Sitting posture: a predictive factor for upper quadrant musculoskeletal pain in computing high school students

by

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Dissertation presented for the degree of Doctor of Philosophy (Physiotherapy) in the Faculty of Medicine and Health Sciences at Stellenbosch University

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December 2012

DECLARATION

By submitting this dissertation electronically, I declare that the entirety of the work contained therein is my own, original work, that I am the sole author thereof (save to the extent explicitly otherwise stated), that reproduction and publication thereof by Stellenbosch University will not infringe any third party rights and that I have not previously in its entirety or in part submitted it for obtaining any qualification.

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December 2012

ABSTRACT

Introduction: The increased prevalence of adolescent upper quadrant musculoskeletal pain (UQMP) is becoming a great concern to health professionals. The risk factors associated with adolescent UQMP are complex and multifactorial, including, among others sitting as a physical risk factor. However, no evidence exists to support sitting postural angles as a potential predictive factor for adolescent UQMP in computing high school students. Thus, the current project aimed to describe the three-dimensional (3D) sitting postural angles of computing South African high school students in a real-life setting, using a well-tested and documented posture measurement instrument. **Methodology:** This research project is comprised of seven related studies. Part I of the dissertation presents a systematic review describing the reliability and validity testing of posture measurement instruments. This is followed by three primary correlation and repeated measures observational studies aimed at ascertaining the reliability and validity of a newly developed 3D Posture Analysis Tool (3D-PAT) in the measurement of nine sitting postural angles of computing high school students. Part II of the dissertation presents a systematic review, that evaluates the latest published research evidence of whether sitting is related to UQMP, and, if so, to identify the elements of sitting that significantly contribute to UQMP. This review is followed by a description of a cohort study, with a prospective period of one year. The 3D-PAT was implemented in a clinical research setting in order to measure the 3D sitting posture of a cohort of asymptomatic computing high school students and in order to assess the outcome, seated-related UQMP, prospectively. The prospective study design enabled the research project to contribute to an understanding of any causative relationship between the exposure (sitting postural angles) and the outcome (seated-related UQMP) in a subgroup of adolescents (computer users). **Results:** After the first

phase of psychometric testing of the 3D-PAT using high school students, the findings indicated that the instrument required modifications prior to further psychometric testing. The second phase of testing revealed that the 3D-PAT compared very well with the reference standard for measurement of the X-, Y- and Z-coordinates of the reflective markers on a mannequin. The findings from the phase three study, again using high school students, indicated that the 3D-PAT compared very well with the reference standard and justified its use for the measurement of six sitting postural angles of the upper quadrant in computing high school students. For the cohort study, a 60% response rate for participation was achieved at baseline, with 98% of the students participating at six-month and 80% at one-year follow up. Of the students, 33.5% complained of seated-related UQMP during the follow-up period. Exposure to increased head flexion (>80°) (ρ=0.0001) and the combination of increased head flexion and decreased cranio-cervical angles (ρ=0.007) were significant predictors of seated-related UQMP for those computing high school students complaining of pain greater than the 90th percentile for such. **Conclusion:** The project described in the current dissertation is the first research project to assess sitting postural angles in asymptomatic high school students, while they worked on desktop computers in a school computer classroom and to assess UQMP prospectively. The research project reports a causal relationship between increased head flexion and seated-related UQMP as increased head flexion was found to be a predictor of seated-related UQMP developing within six to 12 months for computing high school students with a pain score equal or greater than the 90th percentile for pain. The research project emphasises that further research is warranted to investigate the causal pathway between sitting posture and adolescents' UQMP.

