1984; Henbest & Stewart, 1990; Butow, Dunn, Tattersall, & Jones, 1995; Cape, 1996; Winefield et al., 1996; Wissow et al., 1998). The results from the current study have found that the use of a personalised

educational e-booklet was more effective than a standard booklet for treating pain, disability and fear avoidance behaviour at work in acute and chronic LBP patients.

The originality of the study lies on with the development and evaluation of the MSTS. To the best of the researchers' knowledge, this is the first comprehensive multifaceted study that has developed and evaluated the novel MSTS together with its reliability, validity and clinicians' acceptance by clinicians and patients with spinal disorders

### **7.3 Research and Clinical Implications**

There are currently numerous commercially available tools that measure 3D posture and back shape; with a number of them having high reliability and validity (Cheriet et al., 2007; Berryman et al., 2008; Kowalski et al., 2013; Betsch et al., 2013; Furian et al., 2013 and Fathi & Curran, 2017). However, most of these instruments are primarily used within a research setting and not within a clinical environment. The difficulty is that these tools are either complex to use, very expensive or heavy to carry around.

The MSTS is not only portable and low-cost, but also easy-to-use. Within the current study, this novel instrument has shown that is capable of measuring small angular differences both between participants, and also between trials. This is important when considering the use of an instrument for evidence-based clinical use. Further, the system is also capable of measuring whole-body posture, as recommended by Fortin et al. (2010), but which to date has not been documented. Furthermore, this novel tool has the secondary advantage of being able to capture and measure human posture in different poses like for instance the forward-bend test and sitting posture and can also

measure spinal mobility; this is essential for patients with spinal disorders and other spinal deformities (see Appendix 10). The quality and the adaptability of the tool not only enhances the MSTS use within a clinical environment but also provide opportunities for screening large number of people at their work place or home.

The high clinical acceptance by healthcare practitioners could be due to all the following features: its usefulness, portability and a simple software interface. Providing comprehensive workshops with hands on practice regarding the use of the tool to the practitioner is essential to both maximise the benefits of the MSTS and also promote its acceptance and reduce or eliminate any resistance to the use of the MSTS by practitioners within the clinical environment.

Furthermore, the personalised interactive educational E-booklet that was developed not only helped low- back pain patients to self-management of symptoms, but it also lowered their psychological pain perception. This subsequently led in the alteration of the patients' movement behaviour, which in turn helped to improved patient satisfaction. The novelty of this concept could be applied to a diverse range of patients with spinal disorders, for example in patients with scoliosis and increased thoracic kyphosis

#### **7.4 Limitations**

There were a number of limitations within the current research: Firstly, the sample size was small and only young healthy adults were included in the reliability and validity study. Consequently, the results and conclusions only apply to a limited section of the

population. Nevertheless, similar validation is warranted in mixed samples of participants with diverse spinal disorders and deformities.

Secondly, in the both reliability and validity studies, although the author tried to minimise any measurement errors by setting up standard procedures for both patients and raters as well as training the raters, the reliability and validity results need to be interpreted with caution, as any influence of postural sway on the results could not be quantified. Further research is needed to identify the best way to deal with this. The author also anticipates that bias and variation in postural measurements would be greater in populations who had difficulty maintaining a standing position, for example, the elderly and frail individuals who complain of pain.

Thirdly, the duration of data collection for each trial in the validation study using the Vicon system with six cameras lasted only for an average of 3 secs whilst, the data collection using the MSTS took an average of 30 – 40 seconds and only used one camera. Further studies on the simultaneous use of more than two MSTS cameras may potentially strengthen the quality of the 3D data collected, thereby strengthening the current validation results.

Furthermore, as presented in the Chapter 6, the RCT study evaluating the personalised E-Booklet, did not quantify the frequency of use of the booklet and the time spent on reading the material each time the patients used it. This may have influenced the results as well as the effectiveness of the educational material. Additionally, in both the control and experimental group, the physiotherapy

management each patient was undergoing was beyond the author's control, for example passive mobilisation, manipulation or other administration of therapeutic modalities. Despite the variability introduced by this lack of controls the results still demonstrated an advantage for personalised patient education. In summary, the current study demonstrates that the MSTS is reliable and valid to study the most of the posture and back surface variables in patients with spinal deformities.

### **7.5 Further Research and Recommendations**

Based on the presented results in the current research, there is sufficient justification for future development of an automated bespoke 3D posture-analysing mobile application. Developing a tool with automatic recognition of markers as well as having the ability to automatically calculate angles could potentially reduce further time consumption in the data collection and analysis processes.

In order to decrease the duration of data acquisition further the author is also considering the feasibility of using more than one camera together with synchronized data capture. This will further help data acquisition in people with pain or balance disorders by decreasing their stance duration. There is also a need for a similar study comparing the reliability of the posture results with and without reflective markers.

As the MSTS has good to excellent reliability, several potential future studies could be implemented; studies with larger and wider sample sizes (in terms of age and gender) on healthy participants could provide database of normative values. Mass screening could be undertaken to develop risk-factor modelling for different types of spinal

deformity. This is because numerous research studies have shown that early intervention can decrease the progression of spinal deformities but can also reduce pain, future discomfort and deterioration (Hawes, 2003).

Potential studies on patients with spinal deformity could also analyse the correlation with different postures and medical conditions, for example Schuerman's disease and spondylolisthesis. Furthermore, as shown in the current research the novel MSTS is appropriate for measuring objective posture and back shape data for use in pre- and post-treatment clinical trials to measure the impact of conservative and surgical interventions. Thereby, as recommended by the Chartered Society of Physiotherapy (CSP) regarding evidence-based practice (CSP, 2016), this objective evidence-based postural evaluation tool will significantly improve the way the profession currently assess posture and manages patient care. The ability of the tool, to provide objective data will hopefully enable researchers to further develop and promote new research in this field. It has the potential to help in the generation of new evidence, knowledge transfer as well as service improvement for the management of patients with spinal disorders.

In order to demonstrate and promote wide system acceptance across relevant disciplines in the carer of spinal health conditions, the clinical acceptance of the MSTS needs to be explored in a wider range of practitioners, varying from spinal nurses to spinal consultants/surgeons. There is also a need for longitudinal study to analyse the long-term acceptance of the tool within the clinical environment. Furthermore, there is

a need for evaluation of the long-term effectiveness of the personalised educational intervention through a larger longitudinal study in the management of LBP patients.

## **7.6 Conclusions**

The originality of this first comprehensive multifaceted study lies firstly in the development of a novel MSTS that is portable, low-cost and easy to use within current clinical practice. Secondly, the current study results demonstrate good to moderate inter- and intra-rater reliability and validity to measure majority of the three-dimensional posture and back shape variables in standing using the MSTS.

Thirdly, in the affirmation of the clinical acceptance of the tool by clinical practitioners, suggest that the three-dimensional visualisation of patient posture data and its ability to quantitatively measure was greatly embraced by healthcare professionals. Even though the quantitative and qualitative results presented in the current thesis have broadened and strengthened previous clinical-acceptance research, healthcare professionals' intention towards the acceptance of technology demands a deeper understanding to facilitate further the creation of innovative products to enhance the delivery and quality of clinical care.

Finally, in the endorsement of the value of the output of the tool by patients for the self-management of their spinal disorders, the personalised interactive educational booklet showed greater improvement compared to the control group in majority of the outcome measures (physical, behavioural and at work) at 4-week follow-up. In addition, the

users of the personalised intervention (e-booklet) group showed greater satisfaction and scored better on both perceived pain and disability.

Overall the above multifaceted studies not only provide insight understanding of the MSTS and its applicability but also provide a base for future studies. This low-cost, portable and easy-to-use instrument has the potential to be used as a complementary tool alongside the subjective assessment for patients with a wide variety of spinal pathologies.



# References

- Abbott, A.D., Tyni-Lenné, R., and Hedlund, R. (2010) 'Early Rehabilitation Targeting Cognition, Behavior, and Motor Function after Lumbar Fusion: A Randomized Controlled Trial'. *Spine* 35 (8), 848–857
- Abelin-Genevois, K., Idjerouidene, A., Roussouly, P., Vital, J.M., and Garin, C. (2014) 'Cervical Spine Alignment in the Pediatric Population: A Radiographic Normative Study of 150 Asymptomatic Patients'. *European Spine Journal* 23 (7), 1442–1448
- Adair, I. V, Van Wijk, M.C., and Armstrong, G.W.D. (1977) 'Moiré Topography in Scoliosis Screening.' *Clinical Orthopaedics and Related Research* 129, 165–171
- Adami Sedrez, J., Tarragô Candotti, C., Silveira Furlanetto, T., and Fagundes Loss, J. (2016) 'Non-Invasive Postural Assessment of the Spine in the Sagittal Plane: A Systematic Review'. *Motricidade* 12 (2)
- Adams, D.A., Nelson, R.R., and Todd, P.A. (1992) 'Perceived Usefulness, Ease of Use, and Usage of Information Technology: A Replication'. *MIS Quarterly* 227–247
- Adner, R. and Kapoor, R. (2010) 'Value Creation in Innovation Ecosystems: How the Structure of Technological Interdependence Affects Firm Performance in New Technology Generations'. *Strategic Management Journal* 31 (3), 306–333
- Adobor, R.D., Rimeslatten, S., Steen, H., and Brox, J.I. (2011) 'School Screening and Point Prevalence of Adolescent Idiopathic Scoliosis in 4000 Norwegian Children Aged 12 Years'. *Scoliosis* 6 (1), 23
- Agarwal, R. and Karahanna, E. (2000) 'Time Flies When You're Having Fun: Cognitive Absorption and Beliefs about Information Technology Usage'. *MIS Quarterly* 665–694
- Agarwal, R. and Prasad, J. (1998) 'A Conceptual and Operational Definition of Personal Innovativeness in the Domain of Information Technology'. *Information Systems Research* 9 (2), 204–215
- Aggelidis, V.P. and Chatzoglou, P.D. (2009) 'Using a Modified Technology Acceptance

- Model in Hospitals'. *International Journal of Medical Informatics* 78 (2), 115–126
- Aizen, M.A. (1991) 'Predación de Semillas de Acacia Aroma Por El Bruchido Pseudopachymerina Grata En Función de La Posición de Las Semillas Y El Número de Semillas Por Vaina'. *Ecol. Austral* 1, 17–23
- Akizuki, K., Yamaguchi, K., and Morita, Y. (2016) *The Effect of Proficiency Level on Measurement Error of Range of Motion*. 2644–2651
- Al-Debei, M.M. (2014) 'The Quality and Acceptance of Websites: An Empirical Investigation in the Context of Higher Education'. *International Journal of Business Information Systems* 15 (2), 170–188
- Aldosari, B. (2012) 'User Acceptance of a Picture Archiving and Communication System (PACS) in a Saudi Arabian Hospital Radiology Department'. *BMC Medical Informatics and Decision Making* 12 (1), 44
- Alhwarin, F., Ferrein, A., and Scholl, I. (2014) 'IR Stereo Kinect: Improving Depth Images by Combining Structured Light with IR Stereo'. *Lecture Notes in Computer Science (Including Subseries Lecture Notes in Artificial Intelligence and Lecture Notes in Bioinformatics)* 8862, 409–421
- Allum, J.H.J. and Carpenter, M.G. (2005) 'A Speedy Solution for Balance and Gait Analysis: Angular Velocity Measured at the Centre of Body Mass'. *Current Opinion in Neurology* 18 (1), 15–21
- Alshami, A.M. (2015) 'Prevalence of Spinal Disorders and Their Relationships with Age and Gender'. *Saudi Medical Journal* 36 (6), 725
- Altaf, F., Drinkwater, J., Phan, K., and Cree, A.K. (2017) 'Systematic Review of School Scoliosis Screening'. *Spine Deformity* 5 (5), 303–309
- Amann, M.-C., Bosch, T.M., Lescure, M., Myllylae, R.A., and Rioux, M. (2001) 'Laser Ranging: A Critical Review of Unusual Techniques for Distance Measurement'. *Optical Engineering* 40 (1), 10–20

- Amendt, L.E., Ause-Ellias, K.L., Eybers, J.L., Wadsworth, C.T., Nielsen, D.H., and Weinstein, S.L. (1990) 'Validity and Reliability Testing of the Scoliometer®'. *Physical Therapy* 70 (2), 108–117
- Amin, M., Rezaei, S., and Abolghasemi, M. (2014) 'User Satisfaction with Mobile Websites: The Impact of Perceived Usefulness (PU), Perceived Ease of Use (PEOU) and Trust'. *Nankai Business Review International* 5 (3), 258–274
- Ammenwerth, E., Mansmann, U., Iller, C., and Eichstädter, R. (2003) 'Factors Affecting and Affected by User Acceptance of Computer-Based Nursing Documentation: Results of a Two-Year Study'. *Journal of the American Medical Informatics Association* 10 (1), 69–84
- Amorim, A.B., Pappas, E., Simic, M., Ferreira, M.L., Tiedemann, A., Jennings, M., and Ferreira, P.H. (2016) 'Integrating Mobile Health and Physical Activity to Reduce the Burden of Chronic Low Back Pain Trial (IMPACT): A Pilot Trial Protocol'. *BMC Musculoskeletal Disorders* 17 (1), 36
- Anatomical Planes* (n.d.) available from <<https://bodytomy.com/sagittal-coronal-transverse-3anatomical-planes-of-human-motion>>.
- Anderson, E., Bai, Z., Bischof, C., Blackford, L.S., Demmel, J., Dongarra, J., Du Croz, J., Greenbaum, A., Hammarling, S., McKenney, A., and others (1999) *LAPACK Users' Guide*. SIAM
- Anderson, J.G. (1997) 'Clearing the Way for Physicians' Use of Clinical Information Systems'. *Communications of the ACM* 40 (8), 83–90
- Andersson, G.B.J., Lucente, T., Davis, A.M., Kappler, R.E., Lipton, J.A., and Leurgans, S. (1999) 'A Comparison of Osteopathic Spinal Manipulation with Standard Care for Patients with Low Back Pain'. *New England Journal of Medicine* 341 (19), 1426–1431
- Andrade, M.F., Chaves, É. de C.L., Miguel, M.R.O., Simão, T.P., Nogueira, D.A., and

- lunes, D.H. (2017) 'Evaluation of Body Posture in Nursing Students'. *Revista Da Escola de Enfermagem Da USP* 51
- Anema, J.R., Steenstra, I.A., Bongers, P.M., de Vet, H.C.W., Knol, D.L., Loisel, P., and van Mechelen, W. (2007) 'Multidisciplinary Rehabilitation for Subacute Low Back Pain: Graded Activity or Workplace Intervention or Both?: A Randomized Controlled Trial'. *Spine* 32 (3), 291–298
- Anwary, A.R. (2012) *Statistical Shape Analysis for the Human Back Statistical Shape Analysis for the Human Back*.
- Arnold, C.M. (2000) 'The Reliability of Five Clinical Postural Alignment Measures for Women with Osteoporosis'. *Physiother Can* 52, 286–294
- Asher, M.A. and Burton, D.C. (2006) 'Adolescent Idiopathic Scoliosis: Natural History and Long Term Treatment Effects'. *Scoliosis* 1 (1), 2
- Ashworth, M.A., Hancock, J.A., Ashworth, L., and Tessier, K.A. (1988) 'Scoliosis Screening An Approach to Cost/Benefit Analysis.' *Spine* 13 (10), 1187–1188
- Axén, I., Bodin, L., Bergström, G., Halasz, L., Lange, F., Lövgren, P.W., Rosenbaum, A., Leboeuf-Yde, C., and Jensen, I. (2011) 'Clustering Patients on the Basis of Their Individual Course of Low Back Pain over a Six Month Period'. *BMC Musculoskeletal Disorders* 12 (1), 99
- Bailey, J.F., Sparrey, C.J., Been, E., and Kramer, P.A. (2016) 'Morphological and Postural Sexual Dimorphism of the Lumbar Spine Facilitates Greater Lordosis in Females'. *Journal of Anatomy* 229 (1), 82–91
- Barker, A., Krull, G., and Mallinson, B. (2005) 'A Proposed Theoretical Model for M-Learning Adoption in Developing Countries'. in *Proceedings of mLearn*. held 2005. 4th
- Barua, M. (2012) 'E-Governance Adoption in Government Organization of India'. *International Journal of Managing Public Sector Information and Communication*

- Batavia, M. (2001) *Clinical Research for Health Professionals: A User-Friendly Guide*. Butterworth-Heinemann
- Battaglia, P.J., Maeda, Y., Welk, A., Hough, B., and Kettner, N. (2014) 'Reliability of the Goutallier Classification in Quantifying Muscle Fatty Degeneration in the Lumbar Multifidus Using Magnetic Resonance Imaging'. *Journal of Manipulative & Physiological Therapeutics* 37 (3), 190–197
- Bayar, K., Bayar, B., Yakut, E., and Yakut, Y. (2003) 'Reliability and Construct Validity of the Oswestry Low Back Pain Disability Questionnaire in the Elderly with Low Back Pain'. *The Pain Clinic* 15 (1), 55–59
- Bazeley, P. and Jackson, K. (2013) *Qualitative Data Analysis with NVivo*. Sage Publications Limited
- Beck, J.S. (1995) *Cognitive Therapy: Basics and beyond*. New York: Guilford Press
- Beckman, S.M. and Buchanan, T.S. (1995) 'Ankle Inversion Injury and Hypermobility: Effect on Hip and Ankle Muscle Electromyography Onset Latency'. *Archives of Physical Medicine and Rehabilitation* 76 (12), 1138–1143
- Been, E., Barash, A., Marom, A., and Kramer, P.A. (2010) 'Vertebral Bodies or Discs: Which Contributes More to Human-like Lumbar Lordosis?' *Clinical Orthopaedics and Related Research*® 468 (7), 1822–1829
- Been, E. and Kalichman, L. (2014) 'Lumbar Lordosis'. *The Spine Journal* 14 (1), 87–97
- Been, E., Shefi, S., and Soudack, M. (2017) 'Cervical Lordosis: The Effect of Age and Gender'. *The Spine Journal* 17 (6), 880–888
- Behnke, R.S. (2012) *Kinetic Anatomy 3rd Edition*. Human Kinetics
- Bekkering, G.E., Hendriks, H.J.M., Koes, B.W., Oostendorp, R.A.B., Ostelo, R., Thomassen, J.M.C., and Van Tulder, M.W. (2003) 'Dutch Physiotherapy Guidelines

- for Low Back Pain'. *Physiotherapy* 89 (2), 82–96
- Bekkering, G.E., Van Tulder, M.W., Hendriks, E.J.M., Koopmanschap, M.A., Knol, D.L., Bouter, L.M., and Oostendorp, R.A.B. (2005) 'Implementation of Clinical Guidelines on Physical Therapy for Patients with Low Back Pain: Randomized Trial Comparing Patient Outcomes after a Standard and Active Implementation Strategy'. *Physical Therapy* 85 (6), 544–555
- Berdishevsky, H., Lebel, V.A., Bettany-Saltikov, J., Rigo, M., Lebel, A., Hennes, A., Romano, M., Białek, M., M'hango, A., Betts, T., de Mauroy, J.C., and Durmala, J. (2016) 'Physiotherapy Scoliosis-Specific Exercises - a Comprehensive Review of Seven Major Schools.' *Scoliosis and Spinal Disorders* [online] 11, 20. available from <<http://www.ncbi.nlm.nih.gov/pubmed/27525315>>
- Berry, D.A. (2016) 'Right-Sizing Adjuvant and Neoadjuvant Clinical Trials in Breast Cancer'. *Clinical Cancer Research* 22 (1), 3–5
- Berryman, F., Pynsent, P., Fairbank, J., and Disney, S. (2008) 'A New System for Measuring Three-Dimensional Back Shape in Scoliosis.' *European Spine Journal : Official Publication of the European Spine Society, the European Spinal Deformity Society, and the European Section of the Cervical Spine Research Society* [online] 17 (5), 663–72. available from <<http://www.pubmedcentral.nih.gov/articlerender.fcgi?artid=2367415&tool=pmcentrez&rendertype=abstract>> [20 July 2011]
- Bettany-Saltikov, J., Wellburn, S., and Watson, P. (2011) 'An Evaluation of the Information Needs of People with Adolescent Idiopathic Scoliosis at the Point of First Diagnosis at the Hospital Clinic: Final Report'. *Middlesbrough, UK*: [online] (November), 1–106. available from <[http://www.academia.edu/download/30186277/j\\_bettany-saltikov\\_2011.pdf](http://www.academia.edu/download/30186277/j_bettany-saltikov_2011.pdf)>
- Betsch, M., Wild, M., Johnstone, B., Jungbluth, P., Hakimi, M., Kuhlmann, B., and Rapp, W. (2013) 'Evaluation of a Novel Spine and Surface Topography System for

- Dynamic Spinal Curvature Analysis during Gait'. *PLoS ONE* 8 (7), 1–8
- Bettany-Saltikov, J.A., Kandasamy, G., Schreiber, S., Stolinski, L., Czaprowski, D., and Warren, J.G. (2017) *Normative Data of 3D Back Shape in Asymptomatic Subjects*.
- Bettany-Saltikov, J. and Cole, L. (2012) 'The Effect of Frontpacks, Shoulder Bags and Handheld Bags on 3D Back Shape and Posture in Young University Students: An ISIS2 Study'. *Studies in Health Technology and Informatics* 176, 117–121
- Betz, R.R. (2003) 'Kyphosis of the Thoracic and Thoracolumbar Spine in the Pediatric Patient: Normal Sagittal Parameters and Scope of the Problem.' *Instructional Course Lectures* 53, 479–484
- Bhattacharjee, A. (2001a) 'An Empirical Analysis of the Antecedents of Electronic Commerce Service Continuance'. *Decision Support Systems* 32 (2), 201–214
- Bhattacharjee, A. (2001b) 'Understanding Information Systems Continuance: An Expectation-Confirmation Model'. *MIS Quarterly* 351–370
- Billis, E. V, Foster, N.E., and Wright, C.C. (2003) 'Reproducibility and Repeatability: Errors of Three Groups of Physiotherapists in Locating Spinal Levels by Palpation'. *Manual Therapy* 8 (4), 223–232
- Bland, J.M. and Altman, D.G. (1996) 'Statistics Notes: Measurement Error Proportional to the Mean'. *Bmj* 313 (7049), 106
- Van Blommestein, A.S., MaCrae, S., Lewis, J.S., and Morrissey, M.C. (2012) 'Reliability of Measuring Thoracic Kyphosis Angle, Lumbar Lordosis Angle and Straight Leg Raise with an Inclinator'. *Open Spine Journal*
- Borek, J. (2018) *Managerial Strategies for Maximizing Benefits From Electronic Health Record Systems*.
- Boshoff, C. and Gray, B. (2004) 'The Relationships between Service Quality, Customer Satisfaction and Buying Intentions in the Private Hospital Industry'. *South African Journal of Business Management* 35 (4), 27–37



- Bovey, W.H. and Hede, A. (2001) 'Resistance to Organisational Change: The Role of Defence Mechanisms'. *Journal of Managerial Psychology* 16 (7), 534–548
- Braun, B.L. and Amundson, L.R. (1989) 'Quantitative Assessment of Head and Shoulder Posture.' *Archives of Physical Medicine and Rehabilitation* 70 (4), 322–329
- Braun, V. and Clarke, V. (2006) 'Using Thematic Analysis in Psychology'. *Qualitative Research in Psychology* [online] 3 (2), 77–101. available from <<http://www.tandfonline.com/doi/abs/10.1191/1478088706qp0630a>> [26 May 2017]
- Brewer, P., Berryman, F., Baker, D., Pynsent, P., and Gardner, A. (2013) 'Influence of Cobb Angle and ISIS2 Surface Topography Volumetric Asymmetry on Scoliosis Research Society-22 Outcome Scores in Scoliosis'. *Spine Deformity* 1 (6), 452–457
- Brink, Y., Louw, Q., Grimmer, K., Schreve, K., der Westhuizen, G., and Jordaan, E. (2013) 'Development of a Cost Effective Three-Dimensional Posture Analysis Tool: Validity and Reliability'. *BMC Musculoskeletal Disorders* 14 (1), 335
- British Scoliosis Society* (n.d.) available from <<http://www.britscoliosissoc.org.uk/patient-information/bss-documents->>
- Brown, S.A. (2014) *EXPECTATION CONFIRMATION IN INFORMATION SYSTEMS RESEARCH: A TEST OF SIX COMPETING MODELS* 1. 38 (3), 729–756
- Brown, S.A., Massey, A.P., and Ward, K.W. (2016) 'Handle Mergers and Acquisitions with Care: The Fragility of Trust between the IT-Service Provider and End-Users'. *European Journal of Information Systems* 25 (2), 170–186
- Brown, S.A., Venkatesh, V., and Goyal, S. (2014) 'Expectation Confirmation in Information Systems Research: A Test of Six Competing Models.' *Mis Quarterly* 38 (3)
- Bryan, J.M., Mosner, E., Shippee, R., and Stull, M.A. (1990) 'Investigation of the Validity of Postural Evaluation Skills in Assessing Lumbar Lordosis Using Photographs of

- Clothed Subjects'. *Journal of Orthopaedic & Sports Physical Therapy* 12 (1), 24–29
- Bryman, A. (2006) 'Integrating Quantitative and Qualitative Research: How Is It Done?' *Qualitative Research* 6 (1), 97–113
- Buchbinder, R., Jolley, D., and Wyatt, M. (2001) '2001 Volvo Award Winner in Clinical Studies: Effects of a Media Campaign on Back Pain Beliefs and Its Potential Influence on Management of Low Back Pain in General Practice'. *Spine* 26 (23), 2535–2542
- Bullock-Saxton, J. (1988) 'Normal and Abnormal Postures in the Sagittal Plane and Their Relationship to Low Back Pain'. *Physiotherapy Practice* 4 (2), 94–104
- Bültmann, U., Sherson, D., Olsen, J., Hansen, C.L., Lund, T., and Kilsgaard, J. (2009) 'Coordinated and Tailored Work Rehabilitation: A Randomized Controlled Trial with Economic Evaluation Undertaken with Workers on Sick Leave due to Musculoskeletal Disorders'. *Journal of Occupational Rehabilitation* 19 (1), 81–93
- Bunnell, W.P. (2005) 'Selective Screening for Scoliosis.' *Clinical Orthopaedics and Related Research* 434, 40–45
- Bunnell, W.P. (1984) 'An Objective Criterion for Scoliosis Screening.' *J Bone Joint Surg Am* 66 (9), 1381–1387
- Burdett, R.G., Brown, K.E., and Fall, M.P. (1986) 'Reliability and Validity of Four Instruments for Measuring Lumbar Spine and Pelvic Positions'. *Physical Therapy* 66 (5), 677–684
- Burt, S. and Punnett, L. (1999) 'Evaluation of Interrater Reliability for Posture Observations in a Field Study'. *Applied Ergonomics* 30 (2), 121–135
- Burton, A.K. (1987) 'Suggestion From the Field: Measurement of "Regional" Lumbar Sagittal Mobility'. *Journal of Orthopaedic & Sports Physical Therapy* 9 (4), 166–169
- Burton, A.K., Balagué, F., Cardon, G., Eriksen, H.R., Henrotin, Y., Lahad, A., Leclerc, A., Muller, G., and Van Der Beek, A.J. (2004) *European Guidelines for Prevention in*

*Low Back Pain.*

- Bush, T., Cherkin, D., and Barlow, W. (1993) 'The Impact of Physician Attitudes on Patient Satisfaction with Care for Low Back Pain'. *Archives of Family Medicine* 2 (3), 301
- Butow, P.N., Dunn, S.M., Tattersall, M.H.N., and Jones, Q.J. (1995) 'Computer-Based Interaction Analysis of the Cancer Consultation'. *British Journal of Cancer* 71 (5), 1115
- Çakmak, A., Yücel, B., Özyalçın, S.N., Bayraktar, B., Ural, H.I., Duruöz, M.T., and Genç, A. (2004) 'The Frequency and Associated Factors of Low Back Pain among a Younger Population in Turkey'. *Spine* 29 (14), 1567–1572
- Califf, R.M., Robb, M.A., Bindman, A.B., Briggs, J.P., Collins, F.S., Conway, P.H., Coster, T.S., Cunningham, F.E., De Lew, N., DeSalvo, K.B., and others (2016) *Transforming Evidence Generation to Support Health and Health Care Decisions*. Mass Medical Soc
- Calvert, P.T., Edgar, M.A., and Webb, P.J. (1989) 'Scoliosis in Neurofibromatosis. The Natural History with and without Operation'. *Bone & Joint Journal* 71 (2), 246–251
- Campello, M.A., Weiser, S.R., Nordin, M., and Hiebert, R. (2006) 'Work Retention and Nonspecific Low Back Pain'. *Spine* 31 (16), 1850–1857
- Campello, M., Ziemke, G., Hiebert, R., Weiser, S., Brinkmeyer, M., Fox, B., Dail, J., Kerr, S., Hinnant, I., and Nordin, M. (2012) 'Implementation of a Multidisciplinary Program for Active Duty Personnel Seeking Care for Low Back Pain in a US Navy Medical Center: A Feasibility Study'. *Military Medicine* 177 (9), 1075–1080
- Cape, J.D. (1996) 'Psychological Treatment of Emotional Problems by General Practitioners'. *Psychology and Psychotherapy: Theory, Research and Practice* 69 (2), 85–99
- Carr, A.J., Jefferson, R.J., Turner-Smith, A.R., and Beavis, A. (1991) 'An Analysis of Normal Back Shape Measured by ISIS Scanning'. *Spine* 16 (6), 656–659

- Carregaro, R.L., da Silva, E.N., and van Tulder, M. (2018) 'Direct Healthcare Costs of Spinal Disorders in Brazil'. *International Journal of Public Health* 1–9
- Cartwright, L. and Pitney, W. (2011) *Fundamentals of Athletic Training*. Human Kinetics
- De Carvalho, D.E., Soave, D., Ross, K., and Callaghan, J.P. (2010) 'Lumbar Spine and Pelvic Posture between Standing and Sitting: A Radiologic Investigation Including Reliability and Repeatability of the Lumbar Lordosis Measure'. *Journal of Manipulative & Physiological Therapeutics* 33 (1), 48–55
- Castro, A.P.G., Pacheco, J.D., Lourenço, C., Queirós, S., Moreira, A.H.J., Rodrigues, N.F., and Vilaça, J.L. (2017) 'Evaluation of Spinal Posture Using Microsoft Kinect™: A Preliminary Case-Study with 98 Volunteers'. *Porto Biomedical Journal* 2 (1), 18–22
- Cecil, D.W. and Killeen, I. (1997) 'Control, Compliance, and Satisfaction in the Family Practice Encounter.' *Family Medicine* 29 (9), 653–657
- Cedraschi, C., Reust, P., Lorenzi-Cioldi, F., and Vischer, T.L. (1996) 'The Gap between Back Pain Patients' Prior Knowledge and Scientific Knowledge and Its Evolution after a Back School Teaching Programme: A Quantitative Evaluation'. *Patient Education and Counseling* 27 (3), 235–246
- Čelan, D., Papež, B.J., Poredoš, P., and Možina, J. (2015) 'Laser Triangulation Measurements of Scoliotic Spine Curvatures'. *Scoliosis* 10 (1), 25
- Chalomba, N. (2016) *Effectiveness of Baranded Mobile Apps on Brand Loyalty among Generation Y Cunsumers*.
- Chaory, K., Rannou, F., Fermanian, J., Genty, M., Rosenberg, S., Billabert, C., Kemoun, G., Richard, I., Thevenon, A., Coudeyre, L., and others (2004) 'Impact of Functional Restoration Programs on Fears, Avoidance and Beliefs in Chronic Low Back Pain Patients'. in *Annales de Readaptation et de Medecine Physique: Revue Scientifique de La Societe Francaise de Reeducation Fonctionnelle de Readaptation et de*

*Medecine Physique*. held 2004. 93–97

- Chau, P.Y.K. and Hu, P.J. (2002) 'Examining a Model of Information Technology Acceptance by Individual Professionals: An Exploratory Study'. *Journal of Management Information Systems* 18 (4), 191–229
- Chau, P.Y.K. and Hu, P.J.-H. (2001) 'Information Technology Acceptance by Individual Professionals: A Model Comparison Approach'. *Decision Sciences* 32 (4), 699–719
- Chen, C.-H. and Mort, G.S. (2007) 'Consumers' Technology Adoption Behaviour: An Alternative Model'. *The Marketing Review* 7 (4), 355–368
- Chen, I.J., Yang, K.-F., Tang, F.-I., Huang, C.-H., and Yu, S. (2008) 'Applying the Technology Acceptance Model to Explore Public Health Nurses' Intentions towards Web-Based Learning: A Cross-Sectional Questionnaire Survey'. *International Journal of Nursing Studies* 45 (6), 869–878
- Cheriet, F., Laporte, C., Kadoury, S., Labelle, H., and Dansereau, J. (2007) 'A Novel System for the 3-D Reconstruction of the Human Spine and Rib Cage from Biplanar X-Ray Images'. *IEEE Transactions on Biomedical Engineering* 54 (7), 1356–1358
- Cheung, C.-W.J., Zhou, G.-Q., Law, S.-Y., Mak, T.-M., Lai, K.-L., and Zheng, Y.-P. (2015) 'Ultrasound Volume Projection Imaging for Assessment of Scoliosis'. *IEEE Transactions on Medical Imaging* 34 (8), 1760–1768
- Cheung, G.W. and Rensvold, R.B. (2002) 'Evaluating Goodness-of-Fit Indexes for Testing Measurement Invariance'. *Structural Equation Modeling* 9 (2), 233–255
- Chiang, C. (1975) 'Moiré Topography'. *Applied Optics* 14 (1), 177–179
- Chismar, W.G. and Wiley-Patton, S. (2003) 'Does the Extended Technology Acceptance Model Apply to Physicians'. in *System Sciences, 2003. Proceedings of the 36th Annual Hawaii International Conference on*. held 2003. 8--pp
- Cho, Y.J. and Park, H. (2011) 'Exploring the Relationships among Trust, Employee Satisfaction, and Organizational Commitment'. *Public Management Review* 13 (4),

- Chockalingam, N., Dangerfield, P.H., Giakas, G., Cochrane, T., and Dorgan, J.C. (2002) 'Computer-Assisted Cobb Measurement of Scoliosis'. *European Spine Journal* 11 (4), 353–357
- Chou, L., Ranger, T.A., Peiris, W., Cicuttini, F.M., Urquhart, D.M., Sullivan, K., Seneviwickrama, M., Briggs, A.M., and Wluka, A.E. (2018) 'Patients' Perceived Needs of Healthcare Providers for Low Back Pain Management: A Systematic Scoping Review'. *The Spine Journal*
- Chou, R. and Atlas, S. (2016) 'Subacute and Chronic Low Back Pain: Nonsurgical Interventional Treatment'. *UpToDate*
- Choudhry, M.N., Ahmad, Z., and Verma, R. (2016) 'Adolescent Idiopathic Scoliosis'. *The Open Orthopaedics Journal* 10, 143
- Cil, A., Yazici, M., Uzunçugil, A., Kandemir, U., Alanay, A., Alanay, Y., Acaroglu, R.E., and Surat, A. (2005) 'The Evolution of Sagittal Segmental Alignment of the Spine during Childhood'. *Spine* 30 (1), 93–100
- Clare, H.A., Adams, R., and Maher, C.G. (2003) 'Reliability of Detection of Lumbar Lateral Shift'. *Journal of Manipulative & Physiological Therapeutics* 26 (8), 476–480
- Coelho, D.M., Bonagamba, G.H., and Oliveira, A.S. (2013) 'Scoliometer Measurements of Patients with Idiopathic Scoliosis'. *Brazilian Journal of Physical Therapy* 17 (2), 179–184
- Cohen, J. (1988) *Statistical Power Analysis for the Behavioral Sciences*. 2nd. Hillsdale, NJ: erlbaum
- Cohen, J.E., Goel, V., Frank, J.W., Bombardier, C., Peloso, P., and Guillemin, F. (1994) 'Group Education Interventions for People with Low Back Pain. An Overview of the Literature.' *Spine* 19 (11), 1214–1222
- Comerford, M.J. and Mottram, S.L. (2001) 'Movement and Stability Dysfunction--

- Contemporary Developments'. *Manual Therapy* 6 (1), 15–26
- Constand, M.K., MacDermid, J.C., Dal Bello-Haas, V., and Law, M. (2014) 'Scoping Review of Patient-Centered Care Approaches in Healthcare'. *BMC Health Services Research* 14 (1), 271
- Cooper, K., Smith, B.H., and Hancock, E. (2009) 'Patients' Perceptions of Self-Management of Chronic Low Back Pain: Evidence for Enhancing Patient Education and Support'. *Physiotherapy* 95 (1), 43–50
- Coudeyre, E., Rannou, F., Tubach, F., Baron, G., Coriat, F., Brin, S., Revel, M., and Poiraudreau, S. (2006) 'General Practitioners' Fear-Avoidance Beliefs Influence Their Management of Patients with Low Back Pain'. *Pain* 124 (3), 330–337
- Council, N.R. and others (1990) 'Committee on the Biological Effects of Ionizing Radiation'. *Health Effects of Exposure to Low Levels of Ionizing Radiation (BEIR V)*
- Cramer, G.D., Cantu, J.A., Pocius, J.D., Cambron, J.A., and McKinnis, R.A. (2010) 'Reliability of Zygapophysial Joint Space Measurements Made from MRI Scans of Acute Low Back Pain Subjects: Comparison of Two Statistical Methods'. *Journal of Manipulative and Physiological Therapeutics* 33 (3), 220
- Cramer, G.D. and Darby, S.A. (2014) 'Clinical Anatomy of the Spine, Spinal Cord, and ANS. 3'. *St. Louis, Mo: Elsevier* 672
- Creswell, J.W. and Clark, V.L.P. (2017) *Designing and Conducting Mixed Methods Research*. Sage publications
- Creswell, J.W., Klassen, A.C., Plano Clark, V.L., and Smith, K.C. (2011) 'Best Practices for Mixed Methods Research in the Health Sciences'. *Bethesda (Maryland): National Institutes of Health* 2013, 541–545
- Della Croce, U., Cappozzo, A., and Kerrigan, D.C. (1999) 'Pelvis and Lower Limb Anatomical Landmark Calibration Precision and Its Propagation to Bone Geometry and Joint Angles'. *Medical & Biological Engineering & Computing* 37 (2), 155–161

- Croft, P.R., Macfarlane, G.J., Papageorgiou, A.C., Thomas, E., and Silman, A.J. (1998) 'Outcome of Low Back Pain in General Practice: A Prospective Study'. *Bmj* 316 (7141), 1356
- Crombez, G., Vlaeyen, J.W.S., Heuts, P.H.T.G., and Lysens, R. (1999) 'Pain-Related Fear Is More Disabling than Pain Itself: Evidence on the Role of Pain-Related Fear in Chronic Back Pain Disability'. *Pain* 80 (1–2), 329–339
- Cross, M., Smith, E., Hoy, D., Nolte, S., Ackerman, I., Fransen, M., Bridgett, L., Williams, S., Guillemin, F., Hill, C.L., and others (2014) 'The Global Burden of Hip and Knee Osteoarthritis: Estimates from the Global Burden of Disease 2010 Study'. *Annals of the Rheumatic Diseases* annrheumdis--2013
- Cz, Detchev, I., and Habib, A. (2008) 'A Photogrammetric System for 3D Reconstruction of a Scoliotic Torso'. *A Master Thesis. Department of ...* [online] 1 (20274), 126–137. available from <[http://www.ucalgary.ca/engo\\_webdocs/AH/08.20274.YC\(David\)Chang.pdf](http://www.ucalgary.ca/engo_webdocs/AH/08.20274.YC(David)Chang.pdf)>
- Czaprowski, D., Pawłowska, P., Głebicka, A., Sitarski, D., and Kotwicki, T. (2012) 'Intra- and Interobserver Repeatability of the Assessment of Anteroposterior Curvatures of the Spine Using Saunders Digital Inclinator.' *Ortopedia, Traumatologia, Rehabilitacja* 14 (2), 145–153
- Czaprowski, D., Pawłowska, P., Kolwicz-Gańko, A., Sitarski, D., and Kłedra, A. (2017) 'The Influence of the "Straighten Your Back" Command on the Sagittal Spinal Curvatures in Children with Generalized Joint Hypermobility'. *BioMed Research International* 2017
- D'Amico, M., Kinel, E., and Roncoletta, P. (2017) 'Normative 3D Opto-Electronic Stereo-Photogrammetric Posture and Spine Morphology Data in Young Healthy Adult Population'. *PloS One* 12 (6), e0179619
- D'Apuzzo, N. (2007) '3D Body Scanning Technology for Fashion and Apparel Industry'. in *Electronic Imaging 2007*. held 2007. International Society for Optics and



- D'osualdo, F., Schierano, S., and Iannis, M. (1997) 'Validation of Clinical Measurement of Kyphosis with a Simple Instrument, the Arcometer'. *Spine* 22 (4), 408–413
- Danielson, B. and Willén, J. (2001) 'Axially Loaded Magnetic Resonance Image of the Lumbar Spine in Asymptomatic Individuals'. *Spine* 26 (23), 2601–2606
- Danielsson, A.J., Wiklund, I., Pehrsson, K., and Nachemson, A.L. (2001) 'Health-Related Quality of Life in Patients with Adolescent Idiopathic Scoliosis: A Matched Follow-up at Least 20 Years after Treatment with Brace or Surgery'. *European Spine Journal* 10 (4), 278–288
- Davies, R., Everitt, H., and Simon, C. (2006) *Musculoskeletal Problems*. Oxford University Press, USA
- Davis, F. and others (1985) 'Technology Acceptance Model'. in *Proceedings of CSCW'02 Conference*. held 1985. 107–114
- Davis, F.D. (1993) 'User Acceptance of Information Technology: System Characteristics, User Perceptions and Behavioral Impacts'. *International Journal of Man-Machine Studies* 38 (3), 475–487
- Davis, F.D. (1989) 'Perceived Usefulness, Perceived Ease of Use, and User Acceptance of Information Technology'. *MIS Quarterly* 319–340
- Davis, F.D. and Venkatesh, V. (2004) 'Toward Preprototype User Acceptance Testing of New Information Systems: Implications for Software Project Management'. *IEEE Transactions on Engineering Management* 51 (1), 31–46
- Deyo, Richard A; Weinstein, J. (2001) 'Low Back Pain'. *N Engl J Med* 344 (5), 363–370
- Deyo, R.A., Mirza, S.K., and Martin, B.I. (2006) 'Back Pain Prevalence and Visit Rates: Estimates from US National Surveys, 2002'. *Spine* 31 (23), 2724–2727
- Dickson, R.A. (1999) 'Spinal Deformity-Adolescent Idiopathic Scoliosis: Nonoperative

- Treatment'. *Spine* 24 (24), 2601
- Dinev, T., Xu, H., Smith, J.H., and Hart, P. (2013) 'Information Privacy and Correlates: An Empirical Attempt to Bridge and Distinguish Privacy-Related Concepts'. *European Journal of Information Systems* 22 (3), 295–316
- Doody, M.M., Lonstein, J.E., Stovall, M., Hacker, D.G., Luckyanov, N., Land, C.E., and others (2000) 'Breast Cancer Mortality after Diagnostic Radiography: Findings from the US Scoliosis Cohort Study'. *Spine* 25 (16), 2052–2063
- Drake, R., Vogl, A.W., Mitchell, A.W.M., Tibbitts, R., and Richardson, P. (2014) *Gray's Atlas of Anatomy E-Book*. Elsevier Health Sciences
- Drerup, B. and Hierholzer, E. (1996) 'Assessment of Scoliotic Deformity from Back Shape Asymmetry Using an Improved Mathematical Model'. *Clinical Biomechanics* 11 (7), 376–383
- Driscoll, T., Jacklyn, G., Orchard, J., Passmore, E., Vos, T., Freedman, G., Lim, S., and Punnett, L. (2014) 'The Global Burden of Occupationally Related Low Back Pain: Estimates from the Global Burden of Disease 2010 Study'. *Annals of the Rheumatic Diseases* annrheumdis-2013
- Duff, E.S. and Draper, R. (1987) 'Survey of Normal Adolescent Back Shape as Measured by ISIS'. Stokes, IF, Pekelsky, Moreland, MS (Eds.). *Surface Topography and Spinal Deformity IV, Gustav-Fisher, Stuttgart, New York* 163–169
- Duncan, E.A.S. and Nicol, M.M. (2004) 'Subtle Realism and Occupational Therapy: An Alternative Approach to Knowledge Generation and Evaluation'. *British Journal of Occupational Therapy* 67 (10), 453–456
- Dunk, N.M., Chung, Y.Y., Compton, D.S., and Callaghan, J.P. (2004) 'The Reliability of Quantifying Upright Standing Postures as a Baseline Diagnostic Clinical Tool'. *Journal of Manipulative and Physiological Therapeutics* 27 (2), 91–96
- Dunk, N.M., Lalonde, J., and Callaghan, J.P. (2005) 'Implications for the Use of Postural

- Analysis as a Clinical Diagnostic Tool: Reliability of Quantifying Upright Standing Spinal Postures from Photographic Images'. *Journal of Manipulative and Physiological Therapeutics* 28 (6), 386–392
- Dunleavy, K., Mariano, H., Wiater, T., and Goldberg, A. (2010) 'Reliability and Minimal Detectable Change of Spinal Length and Width Measurements Using the Flexicurve for Usual Standing Posture in Healthy Young Adults 1'. *Journal of Back and Musculoskeletal Rehabilitation* 23 (4), 209–214
- Dunn, K.M. and Croft, P.R. (2006) 'The Importance of Symptom Duration in Determining Prognosis'. *Pain* 121 (1–2), 126–132
- Dutkowsky, J.P., Shearer, D., Schepps, B., Orton, C., Scola, F., Richards, B.S., and Vitale, M.G. (1990) 'Radiation Exposure to Patients Receiving Routine Scoliosis Radiography Measured at Depth in an Anthropomorphic Phantom.' *J Bone Joint Surg Am* 10 (1), 195–198
- Edwards-Jones, A. (2014) 'Qualitative Data Analysis with NVIVO'. *Journal of Education for Teaching* [online] 40 (2), 193–195. available from <<http://www.tandfonline.com/doi/abs/10.1080/02607476.2013.866724>> [26 May 2017]
- Egoscue, P. and Gittines, R. (2014) *Pain Free: A Revolutionary Method for Stopping Chronic Pain*. Bantam
- Ehara, Y., Fujimoto, H., Miyazaki, S., Mochimaru, M., Tanaka, S., and Yamamoto, S. (1997) 'Comparison of the Performance of 3D Camera Systems II'. *Gait & Posture* 5 (3), 251–255
- Elabd, A., Ibrahim, A., and Elhafez, H. (2017) 'Kinesio Taping versus Postural Correction Exercises on Mechanically Triggered Neck Dysfunction'. *International Journal of Therapy And Rehabilitation* 24 (4), 155–162
- Erkan, S., Yercan, H.S., Okcu, G., and Ozalp, R.T. (2010) 'The Influence of Sagittal

Cervical Profile, Gender and Age on the Thoracic Kyphosis.’ *Acta Orthopaedica Belgica* 76 (5), 675

- Esmailzadeh, P., Sambasivan, M., and Kumar, N. (2010) ‘The Effect of the Healthcare professional—Hospital Relationship on Accepting New Clinical IT: A Modified Technology Acceptance Model from a Relational Perspective’. in *Education and Management Technology (ICEMT), 2010 International Conference on*. held 2010. 210–217
- Eysenbach, G. and Köhler, C. (2002) *How Do Consumers Search for and Appraise Health Information on the World Wide Web ? Qualitative Study Using Focus Groups , Usability Tests , and in-Depth Interviews*. 324 (March), 573–577
- Fa, T. and others (2007) ‘Confiabilidade E Validade Das Medidas Da Cifose Torácica Através Do Método Flexicurva’. *Rev. Bras. Fisioter., São Carlos* 11 (3), 199–204
- Fairbank, J., Frost, H., Wilson-MacDonald, J., Yu, L.-M., Barker, K., and Collins, R. (2005) ‘Randomised Controlled Trial to Compare Surgical Stabilisation of the Lumbar Spine with an Intensive Rehabilitation Programme for Patients with Chronic Low Back Pain: The MRC Spine Stabilisation Trial’. *Bmj* 330 (7502), 1233
- Fällström, K., Cochran, T., and Nachemson, A. (1986) ‘Long-Term Effects on Personality Development in Patients with Adolescent Idiopathic Scoliosis. Influence of Type of Treatment.’ *Spine* 11 (7), 756–758
- Fathi, A. and Curran, K. (2017) ‘Detection of Spine Curvature Using Wireless Sensors’. *Journal of King Saud University-Science* 29 (4), 553–560
- Faul, F., Erdfelder, E., Lang, A.-G., and Buchner, A. (2007) ‘G\* Power 3: A Flexible Statistical Power Analysis Program for the Social, Behavioral, and Biomedical Sciences’. *Behavior Research Methods* 39 (2), 175–191
- Fayaz, A., Croft, P., Langford, R.M., Donaldson, L.J., and Jones, G.T. (2016) ‘Prevalence of Chronic Pain in the UK: A Systematic Review and Meta-Analysis of Population

- Studies'. *BMJ Open* 6 (6), e010364
- Fedorak, C., Ashworth, N., Marshall, J., and Paull, H. (2003) 'Reliability of the Visual Assessment of Cervical and Lumbar Lordosis: How Good Are We?' *Spine* 28 (16), 1857–1859
- El Fegoun, A.B., Schwab, F., Gamez, L., Champain, N., Skalli, W., and Farcy, J.-P. (2005) 'Center of Gravity and Radiographic Posture Analysis: A Preliminary Review of Adult Volunteers and Adult Patients Affected by Scoliosis'. *Spine* 30 (13), 1535–1540
- Ferraz, M.B., Quaresma, M.R., Aquino, L.R., Atra, E., Tugwell, P., and Goldsmith, C.H. (1990) 'Reliability of Pain Scales in the Assessment of Literate and Illiterate Patients with Rheumatoid Arthritis.' *The Journal of Rheumatology* 17 (8), 1022–1024
- Ferreira, E.A., Duarte, M., Maldonado, E.P., Bersanetti, A.A., and Marques, A.P. (2011) 'Quantitative Assessment of Postural Alignment in Young Adults Based on Photographs of Anterior, Posterior, and Lateral Views'. *Journal of Manipulative & Physiological Therapeutics* 34 (6), 371–380
- Ferreira, E.A.G., Duarte, M., Maldonado, E.P., Burke, T.N., and Marques, A.P. (2010) 'Postural Assessment Software (PAS/SAPO): Validation and Reliability'. *Clinics* 65 (7), 675–681
- Fisher, K. and Johnston, M. (1997) 'Validation of the Oswestry Low Back Pain Disability Questionnaire, Its Sensitivity as a Measure of Change Following Treatment and Its Relationship with Other Aspects of the Chronic Pain Experience'. *Physiotherapy Theory and Practice* 13 (1), 67–80
- Fon, Gerald T;Pitt, Michael J;Thies, C.J. (1980) 'Thoracic Kyphosis: Range in Normal Subjects'. *AJR Am J Roentgenol* 134, 979–983
- Fong, D.Y.T., Lee, C.F., Cheung, K.M.C., Cheng, J.C.Y., Ng, B.K.W., Lam, T.P., Mak, K.H., Yip, P.S.F., and Luk, K.D.K. (2010) 'A Meta-Analysis of the Clinical Effectiveness of School Scoliosis Screening'. *Spine* 35 (10), 1061–1071

- Fornell, C. and Larcker, D.F. (1981) 'Structural Equation Models with Unobservable Variables and Measurement Error: Algebra and Statistics'. *Journal of Marketing Research* 382–388
- Fortin, C., Feldman, D.E., Cheriet, F., Gravel, D., Gauthier, F., and Labelle, H. (2012) 'Reliability of a Quantitative Clinical Posture Assessment Tool among Persons with Idiopathic Scoliosis.' *Physiotherapy* [online] 98 (1), 64–75. available from <<http://www.ncbi.nlm.nih.gov/pubmed/22265387>> [16 March 2012]
- Fortin, C., Feldman, D.E., Cheriet, F., and Labelle, H. (2011) 'Clinical Methods for Quantifying Body Segment Posture: A Literature Review.' *Disability and Rehabilitation* [online] 33 (5), 367–83. available from <<http://www.ncbi.nlm.nih.gov/pubmed/20568973>>
- Fortin, C., Feldman, D.E., Cheriet, F., and Labelle, H. (2010) 'Validity of a Quantitative Clinical Measurement Tool of Trunk Posture in Idiopathic Scoliosis'. *Spine* 35 (19), E988--E994
- Fourchet, F., Materne, O., Rajeb, A., Horobeanu, C., and Farooq, A. (2014) 'Pelvic Tilt: Reliability of Measuring the Standing Position and Range of Motion in Adolescent Athletes'. *Br J Sports Med* 48 (7), 594
- Fraser, J., Olds, T., and others (2008) *Revising Sizing: Modifying Clothing Templates to Match the 3D Shape of Real Women*. Routledge
- Freburger, J.K. and Riddle, D.L. (1999) 'Measurement of Sacroiliac Joint Dysfunction: A Multicenter Intertester Reliability Study'. *Physical Therapy* 79 (12), 1134–1141
- Free, C., Phillips, G., Galli, L., Watson, L., Felix, L., Edwards, P., Patel, V., and Haines, A. (2013) 'The Effectiveness of Mobile-Health Technology-Based Health Behaviour Change or Disease Management Interventions for Health Care Consumers: A Systematic Review'. *PLoS Medicine* 10 (1), e1001362
- Frerich, J.M., Hertzler, K., Knott, P., and Mardjetko, S. (2012) 'Comparison of

Radiographic and Surface Topography Measurements in Adolescents with Idiopathic Scoliosis.' *The Open Orthopaedics Journal* [online] 6, 261–5. available from

<<http://www.pubmedcentral.nih.gov/articlerender.fcgi?artid=3414720&tool=pmcentrez&rendertype=abstract>>

Fritz, J.M. and George, S.Z. (2002) 'Identifying Psychosocial Variables in Patients with Acute Work-Related Low Back Pain: The Importance of Fear-Avoidance Beliefs'. *Physical Therapy* 82 (10), 973–983

Fritz, J.M., George, S.Z., and Delitto, A. (2001) 'The Role of Fear-Avoidance Beliefs in Acute Low Back Pain: Relationships with Current and Future Disability and Work Status'. *Pain* 94 (1), 7–15

Frobin, W. and Hierholzer, E. (1991) 'Video Rasterstereography: A Method for on-Line Measurement of Body Surfaces'. *Photogrammetric Engineering and Remote Sensing* 57 (10), 1341–1345

Furian, T.C., Rapp, W., Eckert, S., Wild, M., and Betsch, M. (2013) 'Spinal Posture and Pelvic Position in Three Hundred Forty-Five Elementary School Children: A Rasterstereographic Pilot Study'. *Orthopedic Reviews* 5 (1)

Furlan, A.D., Pennick, V., Bombardier, C., van Tulder, M., and others (2009) '2009 Updated Method Guidelines for Systematic Reviews in the Cochrane Back Review Group'. *Spine* 34 (18), 1929–1941

Furlanetto, T.S., Candotti, C.T., Comerlato, T., and Loss, J.F. (2012) 'Validating a Postural Evaluation Method Developed Using a Digital Image-Based Postural Assessment (DIPA) Software'. *Computer Methods and Programs in Biomedicine* 108 (1), 203–212

Furlanetto, T.S., Sedrez, J.A., Candotti, C.T., and Loss, J.F. (2016) 'Photogrammetry as a Tool for the Postural Evaluation of the Spine: A Systematic Review'. *World Journal of Orthopedics* [online] 7 (2), 136. available from <<http://www.wjgnet.com/2218->

- Gadd, C.S. and Penrod, L.E. (2000) 'Dichotomy between Physicians' and Patients' Attitudes Regarding EMR Use during Outpatient Encounters.' in *Proceedings of the AMIA Symposium*. held 2000. 275
- Gagnon, M.-P., Ngangue, P., Payne-Gagnon, J., and Desmartis, M. (2015) 'M-Health Adoption by Healthcare Professionals: A Systematic Review'. *Journal of the American Medical Informatics Association* 23 (1), 212–220
- Gagnon, M.P., Ngangue, P., Payne-Gagnon, J., and Desmartis, M. (2016) 'M-Health Adoption by Healthcare Professionals: A Systematic Review'. *Journal of the American Medical Informatics Association* 23 (1), 212–220
- Gajdosik, R., Simpson, R., Smith, R., and DonTigny, R.L. (1985) 'Pelvic Tilt: Intratester Reliability of Measuring the Standing Position and Range of Motion'. *Physical Therapy* 65 (2), 169–174
- Gall, M.D., Gall, J.P., and Borg, W.R. (2010) *Applying Educational Research: How to Read, Do, and Use Research to Solve Problems of Practice*. Pearson Boston/Hong Kong
- Gallagher, K.M., Campbell, T., and Callaghan, J.P. (2014) 'The Influence of a Seated Break on Prolonged Standing Induced Low Back Pain Development'. *Ergonomics* 57 (4), 555–562
- Gallagher, R.M. (2006) 'Management of Neuropathic Pain: Translating Mechanistic Advances and Evidence-Based Research into Clinical Practice'. *The Clinical Journal of Pain* 22 (1), S2–S8
- Galna, B., Barry, G., Jackson, D., Mhiripiri, D., Olivier, P., and Rochester, L. (2014) 'Accuracy of the Microsoft Kinect Sensor for Measuring Movement in People with Parkinson's Disease'. *Gait & Posture* 39 (4), 1062–1068
- Gammon, D., Årsand, E., Walseth, O.A., Andersson, N., Jenssen, M., and Taylor, T.



- (2005) 'Parent-Child Interaction Using a Mobile and Wireless System for Blood Glucose Monitoring'. *Journal of Medical Internet Research* 7 (5)
- Ganesan, S., Acharya, A.S., Chauhan, R., and Acharya, S. (2017) 'Prevalence and Risk Factors for Low Back Pain in 1,355 Young Adults: A Cross-Sectional Study'. *Asian Spine Journal* 11 (4), 610–617
- Gangnet, N., Dumas, R., Pomero, V., Mitulescu, A., Skalli, W., and Vital, J.-M. (2006) 'Three-Dimensional Spinal and Pelvic Alignment in an Asymptomatic Population'. *Spine* 31 (15), E507--E512
- Gangnet, N., Pomero, V., Dumas, R., Skalli, W., and Vital, J.-M. (2003) 'Variability of the Spine and Pelvis Location with Respect to the Gravity Line: A Three-Dimensional Stereoradiographic Study Using a Force Platform'. *Surgical and Radiologic Anatomy* 25 (5–6), 424–433
- Geng, J. (2011) 'Structured-Light 3D Surface Imaging: A Tutorial'. *Advances in Optics and Photonics* 3, 128–160
- Getty, M., Ryan, A.A., BA, E., and MATTHEW, L.C. (1999) 'A Comparative Study of the Attitudes of Users and Non-Users towards Computerized Care Planning'. *Journal of Clinical Nursing* 8 (4), 431–439
- Giavarina, D. (2015) 'Understanding Bland Altman Analysis'. *Biochemia Medica: Biochemia Medica* 25 (2), 141–151
- Giglio, C.A. and Volpon, J.B. (2007) 'Development and Evaluation of Thoracic Kyphosis and Lumbar Lordosis during Growth'. *Journal of Children's Orthopaedics* 1 (3), 187
- Glassman, S.D., Bridwell, K., Dimar, J.R., Horton, W., Berven, S., and Schwab, F. (2005) 'The Impact of Positive Sagittal Balance in Adult Spinal Deformity.' *Spine* 30 (18), 2024–2029
- Glinkowski, W., Michoński, J., Żukowska, A., Glinkowska, B., Sitnik, R., and Górecki, A. (2014) 'The Time Effectiveness of Three-Dimensional Telediagnostic Postural

- Screening of Back Curvatures and Scoliosis'. *TELEMEDICINE and E-HEALTH* 20 (1), 11–17
- Godfrey, A., Conway, R., Meagher, D., and ÓLaighin, G. (2008) 'Direct Measurement of Human Movement by Accelerometry'. *Medical Engineering and Physics* 30 (10), 1364–1386
- Godwin, A., Agnew, M., and Stevenson, J. (2009) 'Accuracy of Inertial Motion Sensors in Static, Quasistatic, and Complex Dynamic Motion'. *Journal of Biomechanical Engineering* 131 (11), 114501
- Goldberg, C.J., Kaliszer, M., Moore, D.P., Fogarty, E.E., and Dowling, F.E. (2001) 'Surface Topography, Cobb Angles, and Cosmetic Change in Scoliosis'. *Spine* 26 (4), E55–E63
- Good, C.R., Auerbach, J.D., O'Leary, P.T., and Schuler, T.C. (2011) 'Adult Spine Deformity'. *Current Reviews in Musculoskeletal Medicine* 4 (4), 159
- Good, T.L. and Lavigne, A.L. (2017) *Looking in Classrooms*. Routledge
- Gorton III, G.E., Young, M.L., and Masso, P.D. (2012) 'Accuracy, Reliability, and Validity of a 3-Dimensional Scanner for Assessing Torso Shape in Idiopathic Scoliosis'. *Spine* 37 (11), 957–965
- Gracovetsky, S., Newman, N., Pawlowsky, M., Lanzo, V., Davey, B., and Robinson, L. (1995) 'A Database for Estimating Normal Spinal Motion Derived from Noninvasive Measurements.' *Spine* 20 (9), 1036–1046
- Greendale, G.A., Nili, N.S., Huang, M.-H., Seeger, L., and Karlamangla, A.S. (2011) 'The Reliability and Validity of Three Non-Radiological Measures of Thoracic Kyphosis and Their Relations to the Standing Radiological Cobb Angle'. *Osteoporosis International* 22 (6), 1897–1905
- Greenfield, B., Catlin, P.A., Coats, P.W., Green, E., McDonald, J.J., and North, C. (1995) 'Posture in Patients with Shoulder Overuse Injuries and Healthy Individuals'. *Journal*

- Grivas, T.B., Burwell, R.G., Mihas, C., Vasiliadis, E.S., Triantafyllopoulos, G., and Kaspiris, A. (2009) 'Relatively Lower Body Mass Index Is Associated with an Excess of Severe Truncal Asymmetry in Healthy Adolescents: Do White Adipose Tissue, Leptin, Hypothalamus and Sympathetic Nervous System Influence Truncal Growth Asymmetry?' *Scoliosis* 4 (1), 13
- Grivas, T.B., Karras, G.E., Katrabasas, J., and Papavasiliou, N. (1997) 'Study of Posterior Trunk Surface Changes by Age and Sex Using Moiré Topography'. *STUDIES IN HEALTH TECHNOLOGY AND INFORMATICS* 331–334
- Grivas, T.B., Vasiliadis, E.S., Maziotou, C., and Savvidou, O.D. (2007) 'The Direct Cost of "Thriasio" school Screening Program'. *Scoliosis* 2 (1), 7
- Grivon, D., Vezzetti, E., and Violante, M. (2014) 'Study and Development of a Low cost "optInertial" 3D Scanner'. *Precision Engineering* [online] 38 (2), 261–269. available from <<http://dx.doi.org/10.1016/j.precisioneng.2013.09.007>>
- Grob, D., Frauenfelder, H., and Mannion, A.F. (2007) 'The Association between Cervical Spine Curvature and Neck Pain'. *European Spine Journal* 16 (5), 669–678
- Groen, B.E., Geurts, M., Nienhuis, B., and Duysens, J. (2012) 'Sensitivity of the OLGA and VCM Models to Erroneous Marker Placement: Effects on 3D-Gait Kinematics'. *Gait & Posture* 35 (3), 517–521
- Grönblad, M., Hupli, M., Wennerstrand, P., Järvinen, E., Lukinmaa, A., Kouri, J.-P., and Karaharju, E.O. (1993) 'Intercorrelation and Test-Retest Reliability of the Pain Disability Index (PDI) and the Oswestry Disability Questionnaire (ODQ) and Their Correlation with Pain Intensity in Low Back Pain Patients.' *The Clinical Journal of Pain* 9 (3), 189–195
- Grotle, M., Vøllestad, N.K., Veierød, M.B., and Brox, J.I. (2004) 'Fear-Avoidance Beliefs and Distress in Relation to Disability in Acute and Chronic Low Back Pain'. *Pain* 112

(3), 343–352

- Grunstein, E., Fortin, C., Parent, S., Houde, M., Labelle, H., and Ehrmann-Feldman, D. (2013) 'Reliability and Validity of the Clinical Measurement of Trunk List in Children and Adolescents with Idiopathic Scoliosis'. *Spine Deformity* 1 (6), 419–424
- Guest, G., Namey, E.E., and Mitchell, M.L. (2012) *Collecting Qualitative Data: A Field Manual for Applied Research*. Sage
- Günther, M., Keppler, V., Seyfarth, A., and Blickhan, R. (2004) 'Human Leg Design: Optimal Axial Alignment under Constraints'. *Journal of Mathematical Biology* 48 (6), 623–646
- Hadji, B. and Degoulet, P. (2016) 'Information System End-User Satisfaction and Continuance Intention: A Unified Modeling Approach'. *Journal of Biomedical Informatics* 61, 185–193
- Hagins, M., Brown, M., Cook, C., Gstalder, K., Kam, M., Kominer, G., and Strimbeck, K. (1998) 'Intratester and Intertester Reliability of the Palpation Meter (PALM) in Measuring Pelvic Position'. *Journal of Manual & Manipulative Therapy* 6 (3), 130–136
- Hair, J.F., Black, W.C., Babin, B.J., and Anderson, R.E. (2010) *Applications of SEM. Multivariate Data Analysis*. Pearson, Upper Saddle River
- Hair Jr, J.F., Hult, G.T.M., Ringle, C., and Sarstedt, M. (2016) *A Primer on Partial Least Squares Structural Equation Modeling (PLS-SEM)*. Sage Publications
- Hancock, M.J., Maher, C.G., Latimer, J., McLachlan, A.J., Cooper, C.W., Day, R.O., Spindler, M.F., and McAuley, J.H. (2007) 'Assessment of Diclofenac or Spinal Manipulative Therapy, or Both, in Addition to Recommended First-Line Treatment for Acute Low Back Pain: A Randomised Controlled Trial'. *The Lancet* 370 (9599), 1638–1643
- Haneline, M.T. and Young, M. (2009) 'A Review of Intraexaminer and Interexaminer

- Reliability of Static Spinal Palpation: A Literature Synthesis'. *Journal of Manipulative & Physiological Therapeutics* 32 (5), 379–386
- Hanif, M., Niaz, H., and Khan, M.A. (2011) 'Investigating the Possible Role and Usefulness of Video Capture Virtual Reality in Motor Impairment Rehabilitation'. in *Next Generation Information Technology (ICNIT), 2011 The 2nd International Conference on*. held 2011. 23–30
- Hanson, W.E., Creswell, J.W., Clark, V.L.P., Petska, K.S., and Creswell, J.D. (2005) 'Mixed Methods Research Designs in Counseling Psychology.' *Journal of Counseling Psychology* 52 (2), 224
- Harrison, D.D., Janik, T.J., Troyanovich, S.J., and Holland, B. (1996) 'Comparisons of Lordotic Cervical Spine Curvatures to a Theoretical Ideal Model of the Static Sagittal Cervical Spine'. *Spine* 21 (6), 667–675
- Harrison, D.E., Harrison, D.D., Cailliet, R., Troyanovich, S.J., Janik, T.J., and Holland, B. (2000) 'Cobb Method or Harrison Posterior Tangent Method: Which to Choose for Lateral Cervical Radiographic Analysis'. *Spine* 25 (16), 2072–2078
- Hart, D.L. and Rose, S.J. (1986) 'Reliability of a Noninvasive Method for Measuring the Lumbar Curve'. *Journal of Orthopaedic & Sports Physical Therapy* 8 (4), 180–184
- Hawes, M.C. (2003) 'The Use of Exercises in the Treatment of Scoliosis: An Evidence-Based Critical Review of the Literature'. *Pediatric Rehabilitation* 6 (3–4), 171–182
- Hawker, G.A., Mian, S., Kendzerska, T., and French, M. (2011) 'Measures of Adult Pain: Visual Analog Scale for Pain (Vas Pain), Numeric Rating Scale for Pain (Nrs Pain), McGill Pain Questionnaire (Mpq), Short-Form McGill Pain Questionnaire (Sf-Mpq), Chronic Pain Grade Scale (Cpgs), Short Form-36 Bodily Pain Scale (Sf'. *Arthritis Care & Research* 63 (S11)
- Hazard, R.G., Reid, S., Haugh, L.D., and McFarlane, G. (2000) 'A Controlled Trial of an Educational Pamphlet to Prevent Disability after Occupational Low Back Injury'.

- Hecimovich, M.D. and Stomski, N.J. (2016) 'Lumbar Sagittal Plane Spinal Curvature and Junior-Level Cricket Players'. *International Journal of Athletic Therapy and Training* 21 (2), 47–52
- Heijmans, W., Hendriks, H.J.M., Esch, M. van der, Pool-Goudzwaard, A., Scholten-Peeters, G.G.M., Van Tulder, M.W., Wijer, A., and Oostendorp, R.A.B. (2003) *KNGF-Richtlijn Manuele Therapie Bij Lage-Rugpijn*.
- Henbest, R.J. and Stewart, M. (1990) 'Patient-Centredness in the Consultation. 2: Does It Really Make a Difference?' *Family Practice* 7 (1), 28–33
- Henrotin, Y.E., Cedraschi, C., Duplan, B., Bazin, T., and Duquesnoy, B. (2006) 'Information and Low Back Pain Management: A Systematic Review'. *Spine* 31 (11), E326--E334
- Herakleous, K. and Poullis, C. (2014) *3DUNDERWORLD-SLS: An Open-Source Structured-Light Scanning System for Rapid Geometry Acquisition*.
- Hess, T.J., McNab, A.L., and Basoglu, K.A. (2014) 'Reliability Generalization of Perceived Ease of Use, Perceived Usefulness, and Behavioral Intentions.' *Mis Quarterly* 38 (1)
- Hey, H.W.D., Lau, E.T.-C., Wong, G.C., Tan, K.-A., Liu, G.K.-P., and Wong, H.-K. (2017) 'Cervical Alignment Variations in Different Postures and Predictors of Normal Cervical Kyphosis: A New Understanding'. *Spine* 42 (21), 1614–1621
- Hibbard, J.H. and Greene, J. (2013) 'What the Evidence Shows about Patient Activation: Better Health Outcomes and Care Experiences; Fewer Data on Costs'. *Health Affairs* 32 (2), 207–214
- Hickey, E.R., Rondeau, M.J., Corrente, J.R., Abysalh, J., and Seymour, C.J. (2000) 'Reliability of the Cervical Range of Motion (CROM) Device and Plumb-Line Techniques in Measuring Resting Head Posture (RHP)'. *Journal of Manual &*

- Hill, J.C., Whitehurst, D.G.T., Lewis, M., Bryan, S., Dunn, K.M., Foster, N.E., Konstantinou, K., Main, C.J., Mason, E., Somerville, S., and others (2011) 'Comparison of Stratified Primary Care Management for Low Back Pain with Current Best Practice (STarT Back): A Randomised Controlled Trial'. *The Lancet* 378 (9802), 1560–1571
- Hinman, M.R. (2004) 'Interrater Reliability of Flexicurve Postural Measures among Novice Users'. *Journal of Back and Musculoskeletal Rehabilitation* 17 (1), 33–36
- Hoffman, B.M., Papas, R.K., Chatkoff, D.K., and Kerns, R.D. (2007) 'Meta-Analysis of Psychological Interventions for Chronic Low Back Pain.' *Health Psychology* 26 (1), 1
- Hogeweg, J.A., Langereis, M.J., Bernards, A.T.M., Faber, J.A.J., and Helders, P.J.M. (1994) 'Goniometry-Variability in the Clinical Practice of a Conventional Goniometer in Healthy Subjects'. *European Journal of Physical Medicine & Rehabilitation* 4 (1), 2–7
- Holden, R.J., Brown, R.L., Scanlon, M.C., and Karsh, B.-T. (2012) 'Modeling Nurses' Acceptance of Bar Coded Medication Administration Technology at a Pediatric Hospital'. *Journal of the American Medical Informatics Association* 19 (6), 1050–1058
- Holm, I., Friis, A., Storheim, K., and Brox, J.I. (2003) 'Measuring Self-Reported Functional Status and Pain in Patients with Chronic Low Back Pain by Postal Questionnaires: A Reliability Study'. *Spine* 28 (8), 828–833
- Hong, T.-H., Cho, K.-J., Kim, Y.-T., Park, J.-W., Seo, B.-H., and Kim, N.-C. (2017) 'Does Lordotic Angle of Cage Determine Lumbar Lordosis in Lumbar Interbody Fusion?' *Spine* 42 (13), E775--E780
- Houweling, T., Bolton, J., and Newell, D. (2014) 'Comparison of Two Methods of

- Collecting Healthcare Usage Data in Chiropractic Clinics: Patient-Report versus Documentation in Patient Files'. *Chiropractic & Manual Therapies* 22 (1), 32
- Howorth, B. (1946) 'Dynamic Posture'. *Journal of the American Medical Association* 131 (17), 1398–1404
- Hoy, D., Brooks, P., Blyth, F., and Buchbinder, R. (2010) 'The Epidemiology of Low Back Pain'. *Best Practice & Research Clinical Rheumatology* 24 (6), 769–781
- Hoy, D., March, L., Brooks, P., Blyth, F., Woolf, A., Bain, C., Williams, G., Smith, E., Vos, T., Barendregt, J., Murray, C., Burstein, R., and Buchbinder, R. (2014) 'The Global Burden of Low Back Pain: Estimates from the Global Burden of Disease 2010 Study'. *Annals of the Rheumatic Diseases* 73 (6), 968–974
- Hsieh, P.-J. (2015) 'Healthcare Professionals' Use of Health Clouds: Integrating Technology Acceptance and Status Quo Bias Perspectives'. *International Journal of Medical Informatics* 84 (7), 512–523
- Le Huec, J.C., Aunoble, S., Philippe, L., and Nicolas, P. (2011) 'Pelvic Parameters: Origin and Significance'. *European Spine Journal* 20 (5), 564
- Hughes (2017) *Tear down of Structure Sensor™* [online] available from <<https://www.allaboutcircuits.com/news/teardown-tuesday-occipital-3d-structure-sensor/>> [28 January 2018]
- Icn, S., S, A., Bwc, Q., D, P., I, K., Aa, K., Ae, S., Ra, M., and Mt, S. (2007) 'Reliability of Photogrammetry in Relation to Goniometry for Postural Lower Limb Assessment'. *Revista Brasileira de Fisioterapia (São Carlos (São Paulo, Brazil))* 11 (5), 411–417
- Igbaria, M., Zinatelli, N., Cragg, P., and Cavaye, A.L.M. (1997) 'Personal Computing Acceptance Factors in Small Firms: A Structural Equation Model'. *MIS Quarterly* 279–305
- Indahl, A., Velund, L., Reikeraas, O., and others (1995) 'Good Prognosis for Low Back Pain When Left Untampered: A Randomized Clinical Trial'. *SPINE-PHILADELPHIA-*



- Indrakanti, S.S., Weber, M.H., Takemoto, S.K., Hu, S.S., Polly, D., and Berven, S.H. (2012) 'Value-Based Care in the Management of Spinal Disorders: A Systematic Review of Cost-Utility Analysis'. *Clinical Orthopaedics and Related Research*{@} 470 (4), 1106–1123
- Irvine, A.B., Russell, H., Manocchia, M., Mino, D.E., Glassen, T.C., Morgan, R., Gau, J.M., Birney, A.J., and Ary, D. V. (2015) 'Mobile-Web App to Self-Manage Low Back Pain: Randomized Controlled Trial'. *Journal of Medical Internet Research* 17 (1), e1
- Islam, A., Mäntymäki, M., and Bhattacharjee, A. (2017) 'Towards a Decomposed Expectation Confirmation Model of IT Continuance: The Role of Usability'. *Communications of the AIS*
- Iunes, D.H., Bevilaqua-Grossi, D., Oliveira, A.S., Castro, F.A., and Salgado, H.S. (2009) 'Comparative Analysis between Visual and Computerized Photogrammetry Postural Assessment'. *Brazilian Journal of Physical Therapy* 13 (4), 308–315
- Jackson, R.P. and McManus, A.C. (1994) 'Radiographic Analysis of Sagittal Plane Alignment and Balance in Standing Volunteers and Patients with Low Back Pain Matched for Age, Sex, and Size. A Prospective Controlled Clinical Study.' *Spine* 19 (14), 1611–1618
- Jellema, P., van der Windt, D.A.W.M., van der Horst, H.E., Stalman, W.A.B., and Bouter, L.M. (2007) 'Prediction of an Unfavourable Course of Low Back Pain in General Practice: Comparison of Four Instruments'. *Br J Gen Pract* 57 (534), 15–22
- Johnson, K.B. (2001) 'Barriers That Impede the Adoption of Pediatric Information Technology'. *Archives of Pediatrics & Adolescent Medicine* 155 (12), 1374–1379
- Joo, Y.J., Lee, H.W., and Ham, Y. (2014) 'Integrating User Interface and Personal Innovativeness into the TAM for Mobile Learning in Cyber University'. *Journal of Computing in Higher Education* 26 (2), 143–158

- Joseph, R. and Brown, P. (2017) 'The Cloud Gets Personal: Perspectives on Cloud Computing for Personalized Medicine'. *International Journal of E-Health and Medical Communications (IJEHMC)* 8 (2), 1–17
- Kabra, G., Ramesh, A., Akhtar, P., and Dash, M.K. (2017) 'Understanding Behavioural Intention to Use Information Technology: Insights from Humanitarian Practitioners'. *Telematics and Informatics* 34 (7), 1250–1261
- Kado, D.M., Lui, L.-Y., Ensrud, K.E., Fink, H.A., Karlamangla, A.S., and Cummings, S.R. (2009) 'Hyperkyphosis Predicts Mortality Independent of Vertebral Osteoporosis in Older Women'. *Annals of Internal Medicine* 150 (10), 681–687
- Karatas, O.H. and Toy, E. (2014) 'Three-Dimensional Imaging Techniques: A Literature Review'. *European Journal of Dentistry* 8 (1), 132–140
- Karjalainen, K., Malmivaara, A., Pohjolainen, T., Hurri, H., Mutanen, P., Rissanen, P., Pakkajärvi, H., Levon, H., Karpoff, H., and Roine, R. (2003) 'Mini-Intervention for Subacute Low Back Pain: A Randomized Controlled Trial'. *Spine* 28 (6), 533–540
- Katzman, W.B., Sellmeyer, D.E., Stewart, A.L., Wanek, L., and Hamel, K.A. (2007) 'Changes in Flexed Posture, Musculoskeletal Impairments, and Physical Performance after Group Exercise in Community-Dwelling Older Women'. *Archives of Physical Medicine and Rehabilitation* 88 (2), 192–199
- KAYA, D.Ö. and ÇELENAY, \cSEYDA TOPRAK (2017) 'An Investigation of Sagittal Thoracic Spinal Curvature and Mobility in Subjects with and without Chronic Neck Pain: Cut-off Points and Pain Relationship'. *Turkish Journal of Medical Sciences* 47 (3), 891–896
- Kendall, F.P., McCreary, E.K., Provance, P.G., Rodgers, M.M., and Romani, W.A. (2005) *Muscles: Testing and Function, with Posture and Pain (Kendall, Muscles)*. Philadelphia: Lippincott Williams & Wilkins
- Kent, P., Laird, R., and Haines, T. (2015) 'The Effect of Changing Movement and Posture

- Using Motion-Sensor Biofeedback, versus Guidelines-Based Care, on the Clinical Outcomes of People with Sub-Acute or Chronic Low Back Pain-a Multicentre, Cluster-Randomised, Placebo-Controlled, Pilot Trial'. *BMC Musculoskeletal Disorders* 16 (1), 131
- Kent, P.M. and Keating, J.L. (2005) 'The Epidemiology of Low Back Pain in Primary Care'. *Chiropractic & Osteopathy* 13 (1), 13
- Kibler, W. Ben, Press, J., and Sciascia, A. (2006) 'The Role of Core Stability in Athletic Function'. *Sports Medicine* 36 (3), 189–198
- Kilinc, F., Yaman, H., and Atay, E. (2009) 'Investigation of the Effects of Intensive One-Sided and Double-Sided Training Drills on the Postures of Basketball Playing Children'. *Journal of Physical Therapy Science* 21 (1), 23–28
- Kim, D. and Chang, H. (2007) 'Key Functional Characteristics in Designing and Operating Health Information Websites for User Satisfaction: An Application of the Extended Technology Acceptance Model'. *International Journal of Medical Informatics* 76 (11–12), 790–800
- Kim, H.-W. and Kankanhalli, A. (2009) 'Investigating User Resistance to Information Systems Implementation: A Status Quo Bias Perspective'. *MIS Quarterly* 567–582
- Kim, J. and Park, H.-A. (2012) 'Development of a Health Information Technology Acceptance Model Using Consumers' Health Behavior Intention'. *Journal of Medical Internet Research* 14 (5)
- Kim, S.S. and Malhotra, N.K. (2005) 'A Longitudinal Model of Continued IS Use: An Integrative View of Four Mechanisms Underlying Postadoption Phenomena'. *Management Science* 51 (5), 741–755
- Kimberlin, C.L. and Winterstein, A.G. (2008) 'Validity and Reliability of Measurement Instruments Used in Research'. *American Journal of Health-System Pharmacy* 65 (23), 2276–2284

- King, W.R. and He, J. (2006) 'A Meta-Analysis of the Technology Acceptance Model'. *Information & Management* 43 (6), 740–755
- Kinnersley, P., Stott, N., Peters, T.J., and Harvey, I. (1999) 'The Patient-Centredness of Consultations and Outcome in Primary Care.' *Br J Gen Pract* 49 (446), 711–716
- Kirkley, D. and Stein, M. (2004) 'Nurses and Clinical Technology: Sources of Resistance and Strategies for Acceptance'. *Nursing Economics* 22 (4), 216
- Klaus, T. and Blanton, J.E. (2010) 'User Resistance Determinants and the Psychological Contract in Enterprise System Implementations'. *European Journal of Information Systems* 19 (6), 625–636
- Knott, P., Pappo, E., Cameron, M., DeMauroy, J.C., Rivard, C., Kotwicki, T., Zaina, F., Wynne, J., Stikeleather, L., Bettany-Saltikov, J., Grivas, T.B., Durmala, J., Maruyama, T., Negrini, S., O'Brien, J.P., and Rigo, M. (2014) 'SOSORT 2012 Consensus Paper: Reducing X-Ray Exposure in Pediatric Patients with Scoliosis'. *Scoliosis* 9 (1), 1–9
- Knott, P., Smith, K., Mack, L., Peters, L., Patel, N., Thompson, S., and Mardjetko, S. (2012) 'A Comparison of Static vs Dynamic Surface Topography Measurements in the Evaluation of Scoliosis'. *Scoliosis* 7 (1), P12
- Ko, K., Lee, J.W., Chae, S., and Pan, S.B. (2013) *Study on Determining Scoliosis Using Depth Image*. 36–41
- Koes, B. and others (2006) 'Low Back Pain (Chronic)'. *Clinical Evidence* (15), 1634–1653
- Koes, B.W., van Tulder, M., Lin, C.-W.C., Macedo, L.G., McAuley, J., and Maher, C. (2010) 'An Updated Overview of Clinical Guidelines for the Management of Non-Specific Low Back Pain in Primary Care'. *European Spine Journal* 19 (12), 2075–2094
- Koes, B.W., Van Tulder, M.W., and Thomas, S. (2006) 'Diagnosis and Treatment of Low Back Pain'. *BMJ: British Medical Journal* 332 (7555), 1430

- Kongsted, A., Kent, P., Hestbaek, L., and Vach, W. (2015) 'Patients with Low Back Pain Had Distinct Clinical Course Patterns That Were Typically Neither Complete Recovery nor Constant Pain. A Latent Class Analysis of Longitudinal Data'. *Spine Journal* [online] 15 (5), 885–894. available from <<http://dx.doi.org/10.1016/j.spinee.2015.02.012>>
- Konradt, U. and Hoch, J.E. (2007) 'A Work Roles and Leadership Functions of Managers in Virtual Teams'. *International Journal of E-Collaboration* 3 (2), 16
- Koo, T.K. and Li, M.Y. (2016) 'A Guideline of Selecting and Reporting Intraclass Correlation Coefficients for Reliability Research'. *Journal of Chiropractic Medicine* 15 (2), 155–163
- Von Korff, M., Moore, J.E., Lorig, K., Cherkin, D.C., Saunders, K., González, V.M., Laurent, D., Rutter, C., and Comite, F. (1998) 'A Randomized Trial of a Lay Person-Led Self-Management Group Intervention for Back Pain Patients in Primary Care'. *Spine* 23 (23), 2608–2615
- Kostuik, J.P. (2015) 'The History of Spinal Deformity'. in *Spine Deformity*. vol. 3 (5)
- Kotwicki, T., Kinel, E., Stryla, W., and Szulc, A. (2007) 'Discrepancy in Clinical versus Radiological Parameters Describing Deformity due to Brace Treatment for Moderate Idiopathic Scoliosis'. *Scoliosis* 2 (1), 18
- Kovač, V. and Pečina, M. (1999) 'Moiré Topography in Measurement of the Sagittal Curvatures'. *Coll. Antropol* 23 (1), 153–158
- Kovacs, F.M., Muriel, A., Medina, J.M., Abaira, V., Sánchez, M.D.C., Jaúregui, J.O., Network, S.B.P.R., and others (2006) 'Psychometric Characteristics of the Spanish Version of the FAB Questionnaire'. *Spine* 31 (1), 104–110
- Kowalski, I.M., Kotwicki, T., and Siwik, P. (2013) 'Analysis of Diagnostic Methods in Trunk Deformities in the Developmental Age'. *Polish Annals of Medicine* 20 (1), 43–50
- Kraemer, H.C. and Blasey, C. (2015) *How Many Subjects?: Statistical Power Analysis in*

- Kujala, S., Mugge, R., and Miron-Shatz, T. (2017) 'The Role of Expectations in Service Evaluation: A Longitudinal Study of a Proximity Mobile Payment Service'. *International Journal of Human-Computer Studies* 98, 51–61
- Kuo, K.-M., Liu, C.-F., and Ma, C.-C. (2013) 'An Investigation of the Effect of Nurses' Technology Readiness on the Acceptance of Mobile Electronic Medical Record Systems'. *BMC Medical Informatics and Decision Making* 13 (1), 88
- Kupke, T. and Olds, T. (2007) 'Towards a Generalised Anthropometric'. in *Kinanthropometry X: Proceedings of the 10th International Society for the Advancement of Kinanthropometry Conference, Held in Conjunction with the 13th Commonwealth International Sport Conference*. held 2007. 213
- Kuroki, H., Nagai, T., Chosa, E., and Tajima, N. (2018) 'School Scoliosis Screening by Moiré Topography--Overview for 33 Years in Miyazaki Japan'. *Journal of Orthopaedic Science*
- Kuru, A. and Erbuğ, Ç. (2013) 'Explorations of Perceived Qualities of on-Body Interactive Products'. *Ergonomics* 56 (6), 906–921
- Kwon, O., Choi, K., and Kim, M. (2007) 'User Acceptance of Context-Aware Services: Self-Efficacy, User Innovativeness and Perceived Sensitivity on Contextual Pressure'. *Behaviour & Information Technology* 26 (6), 483–498
- Lachat, E., Macher, H., Landes, T., and Grussenmeyer, P. (2015) 'Assessment and Calibration of a RGB-D Camera (Kinect v2 Sensor) towards a Potential Use for Close-Range 3D Modeling'. *Remote Sensing* 7 (10), 13070–13097
- Lærum, H., Ellingsen, G., and Faxvaag, A. (2001) 'Doctors' Use of Electronic Medical Records Systems in Hospitals: Cross Sectional Survey'. *Bmj* 323 (7325), 1344–1348
- Lafage, V., Schwab, F., Patel, A., Hawkinson, N., and Farcy, J.-P. (2009) 'Pelvic Tilt and

- Truncal Inclination: Two Key Radiographic Parameters in the Setting of Adults with Spinal Deformity'. *Spine* 34 (17), E599--E606
- Lamb, S.E., Lall, R., Hansen, Z., Castelnuevo, E., Withers, E.J., Nichols, V., Griffiths, F., Potter, R., Szczepura, A., and Underwood, M. (2010) 'A Multicentred Randomised Controlled Trial of a Primary Care-Based Cognitive Behavioural Programme for Low Back Pain. The Back Skills Training (BeST) Trial'. *Health Technol Assess* 14 (41), 1–253
- Lange, B., Suma, E.A., Bolas, M., and others (2011) 'Virtual Reality Technologies for Research and Education in Obesity and Diabetes-Sponsored by the National Institutes of Health and Department of Defense: Virtual Reality and Interactive Digital Game Technology: New Tools to Address Obesity and Diabetes'. *Journal of Diabetes Science and Technology* 5 (2), 256
- Langewitz, W.A., Eich, P., Kiss, A., and Wossmer, B. (1998) 'Improving Communication Skills-a Randomized Controlled Behaviorally Oriented Intervention Study for Residents in Internal Medicine'. *Psychosomatic Medicine* 60 (3), 268–276
- Lavaste, F., Skalli, W., Robin, S., Roy-Camille, R., and Mazel, C. (1992) 'Three-Dimensional Geometrical and Mechanical Modelling of the Lumbar Spine'. *Journal of Biomechanics* 25 (10), 1153–1164
- Lavy, C.B.D., Msamati, B.C., and Igbigbi, P.S. (2003) 'Racial and Gender Variations in Adult Hip Morphology'. *International Orthopaedics* 27 (6), 331–333
- Leach, R.A., Parker, P.L., and Veal, P.S. (2003) 'PulStar Differential Compliance Spinal Instrument: A Randomized Interexaminer and Intraexaminer Reliability Study'. *Journal of Manipulative & Physiological Therapeutics* 26 (8), 493–501
- Lee, Y., Kozar, K.A., and Larsen, K.R.T. (2003) 'The Technology Acceptance Model: Past, Present, and Future'. *Communications of the Association for Information Systems* 12 (1), 50

- Leeuw, M., Goossens, M.E.J.B., Linton, S.J., Crombez, G., Boersma, K., and Vlaeyen, J.W.S. (2007) 'The Fear-Avoidance Model of Musculoskeletal Pain: Current State of Scientific Evidence'. *Journal of Behavioral Medicine* 30 (1), 77–94
- Legaye, J., Lokietek, W., Orban, C., and Jacquemin, N. (1992) 'The ISIS Optic Scanner: Its Use in the Evaluation and Control of Spinal Deviations'. *Acta Orthopaedica Belgica* 58, 66–72
- Legrís, P., Ingham, J., and Collerette, P. (2003) 'Why Do People Use Information Technology? A Critical Review of the Technology Acceptance Model'. *Information & Management* 40 (3), 191–204
- Letafatkar, A., Abdolvahabi, Z., Rahmati, H., SALIMI, N.S., and BELALI, V.J. (2011) *The Effect of Spinal Postural Abnormalities on Spirometric Indices*.
- Lewis, J.S. and Valentine, R.E. (2010) 'Clinical Measurement of the Thoracic Kyphosis. A Study of the Intra-Rater Reliability in Subjects with and without Shoulder Pain'. *BMC Musculoskeletal Disorders* 11 (1), 39
- Liao, C., Lin, H.-N., Luo, M.M., and Chea, S. (2017) 'Factors Influencing Online Shoppers' Repurchase Intentions: The Roles of Satisfaction and Regret'. *Information & Management* 54 (5), 651–668
- Lichota, M. (2008) 'Spine Shape in Sagittal and Frontal Planes in Short-and Tall-Statured Children Aged 13 Years.' *Physical Education and Sport* 52, 92–95
- Lichota, M., Plandowska, M., and Mil, P. (2011) 'The Shape of Anterior-Posterior Curvatures of the Spine in Athletes Practising Selected Sports'. *Polish Journal of Sport and Tourism* 18 (2), 112–116
- Liddle, S.D., Gracey, J.H., and Baxter, G.D. (2007) 'Advice for the Management of Low Back Pain: A Systematic Review of Randomised Controlled Trials'. *Manual Therapy* 12 (4), 310–327
- Lim, S., Xue, L., Yen, C.C., Chang, L., Chan, H.C., Tai, B.C., Duh, H.B.L., and Choolani,



- M. (2011) 'A Study on Singaporean Women's Acceptance of Using Mobile Phones to Seek Health Information'. *International Journal of Medical Informatics* 80 (12), e189--e202
- Limayem, M., Hirt, S.G., and Cheung, C.M.K. (2007) 'How Habit Limits the Predictive Power of Intention: The Case of Information Systems Continuance'. *MIS Quarterly* 705–737
- Line of Gravity* (n.d.) available from  
<[http://www.chiro.org/ACAPress/Body\\_Alignment.html](http://www.chiro.org/ACAPress/Body_Alignment.html)>
- Linton, S.J. (2000) 'A Review of Psychological Risk Factors in Back and Neck Pain'. *Spine* 25 (9), 1148–1156
- Linton, S.J., Hellsing, A.-L., and Halldén, K. (1998) 'A Population-Based Study of Spinal Pain among 35-45-Year-Old Individuals: Prevalence, Sick Leave, and Health Care Use'. *Spine* 23 (13), 1457–1463
- Linton, S.J. and van Tulder, M.W. (2001) 'Preventive Interventions for Back and Neck Pain Problems: What Is the Evidence?' *Spine* 26 (7), 778–787
- Lishan, X., Chiuan, Y.C., Choolani, M., and Chuan, C.H. (2009) 'The Perception and Intention to Adopt Female-Focused Healthcare Applications (FHA): A Comparison between Healthcare Workers and Non-Healthcare Workers'. *International Journal of Medical Informatics* 78 (4), 248–258
- Liu, L. and Ma, Q. (2006) 'Perceived System Performance: A Test of an Extended Technology Acceptance Model'. *ACM SIGMIS Database: The DATABASE for Advances in Information Systems* 37 (2–3), 51–59
- Liu, L. and Ma, Q. (2005) 'The Impact of Service Level on the Acceptance of Application Service Oriented Medical Records'. *Information & Management* 42 (8), 1121–1135
- Liu, Y. and Li, H. (2011) 'Exploring the Impact of Use Context on Mobile Hedonic Services Adoption: An Empirical Study on Mobile Gaming in China'. *Computers in Human*

- Loisel, P., Abenhaim, L., Durand, P., Esdaile, J.M., Suissa, S., Gosselin, L., Simard, R., Turcotte, J., and Lemaire, J. (1997) 'A Population-Based, Randomized Clinical Trial on Back Pain Management'. *Spine* 22 (24), 2911–2918
- Lorussi, F., Rocchia, W., Scilingo, E.P., Tognetti, A., and De Rossi, D. (2004) 'Wearable, Redundant Fabric-Based Sensor Arrays for Reconstruction of Body Segment Posture'. *IEEE Sensors Journal* 4 (6), 807–818
- Lorusso, A., Vimercati, L., and L'Abbate, N. (2010) 'Musculoskeletal Complaints among Italian X-Ray Technology Students: A Cross-Sectional Questionnaire Survey'. *BMC Research Notes* 3 (1), 114
- Lu, J., Yu, C.-S., Liu, C., and Yao, J.E. (2003) 'Technology Acceptance Model for Wireless Internet'. *Internet Research* 13 (3), 206–222
- Luo, X., Pietrobon, R., Sun, S.X., Liu, G.G., and Hey, L. (2004) 'Estimates and Patterns of Direct Health Care Expenditures among Individuals with Back Pain in the United States'. *Spine* 29 (1), 79–86
- Luxton, D.D., McCann, R.A., Bush, N.E., Mishkind, M.C., and Reger, G.M. (2011) 'mHealth for Mental Health: Integrating Smartphone Technology in Behavioral Healthcare.' *Professional Psychology: Research and Practice* 42 (6), 505
- M'linguez, M.F., Buend'ia, M., Cibrián, R.M., Salvador, R., Lagu'ia, M., Mart'in, A., and Gomar, F. (2007) 'Quantifier Variables of the Back Surface Deformity Obtained with a Noninvasive Structured Light Method: Evaluation of Their Usefulness in Idiopathic Scoliosis Diagnosis'. *European Spine Journal* 16 (1), 73–82
- Mac-Thiong, J.-M., Labelle, H., Berthonnaud, E., Betz, R.R., and Roussouly, P. (2007) 'Sagittal Spinopelvic Balance in Normal Children and Adolescents'. *European Spine Journal* 16 (2), 227–234
- MacIntyre, N.J., Bennett, L., Bonnyman, A.M., and Stratford, P.W. (2011) 'Optimizing

- Reliability of Digital Inclinator and Flexicurve Ruler Measures of Spine Curvatures in Postmenopausal Women with Osteoporosis of the Spine: An Illustration of the Use of Generalizability Theory'. *ISRN Rheumatology* 2011
- Macpherson, T.W., Taylor, J., McBain, T., Weston, M., and Spears, I.R. (2016) 'Real-Time Measurement of Pelvis and Trunk Kinematics during Treadmill Locomotion Using a Low-Cost Depth-Sensing Camera: A Concurrent Validity Study'. *Journal of Biomechanics* [online] 49 (3), 474–478. available from <<http://dx.doi.org/10.1016/j.jbiomech.2015.12.008>>
- Magee, D.J. (2014) *Orthopedic Physical Assessment*. Elsevier Health Sciences
- Mair, F.S., May, C., O'Donnell, C., Finch, T., Sullivan, F., and Murray, E. (2012) 'Factors That Promote or Inhibit the Implementation of E-Health Systems: An Explanatory Systematic Review'. *Bulletin of the World Health Organization* 90 (5), 357–364
- Majid, Z., Chong, A.K., Ahmad, A., Setan, H., and Samsudin, A.R. (2005) 'Photogrammetry and 3D Laser Scanning as Spatial Data Capture Techniques for a National Craniofacial Database'. *The Photogrammetric Record* 20 (109), 48–68
- Malmivaara, A., Esmail, R., Koes, B., and others (2000) 'Exercise Therapy for Low Back Pain: A Systematic Review within the Framework of the Cochrane Collaboration Back Review Group.' *Spine* 25 (21), 2784–2796
- Manchikanti, L., Singh, V., Datta, S., Cohen, S.P., and Hirsch, J.A. (2009) 'Comprehensive Review of Epidemiology, Scope, and Impact of Spinal Pain.' *Pain Physician* 12 (4), E35--70
- Manek, N.J. and MacGregor, A.J. (2005) 'Epidemiology of Back Disorders: Prevalence, Risk Factors, and Prognosis'. *Current Opinion in Rheumatology* 17 (2), 134–140
- Maniadakis, N. and Gray, A. (2000) 'The Economic Burden of Back Pain in the UK'. *Pain* 84 (1), 95–103
- Marangunić, N. and Granić, A. (2015) 'Technology Acceptance Model: A Literature

Review from 1986 to 2013'. *Universal Access in the Information Society* 14 (1), 81–95

Marin, T.J., Eerd, D. Van, Irvin, E., Cocuban, R., Koes, B.W., Malmivaara, A., Tulder, M.W. van, and Kamper, S.L. (2017) 'Multidisciplinary Biopsychosocial Rehabilitation for Chronic Low Back Pain'. *Cochrane Database of Systematic Reviews* (6)

Marshall, G.N. and Hays, R.D. (1994) *The Patient Satisfaction Questionnaire Short-Form (PSQ-18)*. Rand Santa Monica, CA

Mattmann, C., Amft, O., Harms, H., Troster, G., and Clemens, F. (2007) 'Recognizing Upper Body Postures Using Textile Strain Sensors'. in *Wearable Computers, 2007 11th IEEE International Symposium on*. held 2007. 29–36

McAlpine, R.T., Bettany-Saltikov, J.A., and Warren, J.G. (2009) 'Computerized Back Postural Assessment in Physiotherapy Practice: Intra-Rater and Inter-Rater Reliability of the MIDAS System'. *Journal of Back and Musculoskeletal Rehabilitation* 22 (3), 173–178

McCloskey, E. V, Spector, T.D., Eyres, K.S., Fern, E.D., O'rourke, N., Vasikaran, S., and Kanis, J.A. (1993) 'The Assessment of Vertebral Deformity: A Method for Use in Population Studies and Clinical Trials'. *Osteoporosis International* 3 (3), 138–147

McClure, P.W., Esola, M., Schreier, R., and Siegler, S. (1997) 'Kinematic Analysis of Lumbar and Hip Motion While Rising from a Forward, Flexed Position in Patients with and without a History of Low Back Pain'. *Spine* 22 (5), 552–558

McCracken, L.M. (1998) 'Learning to Live with the Pain: Acceptance of Pain Predicts Adjustment in Persons with Chronic Pain'. *Pain* 74 (1), 21–27

McCracken, L.M., Gross, R.T., Sorg, P.J., and Edmands, T.A. (1993) 'Prediction of Pain in Patients with Chronic Low Back Pain: Effects of Inaccurate Prediction and Pain-Related Anxiety'. *Behaviour Research and Therapy* 31 (7), 647–652

McCracken, L.M., Zayfert, C., and Gross, R.T. (1992) 'The Pain Anxiety Symptoms Scale:

- Development and Validation of a Scale to Measure Fear of Pain'. *Pain* 50 (1), 67–73
- McKenzie, R. and May, S. (2003) *The Lumbar Spine: Mechanical Diagnosis and Therapy*. vol. 1. Orthopedic Physical Therapy
- McVey, G., Sandborg, M., Dance, D.R., and Alm Carlsson, G. (2003) 'A Study and Optimization of Lumbar Spine X-Ray Imaging Systems'. *The British Journal of Radiology* 76 (903), 177–188
- Mead, N. and Bower, P. (2002) 'Patient-Centred Consultations and Outcomes in Primary Care: A Review of the Literature'. *Patient Education and Counseling* 48 (1), 51–61
- Meankaew, P., Kaewkungwal, J., Khamsiriwatchara, A., Khunthong, P., Singhasivanon, P., and Satimai, W. (2010) 'Application of Mobile-Technology for Disease and Treatment Monitoring of Malaria in the "Better Border Healthcare Programme"'. *Malaria Journal* 9 (1), 237
- Melvin, M., Sylvia, M., Udo, W., Helmut, S., Paletta, J.R., and Adrian, S. (2010) 'Reproducibility of Rasterstereography for Kyphotic and Lordotic Angles, Trunk Length, and Trunk Inclination: A Reliability Study'. *Spine* 35 (14), 1353–1358
- Menken, M., Munsat, T.L., and Toole, J.F. (2000) 'The Global Burden of Disease Study'. *Archives of Neurology* [online] 57 (3), 418–420. available from <<http://uq.summon.serialssolutions.com/>>
- Milanesi, J.M., Borin, G., Corrêa, E.C.R., da Silva, A.M.T., Bortoluzzi, D.C., and Souza, J.A. (2011) 'Impact of the Mouth Breathing Occurred during Childhood in the Adult Age: Biophotogrammetric Postural Analysis'. *International Journal of Pediatric Otorhinolaryngology* 75 (8), 999–1004
- Mior, S.A., Kopansky-Giles, D.R., Crowther, E.R., and Wright, J.G. (1996) 'A Comparison of Radiographic and Electrogoniometric Angles in Adolescent Idiopathic Scoliosis'. *Spine* 21 (13), 1549–1555

- Mitchell, T., O'sullivan, P.B., Burnett, A., Straker, L., Smith, A., Thornton, J., and Rudd, C.J. (2010) 'Identification of Modifiable Personal Factors That Predict New-Onset Low Back Pain: A Prospective Study of Female Nursing Students'. *The Clinical Journal of Pain* 26 (4), 275–283
- Mock, M., Sweeting, K., and others (2007) 'Gait and Posture-Assessment in General Practice'. *Australian Family Physician* 36 (6), 398
- Montori, V.M., Brito, J.P., and Murad, M.H. (2013) 'The Optimal Practice of Evidence-Based Medicine: Incorporating Patient Preferences in Practice Guidelines'. *Jama* 310 (23), 2503–2504
- Moody, L.E., Slocumb, E., Berg, B., and Jackson, D. (2004) 'Electronic Health Records Documentation in Nursing: Nurses' Perceptions, Attitudes, and Preferences'. *CIN: Computers, Informatics, Nursing* 22 (6), 337–344
- Morais, N., Cruz, J., and Marques, A. (2016) 'Posture and Mobility of the Upper Body Quadrant and Pulmonary Function in COPD: An Exploratory Study'. *Brazilian Journal of Physical Therapy* 20 (4), 345–354
- Morais, T., Bernier, M., and Turcotte, F. (1985) 'Age-and Sex-Specific Prevalence of Scoliosis and the Value of School Screening Programs.' *American Journal of Public Health* 75 (12), 1377–1380
- Motta, M.M. da, Pratali, R. de R., and Oliveira, C.E.A.S. de (2017) 'CORRELATION BETWEEN CERVICAL SAGITTAL ALIGNMENT AND FUNCTIONAL CAPACITY IN CERVICAL SPONDYLOSIS'. *Coluna/Columna* 16 (4), 270–274
- Mroczkowski, A. (2013) 'The Effect of Aikido Exercises on Shaping Spinal Curvatures in the Sagittal Plane.' *Journal of Combat Sports & Martial Arts* 4 (2)
- Mubarak, S.J., Wyatt, M.P., and Leach, J. (1984) 'Evaluation of the Intra-Examiner Reliability of the Scoliometer in Measuring Trunk Rotation'. *Orthop Trans* 9, 113
- Murray, C.J.L., Vos, T., Lozano, R., Naghavi, M., Flaxman, A.D., Michaud, C., Ezzati, M.,

- Shibuya, K., Salomon, J.A., Abdalla, S., and others (2012) 'Disability-Adjusted Life Years (DALYs) for 291 Diseases and Injuries in 21 Regions, 1990--2010: A Systematic Analysis for the Global Burden of Disease Study 2010'. *The Lancet* 380 (9859), 2197–2223
- Nelson-Wong, E., Gregory, D.E., Winter, D.A., and Callaghan, J.P. (2008) 'Gluteus Medius Muscle Activation Patterns as a Predictor of Low Back Pain during Standing'. *Clinical Biomechanics* 23 (5), 545–553
- Nelson-Wong, E., Howarth, S., Winter, D.A., and Callaghan, J.P. (2009) 'Application of Autocorrelation and Cross-Correlation Analyses in Human Movement and Rehabilitation Research'. *Journal of Orthopaedic & Sports Physical Therapy* 39 (4), 287–295
- Nelson-Wong, E., Howarth, S.J., and Callaghan, J.P. (2010) 'Acute Biomechanical Responses to a Prolonged Standing Exposure in a Simulated Occupational Setting'. *Ergonomics* 53 (9), 1117–1128
- Netter, F.H. (2014) *Atlas of Human Anatomy, Professional Edition E-Book: Including NetterReference. Com Access with Full Downloadable Image Bank*. Elsevier Health Sciences
- Neuschwander, T.B., Cutrone, J., Macias, B.R., Cutrone, S., Murthy, G., Chambers, H., and Hargens, A.R. (2010) 'The Effect of Backpacks on the Lumbar Spine in Children: A Standing Magnetic Resonance Imaging Study'. *Spine* 35 (1), 83–88
- Ng, T.W.H. and Feldman, D.C. (2008) 'The Relationship of Age to Ten Dimensions of Job Performance.' *Journal of Applied Psychology* 93 (2), 392
- Nguyen, C. V, Izadi, S., and Lovell, D. (2012) 'Modeling Kinect Sensor Noise for Improved 3d Reconstruction and Tracking'. in *3D Imaging, Modeling, Processing, Visualization and Transmission (3DIMPVT), 2012 Second International Conference on*. held 2012. 524–530

*NHMRC Annual Report 2000* (n.d.)

*NICE* 2012 (n.d.) available from  
<<https://www.nice.org.uk/process/pmg6/chapter/introduction>>

*NICE Guidelines 2011* (n.d.) available from <<https://www.health-ni.gov.uk/articles/nice-endorsed-clinical-guidelines-20102011>>

Nichele, L. de F.I., Turra, P., and Badaró, A.F.V. (2001) 'Monitoring of Students Body Posture: A Longitudinal Study.' *Growth*

van Niekerk, S.-M., Louw, Q., Vaughan, C., Grimmer-Somers, K., and Schreve, K. (2008) 'Photographic Measurement of Upper-Body Sitting Posture of High School Students: A Reliability and Validity Study'. *BMC Musculoskeletal Disorders* 9 (1), 113

Nielsen, A.C. (1998) 'Attitudes Towards IT in Australian General Practice: Qualitative Research Report'. *AcNielsen PTY General Practice Branch, North Sydney*

Nilsen, L., Frich, J.C., Friis, S., Norheim, I., and Røssberg, J.I. (2016) 'Participants' Perceived Benefits of Family Intervention Following a First Episode of Psychosis: A Qualitative Study'. *Early Intervention in Psychiatry* 10 (2), 152–159

Nilsen, W. (2015) *The Use of Technology to Enhance Health*. Springer

Nilstad, A., Andersen, T.E., Kristianslund, E., Bahr, R., Myklebust, G., Steffen, K., and Krosshaug, T. (2014) 'Physiotherapists Can Identify Female Football Players with High Knee Valgus Angles during Vertical Drop Jumps Using Real-Time Observational Screening'. *Journal of Orthopaedic & Sports Physical Therapy* 44 (5), 358–365

Nissinen, M., Heliövaara, M., Tallroth, K., and Poussa, M. (1989) 'Trunk Asymmetry and Scoliosis Anthropometric Measurements in Prepuberal School Children'. *Acta Pædiatrica* 78 (5), 747–753

*Normal Curvature of Spine* (n.d.) available from <<https://mayfieldclinic.com/Images/PE->



scoliosis\_Fig1.jpg).>

*Normal Human Spinal Column* (n.d.) available from <<http://oerpub.github.io/epubjs-demo-book/content/m46352.xhtml>> [12 December 2006]

Nøst, T.H., Steinsbekk, A., Bratås, O., and Grønning, K. (2018) 'Twelve-Month Effect of Chronic Pain Self-Management Intervention Delivered in an Easily Accessible Primary Healthcare Service - a Randomised Controlled Trial'. *BMC Health Services Research* [online] 18 (1), 1012. available from <<https://doi.org/10.1186/s12913-018-3843-x>>

Nunnally, J.C. and Bernstein, I.H. (1994) 'Psychological Theory'. *New York, NY: MacGraw-Hill*

O'Connor, Y. and O'Reilly, P. (2016) 'Examining the Infusion of Mobile Technology by Healthcare Practitioners in a Hospital Setting'. *Information Systems Frontiers* 1–21

O'Neill, T.W., Felsenberg, D., Varlow, J., Cooper, C., Kanis, J.A., Silman, A.J., and Group, E.V.O.S. (1996) 'The Prevalence of Vertebral Deformity in European Men and Women: The European Vertebral Osteoporosis Study'. *Journal of Bone and Mineral Research* 11 (7), 1010–1018

Oestreich, A.E., Young, L.W., and Poussaint, T.Y. (1998) 'Scoliosis circa 2000: Radiologic Imaging Perspective'. *Skeletal Radiology* 27 (11), 591–605

Van Offenbeek, M., Boonstra, A., and Seo, D. (2013) 'Towards Integrating Acceptance and Resistance Research: Evidence from a Telecare Case Study'. *European Journal of Information Systems* 22 (4), 434–454

Office for National Statistics (n.d.) available from <<https://www.ons.gov.uk/census/2011census>>

Ohara, A., Miyamoto, K., Naganawa, T., Matsumoto, K., and Shimizu, K. (2006) 'Reliabilities of and Correlations among Five Standard Methods of Assessing the Sagittal Alignment of the Cervical Spine'. *Spine* 31 (22), 2585–2591

- Ohrt-Nissen, S., Hallager, D.W., Henriksen, J.L., Gehrchen, M., and Dahl, B. (2016) 'Curve Magnitude in Patients Referred for Evaluation of Adolescent Idiopathic Scoliosis: Five Years' Experience From a System Without School Screening'. *Spine Deformity* 4 (2), 120–124
- de Oliveira, T.S., Candotti, C.T., La Torre, M., Pelinson, P.P.T., Furlanetto, T.S., Kutchak, F.M., and Loss, J.F. (2012) 'Validity and Reproducibility of the Measurements Obtained Using the Flexicurve Instrument to Evaluate the Angles of Thoracic and Lumbar Curvatures of the Spine in the Sagittal Plane'. *Rehabilitation Research and Practice* 2012
- de Oliveira Pezzan, P.A., João, S.M.A., Ribeiro, A.P., and Manfio, E.F. (2011) 'Postural Assessment of Lumbar Lordosis and Pelvic Alignment Angles in Adolescent Users and Nonusers of High-Heeled Shoes'. *Journal of Manipulative & Physiological Therapeutics* 34 (9), 614–621
- Oliver, R.L., Rust, R.T., and Varki, S. (1997) 'Customer Delight: Foundations, Findings, and Managerial Insight'. *Journal of Retailing* 73 (3), 311–336
- Orruño, E., Gagnon, M.P., Asua, J., and Abdeljelil, A. Ben (2011) 'Evaluation of Teledermatology Adoption by Health-Care Professionals Using a Modified Technology Acceptance Model'. *Journal of Telemedicine and Telecare* 17 (6), 303–307
- Owens, E.F., Hart, J.F., Donofrio, J.J., Haralambous, J., and Mierzejewski, E. (2004) 'Paraspinal Skin Temperature Patterns: An Interexaminer and Intraexaminer Reliability Study'. *Journal of Manipulative & Physiological Therapeutics* 27 (3), 155–159
- Oxborrow, N.J. (2000) 'Assessing the Child with Scoliosis: The Role of Surface Topography'. *Archives of Disease in Childhood* 83 (5), 453–455
- Pallant, J. (2010) *SPSS Survival Manual: A Step by Step Guide to Data Analysis Using SPSS*.

- Palm, J.-M., Dart, T., Dupuis, I., Leneveut, L., and Degoulet, P. (2010) 'Clinical Information System Post-Adoption Evaluation at the Georges Pompidou University Hospital'. in *AMIA Annual Symposium Proceedings*. held 2010. 582
- Papageorgiou, A.C., Croft, P.R., Thomas, E., Ferry, S., Jayson IV, M., and Silman, A.J. (1996) 'Influence of Previous Pain Experience on the Episode Incidence of Low Back Pain: Results from the South Manchester Back Pain Study'. *PAIN®* 66 (2–3), 181–185
- Parker, S.L., Chotai, S., Devin, C.J., Tetreault, L., Mroz, T.E., Brodke, D.S., Fehlings, M.G., and McGirt, M.J. (2017) 'Bending the Cost Curve—establishing Value in Spine Surgery'. *Neurosurgery* 80 (3S), S61--S69
- Patel, R.M. and Pinto, J.M. (2014) 'Olfaction: Anatomy, Physiology, and Disease'. *Clinical Anatomy* 27 (1), 54–60
- Patias, P., Grivas, T.B., Kaspiris, A., Aggouris, C., and Drakoutos, E. (2010) 'A Review of the Trunk Surface Metrics Used as Scoliosis and Other Deformities Evaluation Indices'. *Scoliosis* 5 (1), 1–20
- Patton, M.Q. (2005) 'Diverse and Creative Uses of Cases for Teaching'. *New Directions for Evaluation* 2005 (105), 91–100
- Patton, M.Q. (1990) 'The Challenge of Being a Profession'. *Evaluation Practice* 11 (1), 45–51
- Pazos, V., Cheriet, F., Danserau, J., Ronsky, J., Zernicke, R.F., and Labelle, H. (2007) 'Reliability of Trunk Shape Measurements Based on 3-D Surface Reconstructions'. *European Spine Journal* 16 (11), 1882–1891
- Pearsall, D.J., Reid, J.G., and Hedden, D.M. (1992) 'Comparison of Three Noninvasive Methods for Measuring Scoliosis'. *Physical Therapy* 72 (9), 648–657
- Pengel, L.H.M., Herbert, R.D., Maher, C.G., and Refshauge, K.M. (2003) 'Acute Low Back Pain: Systematic Review of Its Prognosis'. *Bmj* 327 (7410), 323

- Penha, P.J., Casarotto, R.A., Sacco, I.C.N., Marques, A.P., and João, S.M.A. (2008) 'Qualitative Postural Analysis among Boys and Girls of Seven to Ten Years of Age'. *Brazilian Journal of Physical Therapy* 12 (5), 386–391
- Perry, J., Klopfer, E., Norton, M., Sutch, D., Sandford, R., and Facer, K. (2008) 'AR Gone Wild: Two Approaches to Using Augmented Reality Learning Games in Zoos'. in *Proceedings of the 8th International Conference on International Conference for the Learning Sciences-Volume 3*. held 2008. 322–329
- Petter, S., DeLone, W., and McLean, E. (2008) 'Measuring Information Systems Success: Models, Dimensions, Measures, and Interrelationships'. *European Journal of Information Systems* 17 (3), 236–263
- Pfingsten, M., Kröner-Herwig, B., Leibing, E., and Kronshage, U. (2000) 'Validation of the German Version of the Fear-Avoidance Beliefs Questionnaire (FABQ)'. *European Journal of Pain* 4 (3), 259–266
- Physiotherapy, C. society (2016) *CSP Evidence Based Practice* [online] available from <<http://www.csp.org.uk/professional-union/practice/evidence-base/evidence-based-practice>> [10 May 2018]
- Picavet, H.S.J., Vlaeyen, J.W.S., and Schouten, J.S.A.G. (2002) 'Pain Catastrophizing and Kinesiophobia: Predictors of Chronic Low Back Pain'. *American Journal of Epidemiology* 156 (11), 1028–1034
- Pino-Almero, L., M<sup>o</sup>linguez-Rey, M.F., Rodr<sup>o</sup>iguez-Mart<sup>o</sup>inez, D., de Anda, R.M.C.-O., Salvador-Palmer, M.R., and Sentamans-Segarra, S. (2017) 'Clinical Application of Back Surface Topography by Means of Structured Light in the Screening of Idiopathic Scoliosis'. *Journal of Pediatric Orthopaedics B* 26 (1), 64–72
- Pinto, R.Z.A., Souza, T.R., Trede, R.G., Kirkwood, R.N., Figueiredo, E.M., and Fonseca, S.T. (2008) 'Bilateral and Unilateral Increases in Calcaneal Eversion Affect Pelvic Alignment in Standing Position'. *Manual Therapy* 13 (6), 513–519

- Polit, D.F. and Beck, C.T. (2010) *Essentials of Nursing Research: Appraising Evidence for Nursing Practice*. Lippincott Williams & Wilkins
- Poredoš, P., Povšič, K., Novak, B., and Jezerš, M. (2015) *Three-Dimensional Measurements of Bodies in Motion Based on Multiple- Laser-Plane Triangulation*. [online] 38, 53–61. available from <5 star>
- Portek, I., Pearcy, M.J., Reader, G.P., and Mowat, A.G. (1983) 'Correlation between Radiographic and Clinical Measurement of Lumbar Spine Movement'. *Rheumatology* 22 (4), 197–205
- Portney, L.G. and Watkins, M.P. (2000) *Foundations of Clinical Research: Applications to Practice*. vol. 2. Prentice Hall Upper Saddle River, NJ
- Porto, F., Gurgel, J.L., Russomano, T., and Farinatti, P.D.T.V. (2010) 'Moiré Topography: Characteristics and Clinical Application'. *Gait & Posture* 32 (3), 422–424
- Poussa, M.S., Heliövaara, M.M., Seitsamo, J.T., Könönen, M.H., Hurmerinta, K.A., and Nissinen, M.J. (2005) 'Development of Spinal Posture in a Cohort of Children from the Age of 11 to 22 Years'. *European Spine Journal* 14 (8), 738–742
- Pransky, G.S., Verma, S.K., Okurowski, L., and Webster, B. (2006) 'Length of Disability Prognosis in Acute Occupational Low Back Pain: Development and Testing of a Practical Approach'. *Spine* 31 (6), 690–697
- Propst-Proctor, S.L. and Bleck, E.E. (1983) 'Radiographic Determination of Lordosis and Kyphosis in Normal and Scoliotic Children.' *Journal of Pediatric Orthopaedics* 3 (3), 344–346
- Prowse, A., Aslaksen, B., Kierkegaard, M., Furness, J., Gerdhem, P., and Abbott, A. (2017) 'Reliability and Concurrent Validity of Postural Asymmetry Measurement in Adolescent Idiopathic Scoliosis'. *World Journal of Orthopedics* [online] 8 (1), 68. available from <<http://www.wjgnet.com/2218-5836/full/v8/i1/68.htm>>
- Prujls, J.E.H., Keessen, W., Meer, R., and Wieringen, J.C. (1995) 'School Screening for

- Scoliosis: The Value of Quantitative Measurement'. *European Spine Journal* 4 (4), 226–230
- Putzer, G.J. and Park, Y. (2010) 'The Effects of Innovation Factors on Smartphone Adoption among Nurses in Community Hospitals'. *Perspectives in Health Information Management/AHIMA, American Health Information Management Association* 7 (Winter)
- Pynoo, B., Devolder, P., Duyck, W., van Braak, J., Sijnave, B., and Duyck, P. (2012) 'Do Hospital Physicians' Attitudes Change during PACS Implementation? A Cross-Sectional Acceptance Study'. *International Journal of Medical Informatics* 81 (2), 88–97
- Quinzio, L., Junger, A., Gottwald, B., Benson, M., Hartmann, B., Jost, A., Banzhaf, A., and Hempelmann, G. (2003) 'User Acceptance of an Anaesthesia Information Management System'. *European Journal of Anaesthesiology* 20 (12), 967–972
- Radcliff, K., Rubin, T., Reitman, C.A., Smith, J., Kepler, C., and Hilibrand, A. (2011) 'Normal Cervical Alignment'. *Seminars in Spine Surgery* [online] 23 (3), 159–164. available from <<http://dx.doi.org/10.1053/j.semss.2011.04.006>>
- Radebold, A., Cholewicki, J., Panjabi, M.M., and Patel, T.C. (2000) 'Muscle Response Pattern to Sudden Trunk Loading in Healthy Individuals and in Patients with Chronic Low Back Pain'. *Spine* 25 (8), 947–954
- Raine, S. and Twomey, L.T. (1997) 'Head and Shoulder Posture Variations in 160 Asymptomatic Women and Men'. *Archives of Physical Medicine and Rehabilitation* 78 (11), 1215–1223
- Rajdi, N.N.Z.M., Bakira, A.A., Saleh, S.M., and Wicaksono, D.H.B. (2012) 'Textile-Based Micro Electro Mechanical System (MEMS) Accelerometer for Pelvic Tilt Measurement'. *Procedia Engineering* 41, 532–537
- Rankine, L., Liu, X.C., Tassone, C., Lyon, R., Tarima, S., and Thometz, J. (2012)

- 'Reproducibility of Newly Developed Spinal Topography Measurements for Scoliosis'. *The Open Orthopaedics Journal* 6, 226
- Rathert, C., Williams, E.S., Lawrence, E.R., and Halbesleben, J.R.B. (2012) 'Emotional Exhaustion and Workarounds in Acute Care: Cross Sectional Tests of a Theoretical Framework'. *International Journal of Nursing Studies* 49 (8), 969–977
- Raupp, E.G., Candotti, C.T., Marchetti, B. V, Vieira, A., Medeiros, F.S., and Loss, J.F. (2017) 'The Validity and Reproducibility of the Flexicurve in the Evaluation of Cervical Spine Lordosis'. *Journal of Manipulative & Physiological Therapeutics* 40 (7), 501–510
- Rawstorne, P., Jayasuriya, R., and Caputi, P. (2000) 'Issues in Predicting and Explaining Usage Behaviors with the Technology Acceptance Model and the Theory of Planned Behavior When Usage Is Mandatory'. in *Proceedings of the Twenty First International Conference on Information Systems*. held 2000. 35–44
- Rea, J.A., Steiger, P., Blake, G.M., Potts, E., Smith, I.G., and Fogelman, I. (1998) 'Morphometric X-Ray Absorptiometry: Reference Data for Vertebral Dimensions'. *Journal of Bone and Mineral Research* 13 (3), 464–474
- Redmond, J.M., Gupta, A., Nasser, R., and Domb, B.G. (2015) 'The Hip-Spine Connection: Understanding Its Importance in the Treatment of Hip Pathology'. *Orthopedics* 38 (1), 49–55
- Reitman, C.A., Mauro, K.M., Nguyen, L., Ziegler, J.M., and Hipp, J.A. (2004) 'Intervertebral Motion between Flexion and Extension in Asymptomatic Individuals'. *Spine* 29 (24), 2832–2843
- Rheault, W., Ferris, S., Foley, J.A., Schaffhauser, D., and Smith, R. (1989) 'Intertester Reliability of the Flexible Ruler for the Cervical Spine'. *J Orthop Sports Phys Ther* [online] 10 (7), 254–256. available from <[http://www.ncbi.nlm.nih.gov/entrez/query.fcgi?cmd=Retrieve&db=PubMed&dopt=Citation&list\\_uids=18791322](http://www.ncbi.nlm.nih.gov/entrez/query.fcgi?cmd=Retrieve&db=PubMed&dopt=Citation&list_uids=18791322)>

- Ribeiro, C.Z.P., Akashi, P.M.H., Sacco, I. de C.N., and Pedrinelli, A. (2003) 'Relationship between Postural Changes and Injuries of the Locomotor System in Indoor Soccer Athletes'. *Revista Brasileira de Medicina Do Esporte* 9 (2), 98–103
- Richards, B.S. and Vitale, M.G. (2008) 'Screening for Idiopathic Scoliosis in Adolescents'. *J Bone Joint Surg Am* 90 (1), 195–198
- Riff, D., Lacy, S., and Fico, F. (2014) *Analyzing Media Messages: Using Quantitative Content Analysis in Research*.
- Rillardon, L., Levassor, N., Guigui, P., Wodecki, P., Cardinne, L., Templier, A., and Skalli, W. (2003) 'Validation of a Tool to Measure Pelvic and Spinal Parameters of Sagittal Balance'. *Revue de Chirurgie Orthopedique et Reparatrice de L'appareil Moteur* 89 (3), 218–227
- Rivard, S. and Lapointe, L. (2012) 'Information Technology Implementers' Responses to User Resistance: Nature and Effects'. *MIS Quarterly* 897–920
- Rizzo, D.C. (2015) *Fundamentals of Anatomy and Physiology*. Cengage Learning
- Robinson, J., Dixon, J., Macsween, A., van Schaik, P., and Martin, D. (2015) 'The Effects of Exergaming on Balance, Gait, Technology Acceptance and Flow Experience in People with Multiple Sclerosis: A Randomized Controlled Trial'. *BMC Sports Science, Medicine and Rehabilitation* 7 (1), 8
- Rolton, D., Nnadi, C., and Fairbank, J. (2014) 'Scoliosis: A Review'. *Paediatrics and Child Health* 24 (5), 197–203
- ROSANA MARTINS FERREIRA DE CARVALHO<sup>1</sup>, NILTON MAZZER<sup>2</sup>, C.H.B. (2012) 'ANALYSIS OF THE RELIABILITY AND REPRODUCIBILITY OF GONIOMETRY COMPARED TO HAND'. *Acta Ortop Bras* 20 (3), 139–149
- Rosário, J.L.P. (2014) 'A Review of the Utilization of Baropodometry in Postural Assessment'. *Journal of Bodywork and Movement Therapies* [online] 18 (2), 215–219. available from



<<http://linkinghub.elsevier.com/retrieve/pii/S1360859213000831>> [24 July 2017]

- Roter, D.L., Hall, J.A., and Katz, N.R. (1987) 'Relations between Physicians' Behaviors and Analogue Patients' Satisfaction, Recall, and Impressions'. *Medical Care* 437–451
- Rouibah, K., Abbas, H., and Rouibah, S. (2011) 'Factors Affecting Camera Mobile Phone Adoption before E-Shopping in the Arab World'. *Technology in Society* 33 (3–4), 271–283
- Ruivo, R.M., Pezarat-Correia, P., and Carita, A.I. (2014) 'Cervical and Shoulder Postural Assessment of Adolescents between 15 and 17 Years Old and Association with Upper Quadrant Pain'. *Brazilian Journal of Physical Therapy* 18 (4), 364–371
- Russell, B.S., Muhlenkamp, K.A., Hoiriis, K.T., and DeSimone, C.M. (2012) 'Measurement of Lumbar Lordosis in Static Standing Posture with and without High-Heeled Shoes'. *Journal of Chiropractic Medicine* 11 (3), 145–153
- Ryan, R.M. and Deci, E.L. (2000) 'Intrinsic and Extrinsic Motivations: Classic Definitions and New Directions'. *Contemporary Educational Psychology* 25 (1), 54–67
- Ryan, S.D. and Fried, L.P. (1997) 'The Impact of Kyphosis on Daily Functioning'. *Journal of the American Geriatrics Society* 45 (12), 1479–1486
- Ryu, K., Han, H., and Kim, T.-H. (2008) 'The Relationships among Overall Quick-Casual Restaurant Image, Perceived Value, Customer Satisfaction, and Behavioral Intentions'. *International Journal of Hospitality Management* 27 (3), 459–469
- Saad, K.R., Colombo, A.S., Ribeiro, A.P., and João, S.M.A. (2012) 'Reliability of Photogrammetry in the Evaluation of the Postural Aspects of Individuals with Structural Scoliosis'. *Journal of Bodywork and Movement Therapies* 16 (2), 210–216
- Sadani, S., Jones, C., Seal, A., Bhakta, B., Hall, R., and Levesley, M. (2012) 'A Pilot Study of Scoliosis Assessment Using Radiation Free Surface Topography in

- Children with GMFCS IV and V Cerebral Palsy'. *Child: Care, Health and Development* 38 (6), 854–862
- Safran, C. (2001) 'Electronic Medical Records: A Decade of Experience'. *Jama* 285 (13), 1766
- Sahin, I., Iskender, S., Ozturk, S., Balaban, B., and Isik, S. (2013) 'Evaluation of Breast Reduction Surgery Effect on Body Posture and Gait Pattern Using Three-Dimensional Gait Analysis'. *Aesthetic Plastic Surgery* 37 (3), 549–553
- Sahlstrand, T. (1986) 'The Clinical Value of Moiré Topography in the Management of Scoliosis.' *Spine* 11 (5), 409–417
- Salahzadeh, Z., Maroufi, N., Ahmadi, A., Behtash, H., Razmjoo, A., Gohari, M., and Parnianpour, M. (2014) 'Assessment of Forward Head Posture in Females: Observational and Photogrammetry Methods'. *Journal of Back and Musculoskeletal Rehabilitation* 27 (2), 131–139
- Saltikov, J.A., Van Schaik, P., Bell, J.A., Warren, J.G., Wojcik, A.S., and Papastefanou, S.L. (2002) '3D Back Shape in Normal Young Adults'. *Stud Health Technol Inform* 88, 81–85
- Sansoni, G., Trebeschi, M., and Docchio, F. (2009) 'State-of-the-Art and Applications of 3D Imaging Sensors in Industry, Cultural Heritage, Medicine, and Criminal Investigation'. *Sensors* 9 (1), 568–601
- Santos, M.M., Silva, M.P.C., Sanada, L.S., and Alves, C.R.J. (2009) 'Photogrammetric Postural Analysis on Healthy Seven to Ten-Year-Old Children: Interrater Reliability'. *Brazilian Journal of Physical Therapy* 13 (4), 350–355
- Sardini, E., Serpelloni, M., and Pasqui, V. (2015) 'Wireless Wearable T-Shirt for Posture Monitoring during Rehabilitation Exercises'. *IEEE Transactions on Instrumentation and Measurement* 64 (2), 439–448
- Sawesi, S., Rashrash, M., Phalakornkule, K., Carpenter, J.S., and Jones, J.F. (2016) 'The

- Impact of Information Technology on Patient Engagement and Health Behavior Change: A Systematic Review of the Literature'. *JMIR Medical Informatics* 4 (1)
- Van Schaik, P., Bettany-Saltikov, J. a., and Warren, J.G. (2002) 'Clinical Acceptance of a Low-Cost Portable System for Postural Assessment'. *Behaviour & Information Technology* [online] 21 (1), 47–57. available from <<http://www.tandfonline.com/doi/abs/10.1080/01449290110107236>> [23 February 2012]
- Van Schaik, P., Flynn, D., Van Wersch, A., Douglass, A., and Cann, P. (2004) 'The Acceptance of a Computerised Decision-Support System in Primary Care: A Preliminary Investigation'. *Behaviour & Information Technology* 23 (5), 321–326
- van Schaik, P., Flynn, D., van Wersch, A., Ryan, K., and Ferguson, V. (2007) 'Factors Important in the Design of Information Material for Scoliosis'. *International Journal of Rehabilitation Research* 30 (2), 163–165
- Van Schaik, P. and Ling, J. (2011) 'An Integrated Model of Interaction Experience for Information Retrieval in a Web-Based Encyclopaedia'. *Interacting with Computers* 23 (1), 18–32
- Schiøttz-Christensen, B., Nielsen, G.L., Hansen, V.K., Schødt, T., Sørensen, H.T., and Olesen, F. (1999) 'Long-Term Prognosis of Acute Low Back Pain in Patients Seen in General Practice: A 1-Year Prospective Follow-up Study'. *Family Practice* 16 (3), 223–232
- Scholten-Peeters, G.G.M., Franken, N., Beumer, A., and Verhagen, A.P. (2014) 'The Opinion and Experiences of Dutch Orthopedic Surgeons and Radiologists about Diagnostic Musculoskeletal Ultrasound Imaging in Primary Care: A Survey'. *Manual Therapy* 19 (2), 109–113
- Schüleln, S., Mendoza, S., Malzkorn, R., Harms, J., and Skwara, A. (2013) 'Rasterstereographic Evaluation of Interobserver and Intraobserver Reliability in Postsurgical Adolescent Idiopathic Scoliosis Patients'. *Clinical Spine Surgery* 26 (4),

- Schuller, S., Charles, Y.P., and Steib, J.-P. (2011) 'Sagittal Spinopelvic Alignment and Body Mass Index in Patients with Degenerative Spondylolisthesis'. *European Spine Journal* 20 (5), 713–719
- Schwab, F., Dubey, A., Gamez, L., El Fegoun, A.B., Hwang, K., Pagala, M., and Farcy, J.-P. (2005) 'Adult Scoliosis: Prevalence, SF-36, and Nutritional Parameters in an Elderly Volunteer Population'. *Spine* 30 (9), 1082–1085
- Schwab, F.J., Patel, A., Ungar, B., Farcy, J., and Lafage, V. (2010) 'Adult Spinal Deformity — Postoperative Standing Imbalance Assessing Alignment and Planning Corrective Surgery'. *Spine* 35 (25), 2224–2231
- Schwab, F.J., Smith, V.A., Biseri, M., Gamez, L., Farcy, J.C., and Pagala, M. (2002) *Adult Scoliosis A Quantitative Radiographic and Clinical Analysis*. 27 (4), 387–392
- Schwarz, C. and Zhu, Z. (2015) 'The Impact of Student Expectations in Using Instructional Tools on Student Engagement: A Look through the Expectation Disconfirmation Theory Lens'. *Journal of Information Systems Education* 26 (1), 47
- Schwertner, D.S., Oliveira, R., Mazo, G.Z., Gioda, F.R., Kelber, C.R., and Swarowsky, A. (2016) 'Body Surface Posture Evaluation: Construction, Validation and Protocol of the SPGAP System (Posture Evaluation Rotating Platform System)'. *BMC Musculoskeletal Disorders* [online] 17 (1), 1–11. available from <<http://dx.doi.org/10.1186/s12891-016-1057-0>>
- Scoliosis Research Society* (n.d.) available from <<http://www.srs.org/professionals/online-education-and-resources/glossary/revised-glossary-of-terms>>
- Sedrez, J.A., Candotti, C.T., Rosa, M.I.Z. da, Medeiros, F. da S., Marques, M.T., and Loss, J.F. (2016) 'Validation of a Topography System for Evaluation Spine in Sagittal Plane for Children in Different Nutrient Profiles'. *Fisioterapia E Pesquisa* 23

(2), 163–171

- Sen, S., Fawson, P., Cherrington, G., Douglas, K., Friedman, N., Maljanian, R., Fitzner, K., Tang, P., Soper, S., and Wood, S. (2005) 'Patient Satisfaction Measurement in the Disease Management Industry'. *Disease Management* 8 (5), 288–300
- Seoud, L., Adankon, M.M., Labelle, H., Dansereau, J., and Cheriet, F. (2010) 'Prediction of Scoliosis Curve Type Based on the Analysis of Trunk Surface Topography'. in *Biomedical Imaging: From Nano to Macro, 2010 IEEE International Symposium on.* held 2010. 408–411
- Seoud, L., Cheriet, F., Labelle, H., and Dansereau, J. (2011) 'A Novel Method for the 3-D Reconstruction of Scoliotic Ribs from Frontal and Lateral Radiographs'. *IEEE Transactions on Biomedical Engineering* 58 (5), 1135–1146
- De Sèze, M., Randriaminahisoa, T., Gaunelle, A., de Korvin, G., and Mazaux, J.-M. (2013) 'Inter-Observer Reproducibility of Back Surface Topography Parameters Allowing Assessment of Scoliotic Thoracic Gibbosity and Comparison with Two Standard Postures'. *Annals of Physical and Rehabilitation Medicine* 56 (9–10), 599–612
- Sheeran, L., Sparkes, V., Busse, M., and van Deursen, R. (2010) 'Preliminary Study: Reliability of the Spinal Wheel. A Novel Device to Measure Spinal Postures Applied to Sitting and Standing'. *European Spine Journal* 19 (6), 995–1003
- Sheeran, L., Sparkes, V., Caterson, B., Busse-Morris, M., and van Deursen, R. (2012) 'Spinal Position Sense and Trunk Muscle Activity during Sitting and Standing in Nonspecific Chronic Low Back Pain: Classification Analysis'. *Spine* 37 (8), E486--E495
- Shin, J.K., Lee, J.S., Kang, S.S., Lee, J.M., and Youn, B.H. (2016) 'The Reliabilities of Radiographic Measurements of Cervical Sagittal Alignment in Ankylosing Spondylitis'. *Clinical Spine Surgery* 29 (6), E282–E287

- Shirazi, M.S. and Morris, B. (2015) 'A Typical Video-Based Framework for Counting, Behavior and Safety Analysis at Intersections'. in *Intelligent Vehicles Symposium (IV), 2015 IEEE*. held 2015. 1264–1269
- Shorthouse, F.M., Roffi, V., and Tack, C. (2016) 'Effectiveness of Educational Materials to Prevent Occupational Low Back Pain'. *Occupational Medicine* 66 (8), 623–629
- Sibbald, B. and Roland, M. (1998) 'Understanding Controlled Trials. Why Are Randomised Controlled Trials Important?' *BMJ: British Medical Journal* 316 (7126), 201
- Sielski, R., Rief, W., and Glombiewski, J.A. (2017) 'Efficacy of Biofeedback in Chronic Back Pain: A Meta-Analysis'. *International Journal of Behavioral Medicine* 24 (1), 25–41
- Silva, S., Queiros, S., Moreira, A.H., Oliveira, E., Rodrigues, N.F., and Vilaca, J.L. (2017) 'Classification Algorithms for Body Posture'. *2017 IEEE 5th International Conference on Serious Games and Applications for Health, SeGAH 2017*
- Singla, D. and Veqar, Z. (2014) 'Methods of Postural Assessment Used for Sports Persons.' *Journal of Clinical and Diagnostic Research : JCDR* [online] 8 (4), LE01-4. available from <<http://www.ncbi.nlm.nih.gov/pubmed/24959470>> [24 July 2017]
- Sinnott, P.L., Dally, S.K., Trafton, J., Goulet, J.L., and Wagner, T.H. (2017) 'Trends in Diagnosis of Painful Neck and Back Conditions, 2002 to 2011'. *Medicine* 96 (20)
- Skelton, A.M., Murphy, E.A., Murphy, R.J., and O'Dowd, T.C. (1996) 'Patients' Views of Low Back Pain and Its Management in General Practice.' *Br J Gen Pract* 46 (404), 153–156
- Sliwa, W., Sobczak, D., and Wolniac, J. (1994) 'CHARACTERISTIC OF BODY POSTURE OF THE PARTICIPANTS OF THE EUROPEAN JUNIOR VOLLEYBALL CHAMPIONSHIPS.' in *ISBS-Conference Proceedings Archive*. held 1994
- Smeets, R.J.E.M., Vlaeyen, J.W.S., Kester, A.D.M., and Knottnerus, J.A. (2006)

- 'Reduction of Pain Catastrophizing Mediates the Outcome of Both Physical and Cognitive-Behavioral Treatment in Chronic Low Back Pain'. *The Journal of Pain* 7 (4), 261–271
- Smith, L.K., Weiss, E.L., and Lehmkuhl, L.D. (1996) 'Brunnstrom's "Clinical Kinesiology."' Philadelphia, PA: Davis'. *Google Scholar*
- Snelgrove, J.W., Pikhart, H., and Stafford, M. (2009) 'A Multilevel Analysis of Social Capital and Self-Rated Health: Evidence from the British Household Panel Survey'. *Social Science & Medicine* 68 (11), 1993–2001
- Sohn, C. and Yeo, Y. (2016) 'Enablers for Patients to Adopt Web-Based Personal Health Records (PHR)'. *International Journal of E-Adoption (IJEa)* 8 (1), 1–12
- Al Sokkar, A.A.M. and Law, E.L.-C. (2013) 'In Situ Observations of Non-Verbal Emotional Behaviours for Multimodal Avatar Design in E-Commerce'. in *Proceedings of the International Conference on Multimedia, Interaction, Design and Innovation*. held 2013. 14
- Solomonow, M., Zhou, B.-H., Baratta, R. V, Lu, Y., and Harris, M. (1999) 'Biomechanics of Increased Exposure to Lumbar Injury Caused by Cyclic Loading: Part 1. Loss of Reflexive Muscular Stabilization.' *Spine* 24 (23), 2426–2434
- Somoskeöy, S., Tunyogi-Csapó, M., Bogyó, C., and Illés, T. (2012) 'Accuracy and Reliability of Coronal and Sagittal Spinal Curvature Data Based on Patient-Specific Three-Dimensional Models Created by the EOS 2D/3D Imaging System'. *The Spine Journal* 12 (11), 1052–1059
- Sorensen, C.J., Norton, B.J., Callaghan, J.P., Hwang, C.-T., and Van Dillen, L.R. (2015) 'Is Lumbar Lordosis Related to Low Back Pain Development during Prolonged Standing?' *Manual Therapy* 20 (4), 553–557
- Soucacos, P.N., Souacos, P.K., Zacharis, K.C., Beris, A.E., and Xenakis, T.A. (1997) 'School-Screening for Scoliosis: A Prospective Epidemiological Study in

- Northwestern and Central Greece'. *JBJs* 79 (10), 1498–1503
- Souza, J.A., Pasinato, F., Basso, D., Corrêa, E.C.R., and Silva, A.M.T. da (2011) 'Biophotogrammetry: Reliability of Measurements Obtained with a Posture Assessment Software (SAPO)'. *Revista Brasileira de Cineantropometria & Desempenho Humano* 13 (4), 299–305
- Souza, R.B. and Powers, C.M. (2009) 'Predictors of Hip Internal Rotation during Running: An Evaluation of Hip Strength and Femoral Structure in Women with and without Patellofemoral Pain'. *The American Journal of Sports Medicine* 37 (3), 579–587
- Spaziano, K. (2001) 'Electronic Medical Records'. *Radiologic Technology* 72 (3), 287
- Spinal Deformities* (n.d.) available from <<http://www.zosradio.ba/contents/15036>>
- Srbinoska, H., Dreischarf, M., Consmüller, T., Bergmann, G., and Rohlmann, A. (2013) 'Correlation between Back Shape and Spinal Loads'. *Journal of Biomechanics* 46 (11), 1972–1975
- Staal, J.B., Nelemans, P.J., and de Bie, R.A. (2013) 'Spinal Injection Therapy for Low Back Pain'. *Jama* 309 (23), 2439–2440
- STACHOŃ, A., Burdukiewicz, A., Andrzejewska, J., and Pietraszewska, J. (2012) 'The Imaging and Evaluation of Body Posture Defects in Hearing Impaired Children'. *Bio-Algorithms and Med-Systems* 8 (January), 221–236
- Stagnara, P., De Mauroy, J.C., Dran, G., Gonon, G.P., Costanzo, G., Dimnet, J., and Pasquet, A. (1982) 'Reciprocal Angulation of Vertebral Bodies in a Sagittal Plane: Approach to References for the Evaluation of Kyphosis and Lordosis.' *Spine* 7 (4), 335–342
- Standing, S. and Standing, C. (2008) 'Mobile Technology and Healthcare: The Adoption Issues and Systemic Problems'. *International Journal of Electronic Healthcare* 4 (3–4), 221–235
- Standring, S. (2015) *Gray's Anatomy E-Book: The Anatomical Basis of Clinical Practice*.



- Stankevitz, K., Schoenfisch, A., de Silva, V., Tharindra, H., Stroo, M., and Ostbye, T. (2016) 'Prevalence and Risk Factors of Musculoskeletal Disorders among Sri Lankan Rubber Tappers'. *International Journal of Occupational and Environmental Health* 22 (2), 91–98
- Steenstra, I.A., Verbeek, J.H., Heymans, M.W., and Bongers, P.M. (2005) 'Prognostic Factors for Duration of Sick Leave in Patients Sick Listed with Acute Low Back Pain: A Systematic Review of the Literature'. *Occupational and Environmental Medicine* 62 (12), 851–860
- Sternberg, N., Schnur, E., Huefner, J.C., Muirhead, J., Butler, L., Mihalo, J., Puett, L., Schedin, R., Triplett, D.R., Klee, S., and others (2017) 'A Work in Progress: Electronic Health Record Utilization in Residential Treatment'. *Residential Treatment for Children & Youth* 34 (2), 122–134
- STEWART, M. (1984) 'Patient Characteristics Which Are Related to the Doctor-Patient Interaction'. *Family Practice* 1 (1), 30–36
- Stokes, I.A. and Moreland, M.S. (1989) 'Concordance of Back Surface Asymmetry and Spine Shape in Idiopathic Scoliosis.' *Spine* 14 (1), 73–78
- Stokes, I.A.F. (1994) 'ШЙЃ Three-Dimensional Terminology of Spinal Deformity'. *Spine* 19 (2), 236–248
- Stokes, I.A.F., Armstrong, J.G., and Moreland, M.S. (1988) 'Spinal Deformity and Back Surface Asymmetry in Idiopathic Scoliosis'. *Journal of Orthopaedic Research* 6 (1), 129–137
- Stokes, I.A.F., Pekalsky, J.R., and Moreland, M.S. (1987) 'Surface Topography and Spinal Deformity'. in *Proceedings of the 4-Th International Symposium. New York, Gustaw Verlag. held 1987*
- Stolberg, H.O., Norman, G., and Trop, I. (2004) 'Randomized Controlled Trials'. *American*

*Journal of Roentgenology* 183 (6), 1539–1544

Stoliński, Ł., Czaprowski, D., Kozinoga, M., and Kotwicki, T. (2014) 'Clinical Measurement of Sagittal Trunk Curvatures: Photographic Angles versus Rippstein Plurimeter Angles in Healthy School Children'. *Scoliosis* 9 (1), O15

Street, R.L. (1992) 'Communicative Styles and Adaptations in Physician-Parent Consultations'. *Social Science & Medicine* 34 (10), 1155–1163

*Structure Sensor* (2016) available from <<https://structure.io/developers>> [6 January 2017]

Su, Z., Wang, X., Chen, Z., Ye, L., and Wang, D. (2006) 'A Built-in Active Sensor Network for Health Monitoring of Composite Structures'. *Smart Materials and Structures* 15 (6), 1939

Subramanian, G.H. (1994) 'A Replication of Perceived Usefulness and Perceived Ease of Use Measurement'. *Decision Sciences* 25 (5–6), 863–874

Succi, M.J. and Walter, Z.D. (1999) 'Theory of User Acceptance of Information Technologies: An Examination of Health Care Professionals'. in *Systems Sciences, 1999. HICSS-32. Proceedings of the 32nd Annual Hawaii International Conference on*. held 1999. 7--pp

Sultan, N. (2015) 'Reflective Thoughts on the Potential and Challenges of Wearable Technology for Healthcare Provision and Medical Education'. *International Journal of Information Management* 35 (5), 521–526

Sun, H. and Zhang, P. (2008) 'An Exploration of Affect Factors and Their Role in User Technology Acceptance: Mediation and Causality'. *Journal of the Association for Information Science and Technology* 59 (8), 1252–1263

Sundararajan, V., Bunker, S.J., Begg, S., Marshall, R., McBurney, H., and others (2004) 'Attendance Rates and Outcomes of Cardiac Rehabilitation in Victoria, 1998'. *Medical Journal of Australia* 180 (6), 268–272

*Surface Landmarks of Human Body (Back View)* (n.d.) available from

<<http://language.log.idc.upenn.edu/nll/?p=3157>>

*Surface Landmarks of Human Body (Front View)* (n.d.) available from  
<<http://fredhatt.com/blog/2010/06/20/exercising-perception/>>

Sutkowski, M., Paško, S., and Žuk, B. (2017) 'A Study of Interdependence of Geometry of the Nuchal Neck Triangle and Cervical Spine Line in the Habitual and Straightened Postures'. *Journal of the Anatomical Society of India* 66 (1), 31–36

Suzuki, H., Endo, K., Kobayashi, H., Tanaka, H., and Yamamoto, K. (2010) 'Total Sagittal Spinal Alignment in Patients with Lumbar Canal Stenosis Accompanied by Intermittent Claudication'. *Spine* 35 (9), E344--E346

Swinkels-Meewisse, E., Swinkels, R., Verbeek, A.L.M., Vlaeyen, J.W.S., and Oostendorp, R.A.B. (2003) 'Psychometric Properties of the Tampa Scale for Kinesiophobia and the Fear-Avoidance Beliefs Questionnaire in Acute Low Back Pain'. *Manual Therapy* 8 (1), 29–36

Szajna, B. (1994) 'Software Evaluation and Choice: Predictive Validation of the Technology Acceptance Instrument'. *MIS Quarterly* 319–324

Tabachnick, B.G. and Fidell, L.S. (2007) *Using Multivariate Statistics*. Allyn & Bacon/Pearson Education

Talasila, S.S.A., Gorantla, M., and Thomas, V. (2017) 'A Study on Screening for Scoliosis among School Children in the Age Group of 10-14 Using a Cost Effective and an Innovative Technique'. *International Journal Of Community Medicine And Public Health* 4 (6), 2118–2123

Taneva, E., Kusnoto, B., and Evans, C.A. (2015) '3D Scanning, Imaging, and Printing in Orthodontics'. *Issues in Contemporary Orthodontics* 148

Tao, W., Liu, T., Zheng, R., and Feng, H. (2012) 'Gait Analysis Using Wearable Sensors'. *Sensors* 12 (2), 2255–2283

Taylor, S. and Todd, P.A. (1995) 'Understanding Information Technology Usage: A Test

- of Competing Models'. *Information Systems Research* 6 (2), 144–176
- Teddlie, C. and Tashakkori, A. (2009) *Foundations of Mixed Methods Research: Integrating Quantitative and Qualitative Approaches in the Social and Behavioral Sciences*. Sage
- Teo, T. and Noyes, J. (2011) 'An Assessment of the Influence of Perceived Enjoyment and Attitude on the Intention to Use Technology among Pre-Service Teachers: A Structural Equation Modeling Approach'. *Computers & Education* 57 (2), 1645–1653
- Thelin, A., Holmberg, S., and Thelin, N. (2008) 'Functioning in Neck and Low Back Pain from a 12-Year Perspective: A Prospective Population-Based Study'. *Journal of Rehabilitation Medicine* 40 (7), 555–561
- Thewlis, D., Bishop, C., Daniell, N., and Paul, G. (2013) 'Next-Generation Low-Cost Motion Capture Systems Can Provide Comparable Spatial Accuracy to High-End Systems'. *Journal of Applied Biomechanics* 29 (1), 112–117
- Thigpen, C.A., Padua, D.A., Michener, L.A., Guskiewicz, K., Giuliani, C., Keener, J.D., and Stergiou, N. (2010) 'Head and Shoulder Posture Affect Scapular Mechanics and Muscle Activity in Overhead Tasks'. *Journal of Electromyography and Kinesiology* 20 (4), 701–709
- Thilagaratnam, S. (2007) 'School-Based Screening for Scoliosis: Is It Cost-Effective?' *Singapore Medical Journal* 48 (11), 1012
- Thoomes-de Graaf, M., Scholten-Peeters, G.G.M., Duijn, E., Karel, Y.H.J.M., van den Borne, M.P.J., Beumer, A., Ottenheijm, R.P.G., Dinant, G.J., Tetteroo, E., Lucas, C., and others (2014) 'Inter-Professional Agreement of Ultrasound-Based Diagnoses in Patients with Shoulder Pain between Physical Therapists and Radiologists in the Netherlands'. *Manual Therapy* 19 (5), 478–483
- Tomkinson, G.R. and Shaw, L.G. (2013) 'Quantification of the Postural and Technical Errors in Asymptomatic Adults Using Direct 3D Whole Body Scan Measurements of

- Standing Posture'. *Gait & Posture* 37 (2), 172–177
- Torell, G., Nordwall, A., and Nachemson, A. (1981) 'The Changing Pattern of Scoliosis Treatment due to Effective Screening.' *J Bone Joint Surg Am* 63 (3), 337–341
- Tortschanoff, A., Fritz, A., and Leitner, R. (2014) 'Compact Low-Cost Scanner for 3D-Reconstruction of Body Parts with Structured Light Illumination'. *International Journal of Bio-Science and Bio-Technology* 6 (5), 13–22
- Traeger, A.C., Hübscher, M., Henschke, N., Moseley, G.L., Lee, H., and McAuley, J.H. (2015) 'Effect of Primary Care–Based Education on Reassurance in Patients With Acute Low Back Pain'. *JAMA Internal Medicine* [online] 175 (5), 733. available from <<http://archinte.jamanetwork.com/article.aspx?doi=10.1001/jamainternmed.2015.0217>>
- Treweek, S.P., Glenton, C., Oxman, A.D., and Penrose, A. (2002) 'Computer-Generated Patient Education Materials: Do They Affect Professional Practice? A Systematic Review'. *Journal of the American Medical Informatics Association* 9 (4), 346–358
- Van Tulder, M., Becker, A., Bekkering, T., Breen, A., del Real, M.T., Hutchinson, A., Koes, B., Laerum, E., and Malmivaara, A. (2006) 'Chapter 3 European Guidelines for the Management of Acute Nonspecific Low Back Pain in Primary Care'. *European Spine Journal* 15, s169--s191
- Van Tulder, M.W., Koes, B.W., and Bouter, L.M. (1997) 'Conservative Treatment of Acute and Chronic Nonspecific Low Back Pain: A Systematic Review of Randomized Controlled Trials of the Most Common Interventions'. *Spine* 22 (18), 2128–2156
- Van Tulder, M.W., Malmivaara, A., Esmail, R., Koes, B.W., and others (2000) 'Exercise Therapy for Low Back Pain'. *Cochrane Database Syst Rev* 2, CD000335
- Turner-Smith, A.R., Harris, J.D., Abery, J.M., and Osborne, M. (1981) 'Back Shape Measurement'. *Oxford Orthopaedic Engineering Centre: Annual Report* 8, 41–49
- Turner-Smith, A.R., Harris, J.D., Houghton, G.R., and Jefferson, R.J. (1988) 'A Method

- for Analysis of Back Shape in Scoliosis'. *Journal of Biomechanics* 21 (6), 497–509
- Tveit, P., Daggfeldt, K., Hetland, S., and Thorstensson, A. (1994) 'Erector Spinae Lever Arm Length Variations with Changes in Spinal Curvature.' *Spine* 19 (2), 199–204
- Tveito, T.H., Hysing, M., and Eriksen, H.R. (2004) 'Low Back Pain Interventions at the Workplace: A Systematic Literature Review'. *Occupational Medicine* 54 (1), 3–13
- Tyson, S.F. and DeSouza, L.H. (2003) 'A Clinical Model for the Assessment of Posture and Balance in People with Stroke'. *Disability and Rehabilitation* 25 (3), 120–126
- Uetake, T., Ohtsuki, F., Tanaka, H., and Shindo, M. (1998) 'The Vertebral Curvature of Sportsmen'. *Journal of Sports Sciences* 16 (7), 621–628
- Vaezi, R., Mills, A., Chin, W., and Zafar, H. (2016) 'User Satisfaction Research in Information Systems: Historical Roots and Approaches.' *CAIS* 38, 27
- Valat, J.-P., Goupille, P., and Védere, V. (1997) 'Low Back Pain: Risk Factors for Chronicity.' *Revue Du Rhumatisme (English Ed.)* 64 (3), 189–194
- Valenzuela-Pascual, F., Molina, F., Corbi, F., Blanco-Blanco, J., Gil, R.M., and Soler-Gonzalez, J. (2015) 'The Influence of a Biopsychosocial Educational Internet-Based Intervention on Pain, Dysfunction, Quality of Life, and Pain Cognition in Chronic Low Back Pain Patients in Primary Care: A Mixed Methods Approach'. *BMC Medical Informatics and Decision Making* 15 (1), 97
- Valgma, L. (2016) *Lembit Valgma 3D Reconstruction Using Kinect v2 Camera*.
- Vardeh, D., Mannion, R.J., and Woolf, C.J. (2016) 'Toward a Mechanism-Based Approach to Pain Diagnosis'. *Journal of Pain* [online] 17 (9), T50–T69. available from <<http://dx.doi.org/10.1016/j.jpain.2016.03.001>>
- Venkatesh, V. (2000) 'Determinants of Perceived Ease of Use: Integrating Control, Intrinsic Motivation, and Emotion into the Technology Acceptance Model'. *Information Systems Research* 11 (4), 342–365

- Venkatesh, V. and Bala, H. (2008) 'Technology Acceptance Model 3 and a Research Agenda on Interventions'. *Decision Sciences* 39 (2), 273–315
- Venkatesh, V. and Davis, F.D. (2000) 'A Theoretical Extension of the Technology Acceptance Model: Four Longitudinal Field Studies'. *Management Science* 46 (2), 186–204
- Venkatesh, V., Morris, M.G., Davis, G.B., and Davis, F.D. (2003) 'User Acceptance of Information Technology: Toward a Unified View'. *MIS Quarterly* 425–478
- Venkatesh, V., Thong, J.Y.L., and Xu, X. (2012) 'Consumer Acceptance and Use of Information Technology: Extending the Unified Theory of Acceptance and Use of Technology'. *MIS Quarterly* 157–178
- Ventola, C.L. (2014) 'Medical Applications for 3D Printing: Current and Projected Uses'. *Pharmacy and Therapeutics* 39 (10), 704
- Verbeek, J., Sengers, M.-J., Riemens, L., and Haafkens, J. (2004) 'Patient Expectations of Treatment for Back Pain: A Systematic Review of Qualitative and Quantitative Studies'. *Spine* 29 (20), 2309–2318
- Vernon, H. (1983) 'An Assessment of the Intra-and Inter-Reliability of the Posturometer'. *Journal of Manipulative and Physiological Therapeutics* 6 (2), 57–60
- Vialle, R., Levassor, N., Rillardon, L., Templier, A., Skalli, W., and Guigui, P. (2005) 'Radiographic Analysis of the Sagittal Alignment and Balance of the Spine in Asymptomatic Subjects'. *JBJS* 87 (2), 260–267
- Viazzi, S., Bahr, C., Van Hertem, T., Schlageter-Tello, A., Romanini, C.E.B., Halachmi, I., Lokhorst, C., and Berckmans, D. (2014) 'Comparison of a Three-Dimensional and Two-Dimensional Camera System for Automated Measurement of Back Posture in Dairy Cows'. *Computers and Electronics in Agriculture* 100, 139–147
- Vibe Fersum, K., O'Sullivan, P., Skouen, J.S., Smith, A., and Kvåle, A. (2013) 'Efficacy of Classification-Based Cognitive Functional Therapy in Patients with Non-Specific

- Chronic Low Back Pain: A Randomized Controlled Trial'. *European Journal of Pain* 17 (6), 916–928
- Vlaeyen, J.W.S. and Linton, S.J. (2000) 'Fear-Avoidance and Its Consequences in Chronic Musculoskeletal Pain: A State of the Art'. *Pain* 85 (3), 317–332
- Voinea, G.-D., Butnariu, S., and Mogan, G. (2016) 'Measurement and Geometric Modelling of Human Spine Posture for Medical Rehabilitation Purposes Using a Wearable Monitoring System Based on Inertial Sensors'. *Sensors* 17 (1), 3
- Vos, T., Barber, R.M., Bell, B., Bertozzi-Villa, A., Biryukov, S., Bolliger, I., Charlson, F., Davis, A., Degenhardt, L., Dicker, D., and others (2015) 'Global, Regional, and National Incidence, Prevalence, and Years Lived with Disability for 301 Acute and Chronic Diseases and Injuries in 188 Countries, 1990--2013: A Systematic Analysis for the Global Burden of Disease Study 2013'. *The Lancet* 386 (9995), 743–800
- Vos, T., Carter, R., Barendregt, J., Mihalopoulos, C., Veerman, L., Magnus, A., Cobiac, L., Bertram, M., and Wallace, A. (2010) *Assessing Cost-Effectiveness in Prevention: ACE--Prevention September 2010 Final Report*. University of Queensland
- Vos, T., Flaxman, A.D., Naghavi, M., Lozano, R., Michaud, C., Ezzati, M., Shibuya, K., Salomon, J.A., Abdalla, S., Aboyans, V., and others (2012) 'Years Lived with Disability (YLDs) for 1160 Sequelae of 289 Diseases and Injuries 1990--2010: A Systematic Analysis for the Global Burden of Disease Study 2010'. *The Lancet* 380 (9859), 2163–2196
- Vrtovec, T., Janssen, M.M.A., Likar, B., Castelein, R.M., Viergever, M.A., and Pernuš, F. (2012) 'A Review of Methods for Evaluating the Quantitative Parameters of Sagittal Pelvic Alignment'. *The Spine Journal* 12 (5), 433–446
- Vrtovec, T., Pernuš, F., and Likar, B. (2009) 'A Review of Methods for Quantitative Evaluation of Spinal Curvature'. *European Spine Journal* 18 (5), 593–607
- Waddell, G. and Burton, A.K. (2001) 'Occupational Health Guidelines for the



- Management of Low Back Pain at Work: Evidence Review'. *Occupational Medicine* 51 (2), 124–135
- Waddell, G., O'Connor, M., Boorman, S., and Torsney, B. (2007) 'Working Backs Scotland: A Public and Professional Health Education Campaign for Back Pain'. *Spine* 32 (19), 2139–2143
- Walczuch, R., Lemmink, J., and Streukens, S. (2007) 'The Effect of Service Employees' Technology Readiness on Technology Acceptance'. *Information & Management* 44 (2), 206–215
- Wall, M.S. and Wall, M.R. (2006) *Melzack's Textbook of Pain*. Philadelphia: Elsevier, Churchill Livingstone
- Wang, M.Y. and Mummaneni, P. V (2010) 'Minimally Invasive Surgery for Thoracolumbar Spinal Deformity: Initial Clinical Experience with Clinical and Radiographic Outcomes'. *Neurosurgical Focus* 28 (3), E9
- Ward, R. (2013) 'The Application of Technology Acceptance and Diffusion of Innovation Models in Healthcare Informatics'. *Health Policy and Technology* 2 (4), 222–228
- Warren, J.G., Bettany-Saltikov, J.A., Van Schaik, P., and Papastefanou, S.L. (2002) '3-D Measurement of Posture and Back Shape Using a Low Cost, Portable System-a Reliability Study'. *Studies in Health Technology and Informatics* 100–104
- Watkins-Castillo, S. and Andersson, G. (2014) 'United States Bone and Joint Initiative: The Burden of Musculoskeletal Diseases in the United States (BMUS)'. *Burd Musculoskelet Dis Int He United States*
- Watson, A.W.S. and Mac Donncha, C. (2000) 'A Reliable Technique for the Assessment of Posture: Assessment Criteria for Aspects of Posture'. *Journal of Sports Medicine and Physical Fitness* 40 (3), 260
- Weisz, I., Jefferson, R.J., Turner-Smith, A.R., Houghton, G.R., and Harris, J.D. (1988) 'ISIS Scanning: A Useful Assessment Technique in the Management of Scoliosis.'

- Whitfill, T., Haggard, R., Bierner, S.M., Pransky, G., Hassett, R.G., and Gatchel, R.J. (2010) 'Early Intervention Options for Acute Low Back Pain Patients: A Randomized Clinical Trial with One-Year Follow-up Outcomes'. *Journal of Occupational Rehabilitation* 20 (2), 256–263
- Williams, D.S. and McClay, I.S. (2000) 'Measurements Used to Characterize the Foot and the Medial Longitudinal Arch: Reliability and Validity'. *Physical Therapy* 80 (9), 864–871
- Williamson, E. (2006) 'Fear Avoidance Beliefs Questionnaire (FABQ)'. *Aust J Physiother* 52 (2), 149
- Willner, S. (1981) 'Spinal Pantograph-a Non-Invasive Technique for Describing Kyphosis and Lordosis in the Thoraco-Lumbar Spine'. *Acta Orthopaedica Scandinavica* 52 (5), 525–529
- Willner, S. and Udén, A. (1982) 'A Prospective Prevalence Study of Scoliosis in Southern Sweden'. *Acta Orthopaedica Scandinavica* 53 (2), 233–237
- Wilson, K.G. and Murrell, A.R. (2004) 'Values Work in Acceptance and Commitment Therapy'. *Mindfulness and Acceptance: Expanding the Cognitive-Behavioral Tradition* 120–151
- Winefield, H., Murrell, T., Clifford, J., and Farmer, E. (1996) 'The Search for Reliable and Valid Measures of Patient-Centredness'. *Psychology and Health* 11 (6), 811–824
- Winter, D.A. (2009) *Biomechanics and Motor Control of Human Movement*. John Wiley & Sons
- Wissow, L.S., Roter, D., Bauman, L.J., Crain, E., Kercsmar, C., Weiss, K., Mitchell, H., Mohr, B., and others (1998) 'Patient-Provider Communication during the Emergency Department Care of Children with Asthma'. *Medical Care* 36 (10), 1439–1450
- Wixom, B.H. and Todd, P.A. (2005) 'A Theoretical Integration of User Satisfaction and

- Technology Acceptance'. *Information Systems Research* 16 (1), 85–102
- Wojtys, E.M., Ashton-Miller, J.A., Huston, L.J., and Moga, P.J. (2000) 'The Association between Athletic Training Time and the Sagittal Curvature of the Immature Spine'. *The American Journal of Sports Medicine* 28 (4), 490–498
- Wong, P., Chamari, K., Chaouachi, A., Mao, D.W., Wisløff, U., and Hong, Y. (2007) 'Difference in Plantar Pressure between the Preferred and Non-Preferred Feet in Four Soccer-Related Movements.' *British Journal of Sports Medicine* [online] 41 (2), 84–92. available from <<http://www.pubmedcentral.nih.gov/articlerender.fcgi?artid=2658925&tool=pmcentrez&rendertype=abstract>> [26 March 2013]
- Wong Wai, Y. (2007) *DEVELOPMENT OF A POSTURE MONITORING SYSTEM*. The Hong Kong Polytechnic University
- Wongsa, S., Amatachaya, P., Saengsuwan, J., and Amatachaya, S. (2012) 'Concurrent Validity of Occiput-Wall Distance to Measure Kyphosis in Communities'. *J Clin Trials* 2 (111), 870–2167
- Wright, M.D., Flanagan, M.E., Kunjan, K., Doebbeling, B.N., and Toscos, T. (2016) 'Missing Links: Challenges in Engaging the Underserved with Health Information and Communication Technology'. in *Proceedings of the 10th EAI International Conference on Pervasive Computing Technologies for Healthcare*. held 2016. 122–129
- Wu, J.-H., Shen, W.-S., Lin, L.-M., Greenes, R.A., and Bates, D.W. (2008) 'Testing the Technology Acceptance Model for Evaluating Healthcare Professionals' Intention to Use an Adverse Event Reporting System'. *International Journal for Quality in Health Care* 20 (2), 123–129
- Wu, W., Liang, J., Du, Y., Tan, X., Xiang, X., Wang, W., Ru, N., and Le, J. (2014) 'Reliability and Reproducibility Analysis of the Cobb Angle and Assessing Sagittal Plane by Computer-Assisted and Manual Measurement Tools'. *BMC*

- Wyatt, J.C. and Wyatt, S.M. (2003) 'When and How to Evaluate Health Information Systems?' *International Journal of Medical Informatics* 69 (2–3), 251–259
- Xu, J., Xi, N., Zhang, C., Shi, Q., and Gregory, J. (2011) 'Real-Time 3D Shape Inspection System of Automotive Parts Based on Structured Light Pattern'. *Optics and Laser Technology* 43 (1), 1–8
- Yanagawa, T.L., Maitland, M.E., Burgess, K., Young, L., and Hanley, D. (2000) 'Assessment of Thoracic Kyphosis Using the Flexicurve for Individuals with Osteoporosis'. *Hong Kong Physiotherapy Journal* 18 (2), 53–57
- Yap, Y.L. and Yeong, W.Y. (2014) 'Additive Manufacture of Fashion and Jewellery Products: A Mini Review: This Paper Provides an Insight into the Future of 3D Printing Industries for Fashion and Jewellery Products'. *Virtual and Physical Prototyping* 9 (3), 195–201
- Yeung, S.S. (2012) 'Factors Contributing to Work Related Low Back Pain among Personal Care Workers in Old Age'. *Work* 41 (Supplement 1), 1873–1883
- Yi, M.Y., Fiedler, K.D., and Park, J.S. (2006) 'Understanding the Role of Individual Innovativeness in the Acceptance of IT-Based Innovations: Comparative Analyses of Models and Measures'. *Decision Sciences* 37 (3), 393–426
- Yip, C.H.T., Chiu, T.T.W., and Poon, A.T.K. (2008) 'The Relationship between Head Posture and Severity and Disability of Patients with Neck Pain'. *Manual Therapy* 13 (2), 148–154
- Zaina, F., Negrini, S., and Atanasio, S. (2009) 'TRACE (Trunk Aesthetic Clinical Evaluation), a Routine Clinical Tool to Evaluate Aesthetics in Scoliosis Patients: Development from the Aesthetic Index (AI) and Repeatability'. *Scoliosis* 4 (1), 3
- Zhang, M., Luo, M., Nie, R., and Zhang, Y. (2017) 'Technical Attributes, Health Attribute, Consumer Attributes and Their Roles in Adoption Intention of Healthcare Wearable

- Technology'. *International Journal of Medical Informatics* 108, 97–109
- Zhang, Y., Chen, Y., Huang, H., Sandler, J., Dai, M., Ma, S., and Udelsman, R. (2015) 'Diagnostic X-Ray Exposure Increases the Risk of Thyroid Microcarcinoma: A Population-Based Case-Control Study'. *European Journal of Cancer Prevention: The Official Journal of the European Cancer Prevention Organisation (ECP)* 24 (5), 439
- Zhang, Z. (2012) 'Microsoft Kinect Sensor and Its Effect'. *IEEE Multimedia* 19 (2), 4–10
- Zheng, X., Chaudhari, R., Wu, C., Mehbod, A.A., Transfeldt, E.E., and Winter, R.B. (2010) 'Repeatability Test of C7 Plumb Line and Gravity Line on Asymptomatic Volunteers Using an Optical Measurement Technique'. *Spine* 35 (18), E889--E894
- Zubović, A., Davies, N., Berryman, F., Pynsent, P., Quraishi, N., Lavy, C., Bowden, G., Wilson-Macdonald, J., and Fairbank, J. (2008) 'New Method of Scoliosis Deformity Assessment: ISIS2 System.' *Studies in Health Technology and Informatics* 140, 157–160
- Zvolensky, M.J., Goodie, J.L., McNeil, D.W., Sperry, J.A., and Sorrell, J.T. (2001) 'Anxiety Sensitivity in the Prediction of Pain-Related Fear and Anxiety in a Heterogeneous Chronic Pain Population'. *Behaviour Research and Therapy* 39 (6), 683–696

# Appendices

## Appendix 1. Background Questionnaire (Self Rating of Technology) (Chapter 5)

### Section I: Personal Information

1. What's your age?

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2. Gender:

☐ Male

☐ Female

3. In terms of your current occupation,  
what is your title and scope of practice?  
(Please tick that applies to you)

☐ Physiotherapist

☐ Occupational Therapist

☐ Sports Therapist

☐ ~~Chiropractor~~

☐ Osteopaths

☐ Massage Therapist

☐ Other, Please specify \_\_\_\_\_

4. What is your highest educational  
level achieved?

☐ BSc

☐ MSc

☐ MPhil

☐ Doctorate

☐ Other, Please specify \_\_\_\_\_

5. On an average how many hours do you use digital technology (for example  
using PC or smart phone for internet browsing, email, social activities) in  
your day to day activities at home and at work?

☐ 2 - 4 hours

☐ 4 - 6 hours

☐ 6 - 8 hours

☐ 8 -10 hours

☐ 10 -12 hours

☐ >12 hours

6. How many years of clinical experience do you have?

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7. Using the table below, please indicate how you would rate your level of digital technology expertise (for example using PC or smart phone for internet browsing, email, social activities)

Very low	Low	Average	High	Very High
1	2	3	4	5

Very low expertise	Little to no experience or understanding of digital technology
Low expertise	Infrequent and basic use of digital technology. Able to perform basic tasks at home or in a workplace. For instance, emailing.
Average expertise	Comfortable and frequent use of digital technology
High expertise	Confident and daily use of digital technology Able to use multiple devices such as computers, tablets, smart phones etc.,
Very high expertise	Specialist use and knowledge of digital technology



## Appendix 2. Pre-Expectation Questionnaire



Participant Name: \_\_\_\_\_ Date: \_\_\_\_\_

### Appendix 4: Expectation Measurement Questionnaire

Please complete this survey. All information will be kept confidential. Any concerns can be communicated to (Person, contact info). Thank you for your time and cooperation.

Answer the following questions by circling the most appropriate answer

1. I expect that the new method of capturing and analysing 3D back shape using Structure Sensor<sup>TM</sup> and Netfabb basic software will enable me to accomplish tasks more quickly.

*Strongly Disagree*   *Disagree*   *Neutral*   *Agree*   *Strongly Agree*

2. I expect that the new method of capturing and analysing 3D back shape using Structure Sensor<sup>TM</sup> and Netfabb basic software will improve the quality of the work I do.

*Strongly Disagree*   *Disagree*   *Neutral*   *Agree*   *Strongly Agree*

3. I expect that the new method of capturing and analysing 3D back shape using Structure Sensor<sup>TM</sup> and Netfabb basic software will make it easier to do my job.

*Strongly Disagree*   *Disagree*   *Neutral*   *Agree*   *Strongly Agree*

4. I expect that the new method of capturing and analysing 3D back shape using Structure Sensor<sup>TM</sup> and Netfabb basic software will enhance my effectiveness on the job.

*Strongly Disagree*   *Disagree*   *Neutral*   *Agree*   *Strongly Agree*

5. I expect that the new method of capturing and analysing 3D back shape using Structure Sensor<sup>TM</sup> and Netfabb basic software will give me greater control over my job.

*Strongly Disagree*   *Disagree*   *Neutral*   *Agree*   *Strongly Agree*

6. I expect that the new method of capturing and analysing 3D back shape using Structure Sensor<sup>TM</sup> and Netfabb basic software will improve my productivity.

Participant Name: \_\_\_\_\_ Date: \_\_\_\_\_

*Strongly Disagree*   *Disagree*   *Neutral*   *Agree*   *Strongly Agree*

7. I expect that it will be easy to get the new method of capturing and analysing 3D back shape using Structure Sensor™ and Netfabb basic software to do what I want it to do.

*Strongly Disagree*   *Disagree*   *Neutral*   *Agree*   *Strongly Agree*

8. I expect that overall, the new method of capturing and analysing 3D back shape using Structure Sensor™ and Netfabb basic software will be easy to use.

*Strongly Disagree*   *Disagree*   *Neutral*   *Agree*   *Strongly Agree*

9. I expect that learning to operate the new method of capturing and analysing 3D back shape using Structure Sensor™ and Netfabb basic software will be easy for me.

*Strongly Disagree*   *Disagree*   *Neutral*   *Agree*   *Strongly Agree*

10. I expect that interacting with the new method of capturing and analysing 3D back shape using Structure Sensor™ and Netfabb basic software will not require a lot of my mental effort.

*Strongly Disagree*   *Disagree*   *Neutral*   *Agree*   *Strongly Agree*

**Any other additional comments?**

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### Appendix 3. Post-Expectation Questionnaire



Participant Name: \_\_\_\_\_ Date: \_\_\_\_\_

#### Appendix 5: Experience Measurement Questionnaire

Please complete this survey. All information will be kept confidential. Any concerns can be communicated to (Person, contact info). Thank you for your time and cooperation.

Answer the following questions by circling the most appropriate answer

1. The new method of capturing and analysing 3D back shape using Structure Sensor<sup>TM</sup> and Netfabb basic software enables me to accomplish tasks more quickly.  
*Strongly Disagree*   *Disagree*   *Neutral*   *Agree*   *Strongly Agree*
2. The new method of capturing and analysing 3D back shape using Structure Sensor<sup>TM</sup> and Netfabb basic software improves the quality of the work I do.  
*Strongly Disagree*   *Disagree*   *Neutral*   *Agree*   *Strongly Agree*
3. The new method of capturing and analysing 3D back shape using Structure Sensor<sup>TM</sup> and Netfabb basic software makes it easier to do my job.  
*Strongly Disagree*   *Disagree*   *Neutral*   *Agree*   *Strongly Agree*
4. The new method of capturing and analysing 3D back shape using Structure Sensor<sup>TM</sup> and Netfabb basic software enhances my effectiveness on the job.  
*Strongly Disagree*   *Disagree*   *Neutral*   *Agree*   *Strongly Agree*
5. The new method of capturing and analysing 3D back shape using Structure Sensor<sup>TM</sup> and Netfabb basic software gives me greater control over my job.  
*Strongly Disagree*   *Disagree*   *Neutral*   *Agree*   *Strongly Agree*
6. The new method of capturing and analysing 3D back shape using Structure Sensor<sup>TM</sup> and Netfabb basic software improves my productivity.  
*Strongly Disagree*   *Disagree*   *Neutral*   *Agree*   *Strongly Agree*
7. It is easy to get the new method of capturing and analysing 3D back shape using Structure Sensor<sup>TM</sup> and Netfabb basic software to do what I want it to do.  
*Strongly Disagree*   *Disagree*   *Neutral*   *Agree*   *Strongly Agree*
8. Overall, the new method of capturing and analysing 3D back shape using Structure Sensor<sup>TM</sup> and Netfabb basic software is easy to use.

Participant Name: \_\_\_\_\_ Date: \_\_\_\_\_

~~Strongly Disagree~~   ~~Disagree~~   ~~Neutral~~   ~~Agree~~   ~~Strongly Agree~~

9. Learning to operate the new method of capturing and analysing 3D back shape using Structure Sensor™ and Netfabb basic software is easy for me.

~~Strongly Disagree~~   ~~Disagree~~   ~~Neutral~~   ~~Agree~~   ~~Strongly Agree~~

10. Interacting with the new method of capturing and analysing 3D back shape using Structure Sensor™ and Netfabb basic software does not require a lot of my mental effort.

~~Strongly Disagree~~   ~~Disagree~~   ~~Neutral~~   ~~Agree~~   ~~Strongly Agree~~

11. I am an enthusiastic user of the new method of capturing and analysing 3D back shape using Structure Sensor™ and Netfabb basic software.

~~Strongly Disagree~~   ~~Disagree~~   ~~Neutral~~   ~~Agree~~   ~~Strongly Agree~~

12. All things considered, my continuing to use the new method of capturing and analysing 3D back shape using Structure Sensor™ and Netfabb basic software in my job is (Extremely Negative to Extremely Positive).

~~Extremely Negative~~   ~~Negative~~   ~~Neutral~~   ~~Positive~~   ~~Extremely Positive~~

13. All things considered, my continuing to use the new method of capturing and analysing 3D back shape using Structure Sensor™ and Netfabb basic software in my job is (Extremely Bad to Extremely Good).

~~Extremely Bad~~   ~~Bad~~   ~~Neutral~~   ~~Good~~   ~~Extremely Good~~

14. All things considered, my continuing to use the new method of capturing and analysing 3D back shape using Structure Sensor™ and Netfabb basic software in my job is (Extremely Harmful to Extremely Beneficial).

~~Extremely Harmful~~   ~~Harmful~~   ~~Neutral~~   ~~Beneficial~~   ~~Extremely Beneficial~~

Participant Name: \_\_\_\_\_ Date: \_\_\_\_\_

*Imagine that the new method was continually available to you for use at the place of your practice. Now answer the following three questions.*

15. I intend to continue using the new method of capturing and analysing 3D back shape using Structure Sensor™ and Netfabb basic software.

*Strongly Disagree   Disagree   Neutral   Agree   Strongly Agree*

16. I predict I would continue using the new method of capturing and analysing 3D back shape using Structure Sensor™ and Netfabb basic software.

*Strongly Disagree   Disagree   Neutral   Agree   Strongly Agree*

17. I plan to continue using the new method of capturing and analysing 3D back shape using Structure Sensor™ and Netfabb basic software.

*Strongly Disagree   Disagree   Neutral   Agree   Strongly Agree*

18. I find using Structure Sensor™ and Netfabb basic software to capture and analyse 3D back shape to be enjoyable.

*Strongly Disagree   Disagree   Neutral   Agree   Strongly Agree*

19. The actual process of using Structure Sensor™ and Netfabb basic software to capture and analyse 3D back shape is pleasant.

*Strongly Disagree   Disagree   Neutral   Agree   Strongly Agree*

20. I have fun using Structure Sensor™ and Netfabb basic software to capture and analyse 3D back shape.

*Strongly Disagree   Disagree   Neutral   Agree   Strongly Agree*

*Imagine that the new method was mandatory in your practice. Now answer the following three questions*

21. I will not comply with the change to the new way of capturing and analysing 3D back shape using Structure Sensor™ and Netfabb basic software.

*Strongly Disagree   Disagree   Neutral   Agree   Strongly Agree*

22. I will not cooperate with the change to the new way of capturing and analysing 3D back shape using Structure Sensor™ and Netfabb basic software

*Strongly Disagree   Disagree   Neutral   Agree   Strongly Agree*

Participant Name: \_\_\_\_\_ Date: \_\_\_\_\_

23. I oppose the change to the new way of capturing and analysing 3D back  
shape using Structure Sensor™ and Netfabb basic software

*Strongly Disagree*   *Disagree*   *Neutral*   *Agree*   *Strongly Agree*

24. I do not agree with the change to the new way of capturing and analysing 3D  
back shape using Structure Sensor™ and Netfabb basic software

*Strongly Disagree*   *Disagree*   *Neutral*   *Agree*   *Strongly Agree*

## Appendix 4. Interview questions



Participant Name: \_\_\_\_\_ Date: \_\_\_\_\_

### Interview Questions

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1. What is your impression of the proposed tool to measure and analyse back shape?
2. What particular aspect(s) of the tool did you *like*?
3. What particular aspect(s) of tool did you *dislike*?
4. Did this tool meet your expectations?
5. Imagine this tool were continually available to you to use at the place of your clinical practice, will you use this tool in your day to day patient assessment?



Participant Name: \_\_\_\_\_ Date: \_\_\_\_\_

6. How long does it take you to (a) capture|and (b) ~~analyse~~ data?

7. What are the practical implications of the using this new method in patient screening, for example in terms of time consumption in your clinical practice?

8. Was this tool affordable for use it in your clinical practice

8. Any other comments?



## Appendix 5. Participant Information Sheet (Chapter 6)



### Participant Information Sheet

**Study Title:** Evaluation of Patient Education for Patients with Low back Pain

**Background to the study:**

Low Back Pain (LBP) is one of the leading causes globally of years lived with disability. Almost all adults once in their lifetime complain about LBP, but 10% to 15% develop chronic LBP. Persisting pain for several weeks predicts the development of chronic low back pain, a condition where complete recovery and return to 100% function are often difficult to achieve. Psychological factors are also believed to influence the development of chronic low back pain.

**What is the purpose of the study?**

The aims of this study are firstly to determine the effect of educational booklet on the perception of pain in people with low back pain; and secondly to determine whether any improvement in pain scores are associated with change in behaviour during activities of daily living in the same population.

**Why have I been chosen?**

You have been chosen because you have been experiencing nonspecific LBP for a minimum of 4-12 weeks and report at least a moderate level pain, recorded as 3 or above on a numeric pain rating scale.

**Who is responsible for the study?**

The research is being conducted by Gok Kandasamy, supervised by ~~www~~ Prof. Iain Spears.

**What will happen to me if I take part?**

*All the participants will be given an educational booklet as a self-management of back pain. During 4 weeks of treatment, patients will be re-evaluated on each weekly session for pain and change in behaviour through VAS scale, FABQ and ODQ.*

**Are there any disadvantages in taking part in this study?**

There are no disadvantages in taking part in this study.

**What are the possible risks of taking part?**

There are no risks involved in taking part in this study.

**What are the possible benefits of taking part?**

It is hoped that the study will help add to the research already in this area and provide new knowledge that can be used to reduce fear avoidance of movement and pain in patients with LBP.

**Confidentiality - who will know I am taking part in the study?**

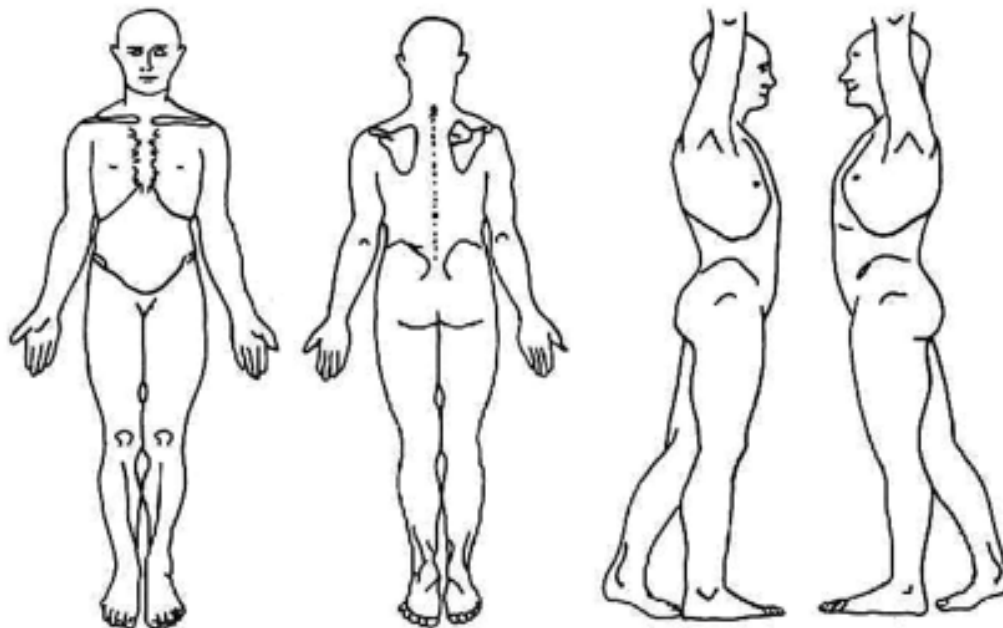
Any personal data and raw research data collected throughout the study will be kept anonymous where participants will be given individual codes. All information will be stored on password-protected computers in which only the researcher and supervisor will have access to.

**Who has approved the study?**  
Teesside University ethics committee

**Researcher contact details:** (Gok Kandasamy, [g.kandasamy@tees.ac.uk](mailto:g.kandasamy@tees.ac.uk), contact number: 07923195962).

## Appendix 6. Numeric Pain Rating Scale (NPRS)

Numerical Pain Rating Scale



Please mark the location of the chart and grade them out of 10 for each location of symptoms.

**Numeric Pain Rating Scale**

Indicate your level of pain by choosing the appropriate number on the scale below.

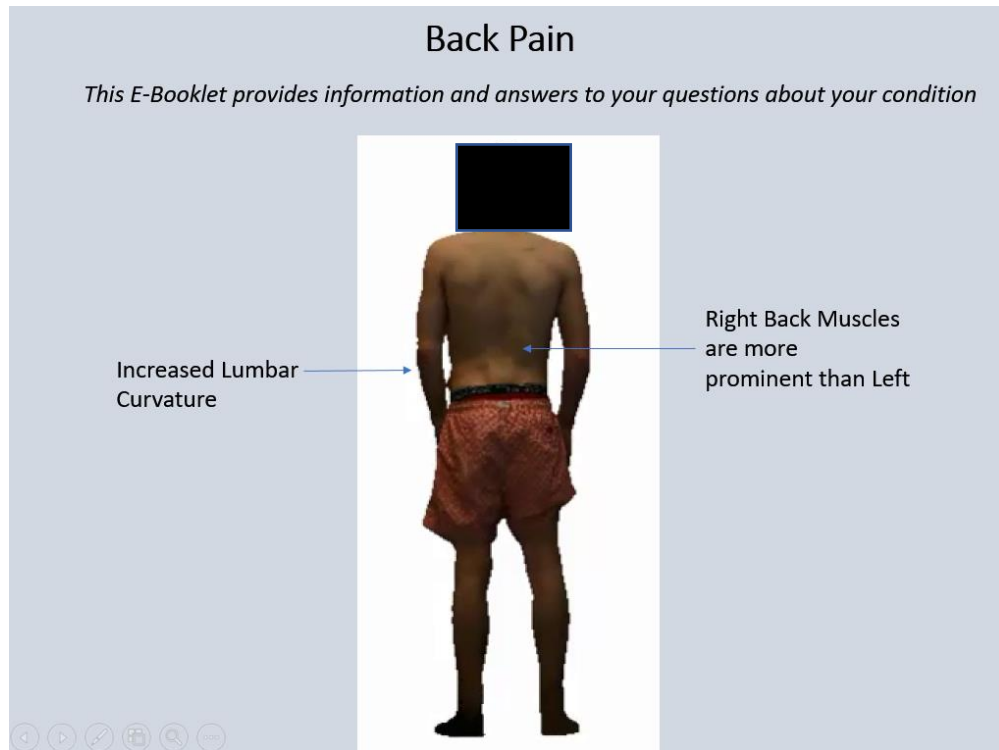
0 1 2 3 4 5 6 7 8 9 10

No Pain Moderate Pain Worst Possible Pain

## Appendix 7. Standard Educational Booklet



## Appendix 8. Sample of Personalised Educational Booklet



1. What is Back Pain?

2. Why keep active?

3. What causes it?

4. What sort of activity I should do?

5. What is the best sitting posture?

6. What is the best sleeping position?

7. Simple exercises for your back pain

8. Contact details

## What is back pain?

- Low back pain is very common and what you do in the early stages is important. The spine is one of the strongest parts of your body. The way it is put together is designed for movement. It is surrounded by strong muscles and ligaments which support and protect the spine. Resting for more than a couple of days after low back pain starts to hurt is not advised. This is because the spine needs movement in order to start to get better.
- Back pain will usually improve within a few days or weeks so that you can return to your normal activities.
- Your GP will be able to discuss your pain with you. They may prescribe pain relief medication in the early days to ease the discomfort and help you to start to move. Being mobile will help your back to get better more quickly and you will then be able to reduce your medication. Although back pain is very distressing, in most cases it is not due to any serious disease or damage.



## Why keep active?

- Moving around will prevent the joints in your spine from getting stiff. Stiff joints can become painful.
- It will keep your muscles strong.
- You will feel more positive.
- It will reduce the severity of your pain.
- You are more likely to be able to return to work quickly.

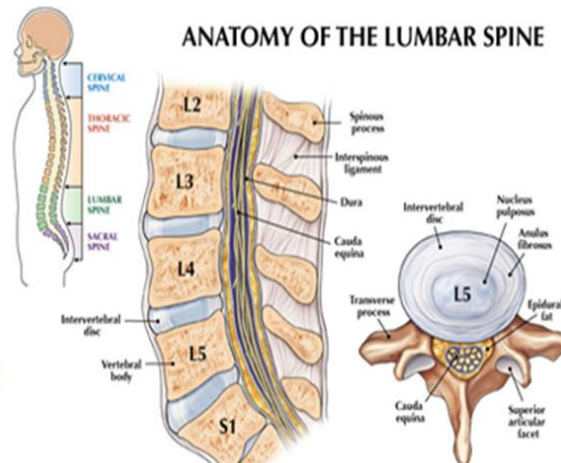




## What causes it?

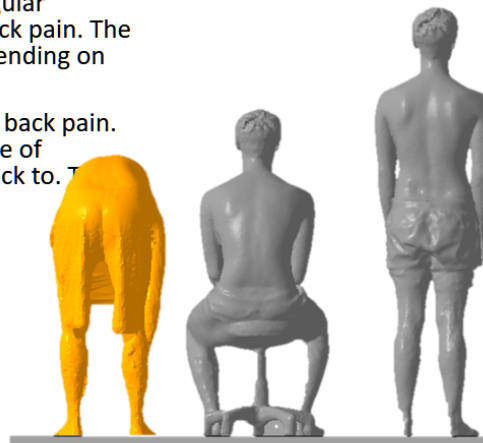
- In most cases the cause of back pain is unclear, but some back pain may be caused by a number of factors, including:

- Poor posture
- Lack of exercise resulting in stiffening of the spine
- Muscle strains and sprains
- But there are some specific conditions linked with a painful back, including spondylosis, sciatica and spinal stenosis

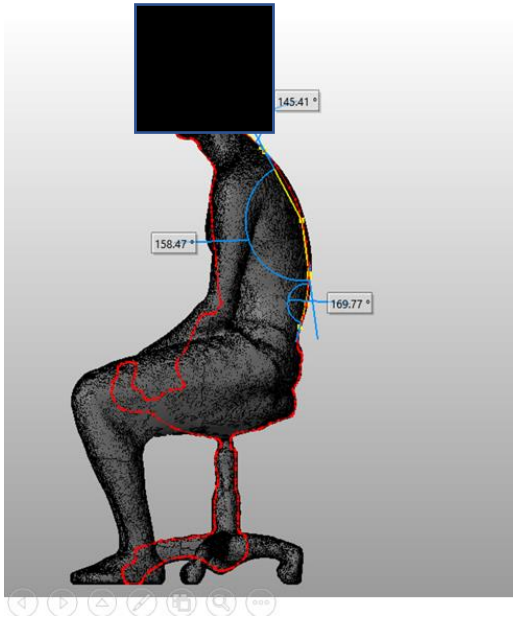


## What sort of activity?

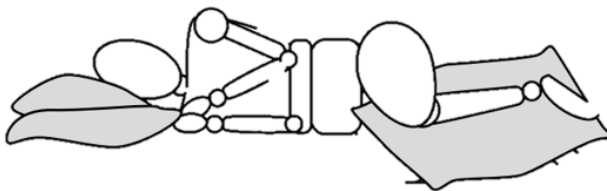
- Research has shown that people who do regular exercise are less likely to develop chronic back pain. The type of exercise you should do will vary depending on your level of fitness.
- There is no 'perfect' type of exercise for low back pain. It is therefore much better that you do a type of exercise which you enjoy and are likely to stick to. This could include:
  - walking
  - swimming
  - pilates
  - yoga
  - dancing.
- However, in the early days or weeks, you can do simple exercises to get you moving. Together with continuing your usual activities at home, these will be enough to help.



What is the best sitting position?



What is the best sleeping position?

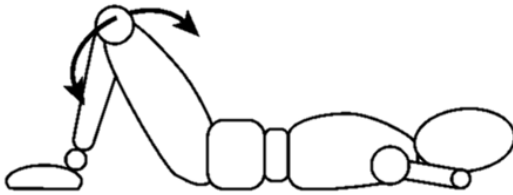




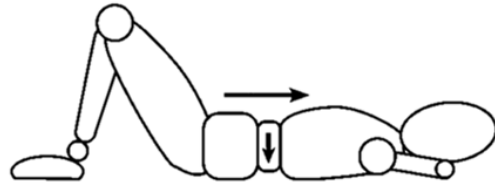
# Simple exercises for your back pain

You can do simple exercises to get you moving. Together with continuing your usual activities at home, these will be enough to help. These exercises could include

**Knee Roll**



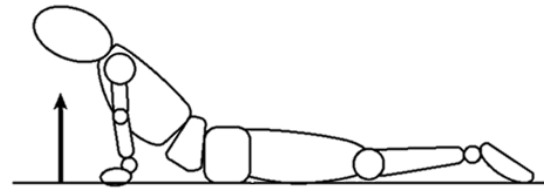
**Pelvic Tilt**



**Knee to Chest**



**Back Extension**



## Appendix 9. Perceived User Satisfaction Scale

### Perceived User Satisfaction

1. What is your general impression of the booklet  
Very Bad      Bad      Neutral      Good      Very good
2. Quantity of information in the booklet is useful to understand and the advice is beneficial in managing my self-care.  
Strongly Disagree      Disagree      Neutral      Agree      Strongly Agree
3. Photos or videos added value  
Strongly Disagree      Disagree      Neutral      Agree      Strongly Agree
4. I found that the booklet was easy to use  
Strongly Disagree      Disagree      Neutral      Agree      Strongly Agree
5. All this considered are you satisfied with the provided booklet  
Strongly Disagree      Disagree      Neutral      Agree      Strongly Agree
6. Will you continue to use for the self-care management?  
Strongly Disagree      Disagree      Neutral      Agree      Strongly Agree
7. What is your preferred format to receive back care programme?  
  
Electronic  
or  
Booklet
8. Any other comments  

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## Appendix 10. A study evaluating the use of MSTS for the assessment of spinal mobility

### *Measurement of spinal Range of Motion (ROM)*

Following the standing posture data, simultaneous data acquisition of spinal ROM using 3D imaging the MSTS was performed for a series of different postures. First, participants kept the knees fully extended and flexed forward as far as possible and attempting to touch the toes as much as possible. The end-position was held for 30 seconds before returning to the upright posture. The differences in the lumbar and thoracic curvatures in the most flexed position, and that of during erect standing was taken as lumbar and thoracic flexion range. Second, the range of extension was given by the difference in lumbar and thoracic curvature from erect standing to full extension. So, the variables measured in sagittal plane are lumbar and thoracic flexion during bending forward and extension during bending backwards (please see Figure 8.1). Third, the range of lateral flexion was measured as the subject stood with feet shoulder-width apart, sliding their hand down the side of the leg whilst maintaining movement in the coronal plane only. This was carried out both to the left and the right sides. The variables measured in this plane are left and right lateral flexion in lumbar and thoracic spine. Fourth, the range of axial rotation was determined with the participants standing with their feet shoulder-width apart and arms crossed over the chest. The movement was initiated by rotating the head to the side, keeping a level gaze, and following through with the trunk and pelvis (please see Figure 8.2 and 8.3). The variables measured in the transverse plane are left and right rotation in both lumbar and thoracic spine (please see Table 8.1).

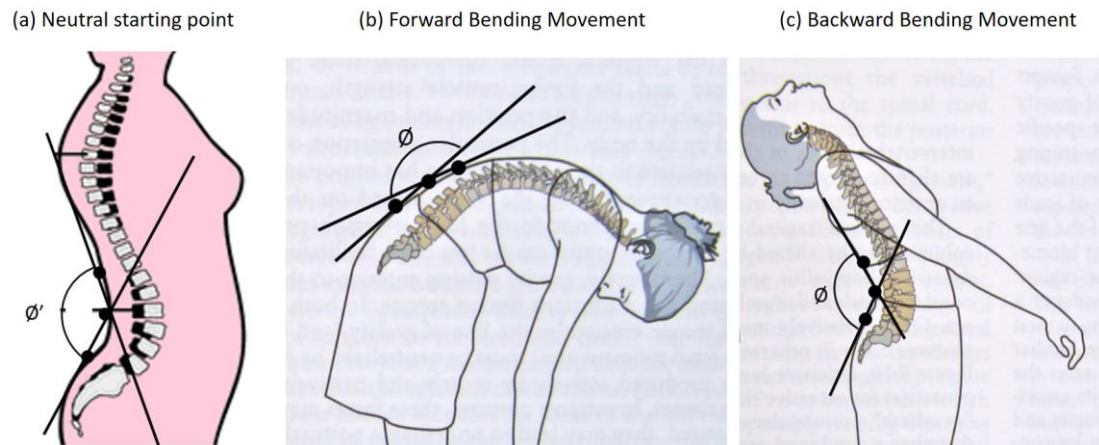


Fig 8.1. Measurement of changes in lumbar lordosis angle during sagittal plane movement.  $\emptyset'$  – Lumbar lordosis angle in neutral spine;  $\emptyset$  – Angular displacement during sagittal plane movement. (b) Lumbar flexion =  $\emptyset - \emptyset'$ ; (c) Lumbar extension =  $\emptyset - \emptyset'$

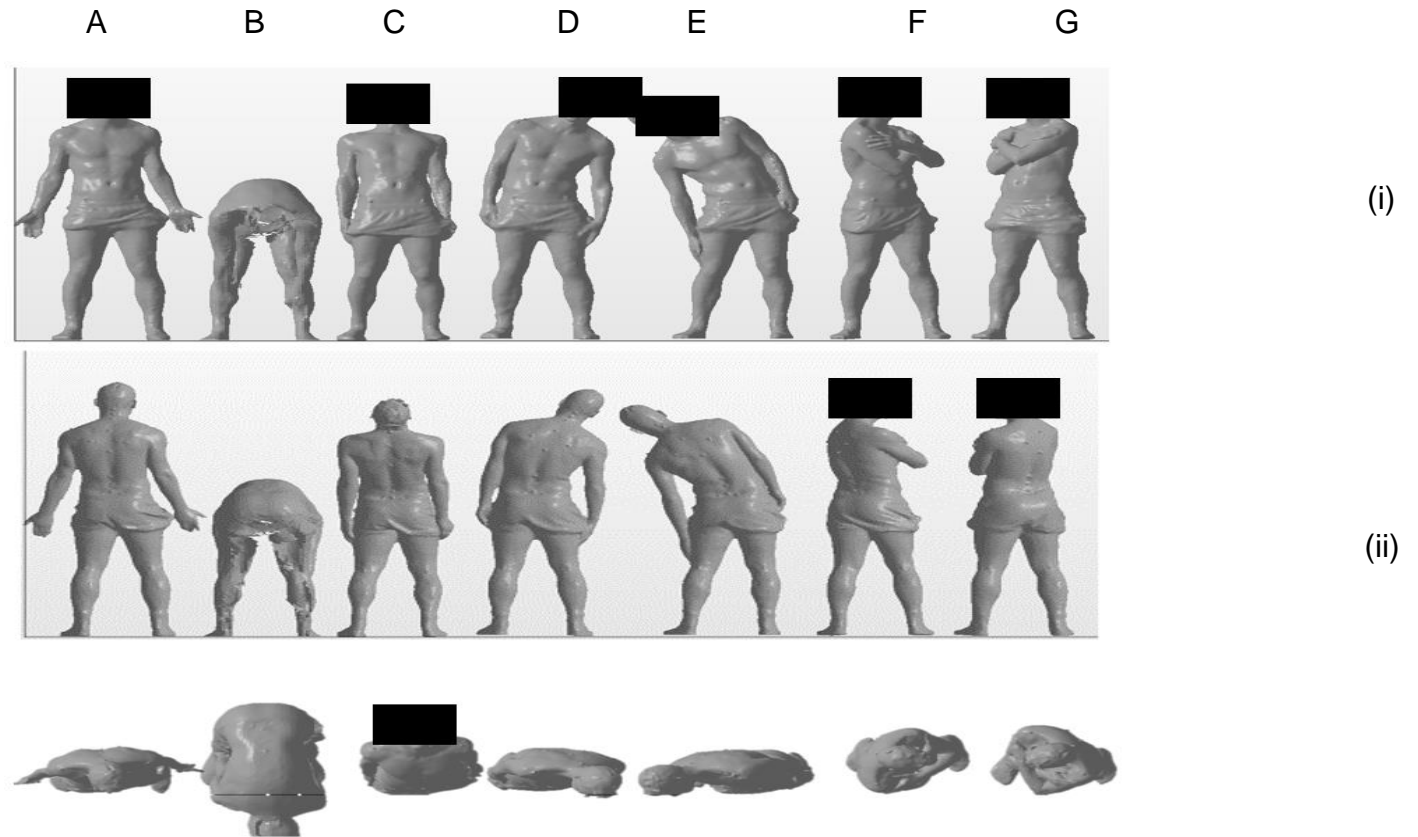


Figure 8.2. Sample of spinal mobility data collected using 3D imaging the MSTS, seen from front, back and top. i) Front view; ii) Back view and iii) Top view. A) Neutral starting point B) Forward bending movement C) Bending backwards D) Left side flexion E) Right side flexion F) Left rotation and G) Right rotation.

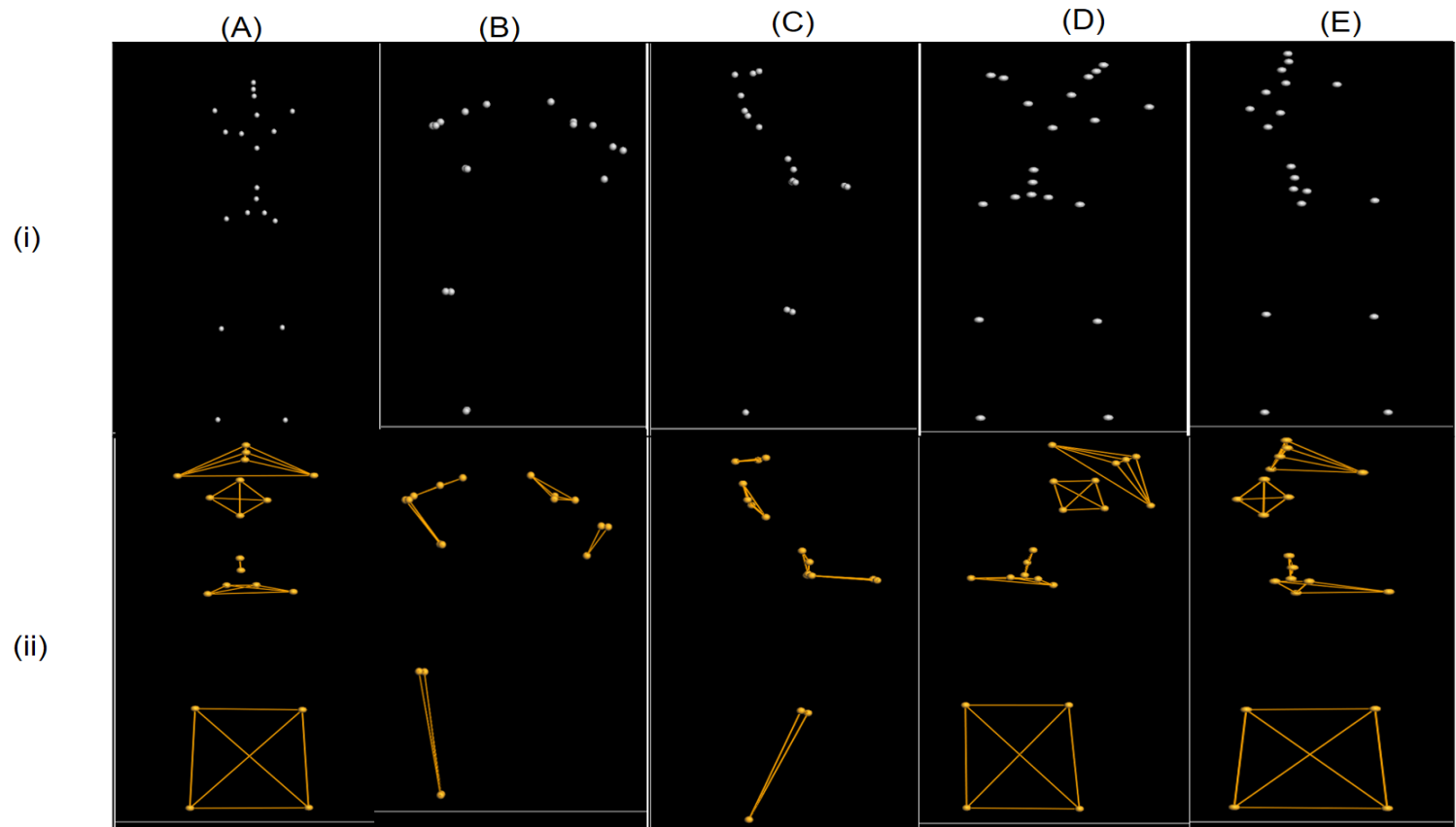
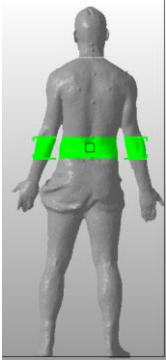

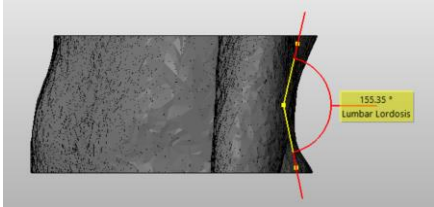
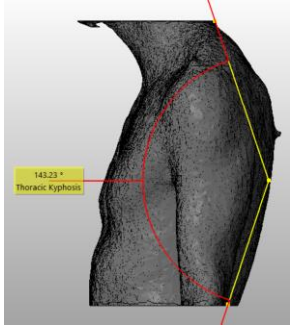
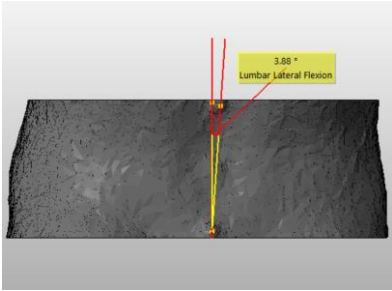
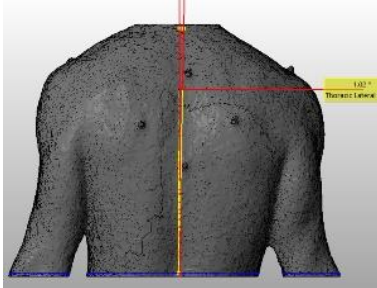


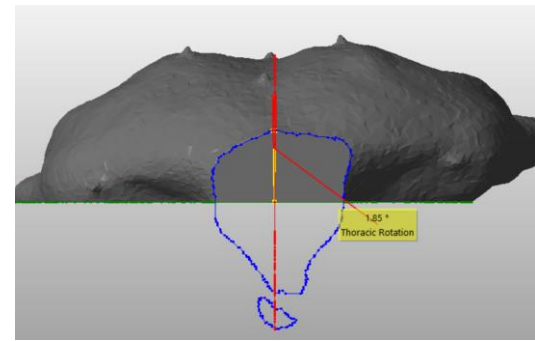
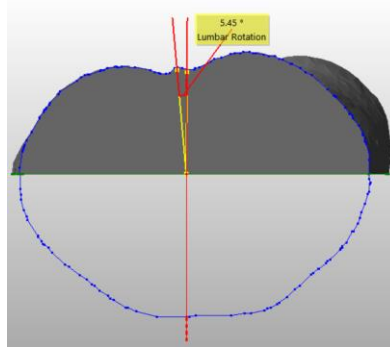
Figure 8.3. Sample of spinal mobility data collected using Vicon system. (i) Unprocessed data with reflective marker set; (ii) Processed data with applied spine model. A) Neutral spine B) Forward bending C) Bending backwards D) Left side flexion and E) Left rotation.

Table 8.1 Description of the twelve spinal mobility angles. It is the difference between standing postures to final position in each plane of movement. For example, the lumbar flexion angle is the difference between lumbar lordosis angle in standing and the final position of full forward bending movement.

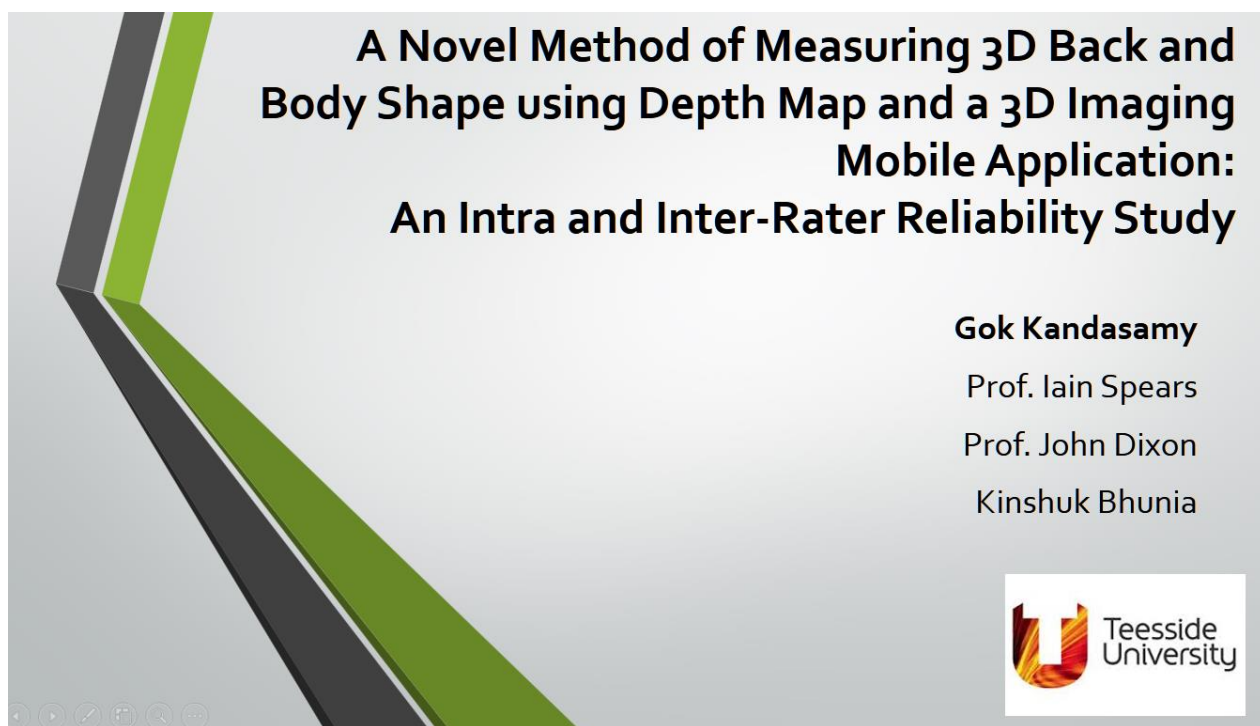
Variables	Lumbar	Thoracic
<div> <div>Spinal Segment</div> <div>   </div> </div>		
<div> <div>Sagittal Plane Analysis</div> <div> <div>(While bending forward, lumbar and thoracic spine flexion angle was measured and extension while bending backward movement)</div>   </div> </div>		
<div> <div>Frontal Plane Analysis</div> <div> <div>(Lumbar and thoracic lateral flexion angle measured in both right and left side flexion movement)</div>   </div> </div>		

## Transverse Plane Analysis

(Rotation in lumbar and thoracic spine was measured in both left and right rotation movement)



## Appendix 11. Evidence of dissemination of results of the studies in conferences





**TITLE: A NOVEL 3D IMAGING, MOBILE AND SURFACE TOPOGRAPHY APP FOR MEASURING 3D BACK AND BODY SHAPE: AN INTRA AND INTER-RATER RELIABILITY STUDY.**

Kandasamy Gokulakannan, Bettany Saltikov Josette and Spears, Iain

**Introduction:** Spinal pain is an extremely common musculoskeletal symptom caused by multiple factors. Postural/spinal deformity is one of the cause that contributes to spinal pain for example: scoliosis, hyper kyphosis as well as marked back asymmetries. These lead to abnormal stress and loading on spinal musculoskeletal structures. To date numerous non-radiographic surface measurement methods for the detection of back shape and posture have been developed e.g. Quantec and ISIS 2. However most of this equipment either laboratory based, very expensive, heavy to move, and can only measure the back. There is demand for a low cost, portable, mobile back shape measurement system. This will allow an extended assessment of full back shape measurement in all planes within the clinical environment.

**Objective(s):** The objective of this study is to present a novel and highly portable method for assessing whole body posture. A further objective is to present the reliability and repeatability of the system to determine its applicability for assessing back and full body shape in normal subjects and patients with spinal deformities.

**Method(s):**

**Participants:** Healthy adults (n=16) participated in this study.

**Instrumentation:** In this study we have used the commercially available iPad based 3D mobile scanning tool 'Structure Sensor™' to capture the shape of the back as well as the whole participants' body. This sensor consists of two different cameras (Color video (red-blue-green) and the depth camera). This sensor along with the normal iPad camera provides real-time anatomical landmarks and reconstructs the whole back and body shape using the triangulation method.

**Procedure:** For each subject, three trials of standing back and body posture were individually measured by two raters on two separate occasions. The data was then processed in the open source software and back shapes was manually measured by both the raters.

**Results and Discussion:** Pearson's Correlation test estimated the reliability and standard error of measurement for the overall, test-retest and inter-rater designs. Bland and Altman's method was used to document agreement between sessions and raters. Good intra and inter reliability was found.

**Conclusions and Significance:** Given that it is inexpensive, extremely portable and very simple to setup, this tool has got a high potential to be used within clinical practice for monitoring spinal deformity. This will reduce dependence on serial radiography and reduce radiation exposure to patients with postural disorders and spinal deformities.

**Key words:** Spinal deformity, back shape, body shape, surface measurement, depth camera, mobile application

# Validation of a novel 3D imaging and surface topography mobile App to assess spinal posture and mobility



Gokulakannan Kandasamy, Josette Bettany-Saltikov and Paul Van-Schaik



## Introduction

- Spinal deformities and marked back asymmetries are potential sources of spinal pain (Nelson-Wong et al., 2010).
- The measurement of 3D spinal posture and mobility is important for both the clinical and research context.
- Although various techniques are available to measure spinal posture and kinematics in a research or lab-based environment, there is still a need for a less expensive, portable, mobile-based application, to record 3D spinal posture and mobility with precision and accuracy

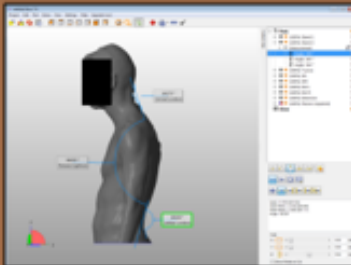
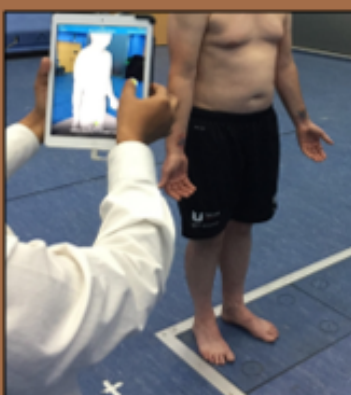
**Aim:** To validate a novel 3D imaging and surface topography mobile App to assess spinal posture and mobility.

## Methods

**Participants:** Twenty-five volunteers (16 males, 9 females, age range of 21-45 years) with no history of spinal pain participated in this study

**Equipment:** The commercially available iPad based 3D mobile scanning tool 'Structure Sensor™' was used to capture the shape of the back as well as the whole participants' body.

**Procedure:** For each subject, an optical motion capture system and 3D mobile scanning tool were simultaneously used to capture three trials of standing, bending forward, backwards, bilateral side flexion and rotation. The 3D mobile data was then processed in the open source software to measure lumbar lordosis, thoracic kyphosis, bilateral side flexion and bilateral rotation. These variables were also measured for the optical motion captured data using commercially available Vicon software.



## Key References

- Nelson-Wong, E. and Callaghan, J.P., 2010. Is muscle co-activation a predisposing factor for low back pain development during standing? A multifactorial approach for early identification of at-risk individuals. *Journal of Electromyography and Kinesiology*, 20(2), pp.256-263.
- Fortin, C., Feldman, D.E., Charlet, F. and Labelle, H., 2010. Validity of a quantitative clinical measurement tool of trunk posture in idiopathic scoliosis. *Spine*, 35(19), pp.E988-E994.
- Frerich, J.M., Hertzler, K., Knott, P. and Mardjetko, S., 2012. Comparison of radiographic and surface topography measurements in adolescents with idiopathic scoliosis. *The open orthopaedics journal*, 6, p.261.
- Grunstein, E., Fortin, C., Parent, S., Houde, M., Labelle, H. and Ehmann-Feldman, D., 2013. Reliability and validity of the clinical measurement of trunk list in children and adolescents with idiopathic scoliosis. *Spine deformity*, 1(6), pp.419-424.

## Results

Table 1. Comparison of accuracy of standing postural measurements between 3D imaging STMA and the gold standard Vicon three-dimensional analysis system

Variables		Mean (SD)		SD Mean Difference	Mean Difference	t value	p value	Pearson Correlation r(3)
		Vicon	STMA					
Sagittal	Lumbar Lordosis	141.67 (5.58)	142.29 (5.58)	0.15	-0.32	-0.68	.50	0.77*
	Thoracic Kyphosis	154.66 (5.90)	157.03 (6.02)	1.21	-6.67	-2.76	.02*	0.67*
	Cervical Lordosis	162.01 (6.45)	162.68 (6.17)	0.42	7.85	2.54	.02*	-0.25
Frontal	Shoulder Elevation	8.77 (1.7)	8.81 (1.86)	0.83	-0.08	-0.17	.86	0.28
	Lateral Pelvic Tilt	8.36 (2.06)	8.15 (1.86)	0.89	-1.28	-0.71	.48	0.80*
	Front Knee Angle (Right)	176.47 (2.88)	172.86 (3.50)	1.56	2.84	1.67	.10	-0.27
Transverse	Front Knee Angle (Left)	176.29 (2.84)	172.29 (3.48)	1.25	8.89	8.18	.00*	-0.16
	Shoulder Rotation (Right)	152.22 (8.45)	145.75 (10.64)	8.15	6.47	2.05	.05*	0.04
	Shoulder Rotation (Left)	152.03 (7.46)	145.61 (10.54)	8.11	6.59	2.11	.04*	0.11

Table 2. Comparison of accuracy of lumbar spine mobility measurements between 3D imaging STMA and the gold standard Vicon three-dimensional analysis system

Variables	Mean (SD) in degrees		SD Mean Difference	Mean Difference	t value	p value	Pearson Correlation r(3)
	Vicon	STMA					
Bending Forward (Flexion)	83.56 (12.56)	85.51 (11.7)	1.80	-1.98	-1.2	.24	0.80*
Bending Backward (Extension)	18.47 (16.52)	82.81 (11.8)	2.17	-29.4	-2.7	.02*	-0.80*
Lateral Flexion (Left)	14.71 (14.37)	28.05 (9.0)	2.01	-6.35	-0.28	.78	-0.60*
Lateral Flexion (Right)	9.62 (16.56)	20.9 (10.1)	8.47	-11.4	-0.45	.65	0.90*
Rotation (Left)	25.29 (11.54)	28.30 (8.76)	3.59	-1.80	-0.7	.48	0.65*
Rotation (Right)	14.40 (11.52)	31.41 (10.1)	4.54	-17.9	-0.89	.38	0.15

Table 3. Comparison of accuracy of thoracic spine mobility measurements between 3D imaging STMA and the gold standard Vicon three-dimensional analysis system

Variables	Mean (SD) in degrees		SD Mean Difference	Mean Difference	t value	p value	Pearson Correlation r(3)
	Vicon	STMA					
Bending Forward (Flexion)	26.62 (17.4)	49.05 (14.08)	5.40	-22.43	-6.0	.00*	0.39
Bending Backward (Extension)	-14.75 (14.62)	80.58 (9.35)	5.43	-25.83	-4.6	.00*	-0.28
Lateral Flexion (Left)	-11.25 (17.02)	32.11 (6.4)	8.67	-23.47	-5.8	.00*	-0.27
Lateral Flexion (Right)	6.79 (16.26)	17.86 (6.42)	2.87	-6.19	-2.8	.00*	0.65*
Rotation (Left)	24.79 (16.84)	49.96 (12.86)	11.14	-15.19	-1.4	.18	-0.45
Rotation (Right)	30.96 (16.32)	49.12 (11.55)	7.85	-22.16	-6.0	.00*	-0.11

## Discussion

- The estimation of measuring sagittal and frontal plane postural variables (lumbar lordosis, thoracic kyphosis, shoulder elevation, lateral pelvic tilt and front knee angle) by STMA system was as good as the Vicon system.
- The current study's correlation results and SEM values (0.74 to 3.42) of the sagittal plane variables are comparable to those previously reported by photogrammetry (Fortin et al., 2010), plumbline (Grunstein et al., 2013) and surface topography method (Frerich et al., 2012).

**Conclusions-** The app has been shown to be valid for the measurement of most variables measured. Given that it is inexpensive, extremely portable and simple to setup, this tool has a high potential to be used within clinical practice for monitoring spinal posture and mobility in the sagittal and frontal plane.