OPSOMMING

Inleiding: Die stygende voorkoms van boonste-kwadrant muskuloskeletale-pyn (BKMP) onder adolessente is besig om ’n groot bron van kommer vir professionele gesondheidswerkers te word. Die risiko-faktore waarmee adolessente BKMP gepaard gaan, is kompleks en multifaktories. Dit sluit onder andere sit as ’n fisiese risiko-faktor in. Daar is egter nog geen bewyse om sittende posturale hoeke as potensiële voorspeller van adolessente BKMP te ondersteun nie. Dus beoog hierdie projek om die drie-dimensionele (3D) sittende posturale hoeke van Suid-Afrikaanse hoërskoolleerders wat ook rekenaargebruikers is, in ’n werklike omgewing te beskryf, deur gebruik te maak van ’n instrument wat postuur meet en wat goed getoets en gedokumenteerd is. **Metodiek:** Hierdie navorsingsprojek is saamgestel uit sewe studies. Gedeelte I van die proefskrif bied ’n sistematiese oorsig van betroubaarheids- en geldigheidstoetsing van instrumente wat postuur meet. Dit word gevolg deur drie primêre korrelasie studies en studies vir die waarneming van herhaalde meting wat die betroubaarheid en geldigheid van n nuut-ontwikkelde 3D instrument vir posturale analise (3D-PAT) bepaal, wanneer nege sittende posturale hoeke van hoërskoolleerders wat rekenaars gebruik, gemeet word. Gedeelte II van die proefskrif bied ’n sistematiese oorsig van die jongste gepubliseerde navorsing om te evalueer of daar bewyse is dat sit verband hou met BKMP, en, indien wel, om die elemente van sit wat betekenisvol bydra tot BKMP, te identifiseer. Die sistematiese oorsig word deur ’n beskrywing van ‘n jaarlange kohortstudie gevolg. Die 3D-PAT is gebruik in ’n kliniese-navorsingsraamwerk om die 3D-sitpostuur van ’n kohort simptoomvrye hoërskoolleerders wat rekenaargebruikers is, te meet en sitverwante BKMP as uitkoms in die vooruitsig te stel. Die studie ontwerp het dit vir die navorsingsprojek moontlik gemaak om ’n insiggewende bydrae te lewer tot begrip vir enige oorsaaklikheidsverwantskap

tussen die blootstelling (sittende posturale hoeke) en die uitkoms (sitverwante BKMP) in ’n subgroup van adolessente (rekenaargebruikers). **Resultate:** Na afloop van die eerste psigometriese toesting van die 3D-PAT, waarin hoërskoolleerders gebruik is, het bevindings daarop gedui dat die instrument verander moet word voordat toetsing kan voortgaan. Die tweede fase van toetsing het getoon dat die 3D-PAT baie goed vergelyk met die verwysingstandaard vir die meet van die X-, Y- en Z-koördinate van die reflektiewe merkers op ’n mannekyn. Die bevindings van die derde fase van die studie, waartydens hoërskoolleerders weer gebruik is, het aangedui dat die 3D-PAT baie goed vergelyk met die verwysingstandaard. Dit het die gebruik van die instrument om ses sittende posturale hoeke van die boonste kwadrant van hoërskoolleerders wat rekenaars gebruik te meet, bevestig. Die kohortstudie het ’n 60%-reaksiesyfer vir deelname behaal tydens die basislynmetings, waarvan 98% leerders deelgeneem het aan die sesmaande-opvolgmetings en 80% aan die eenjaaropvolgmetings. ’n Totaal van 33.5% van die leerders het gekla van sitverwante BKMP gedurende die eenjaar opvolgperiode. Blootstelling aan ’n vergrootte kopfleksie-hoek (>80°) ($\rho = 0.0001$) en die kombinasie van ’n vergrootte kopfleksie- en verminderde kranio-servikale hoek ($\rho = 0.007$) was betekenisvolle voorspellers van sitverwante BKMP vir die hoërskoolleerders wat rekenaars gebruik en kla van groter pyn as die 90ste persentiel daarvan. **Gevolgtrekking:** Hierdie projek is die eerste navorsing wat sittende posturale hoeke van simptoomvrye hoërskoolleerders wat op tafelrekenaars in die skool se rekenaarklaskamer werk, meet en BKMP voorspel. Die navorsingsprojek rapporteer ‘n oorsaaklikheidsverwantskap tussen ‘n vergrootte kopfleksie-hoek en sitverwante BKMP omdat vergrootte kopfleksie ‘n voorspeller is van sitverwante BKMP wat binne ses tot 12 maande by hoërskoolleerders wat rekenaars gebruik, met ‘n pyntelling gelyk of groter as die 90ste persentiel van pyn, ontwikkel. Die navorsingsprojek beklemtoon dat verdere navorsing om die

oorsaaklikheidsroete tussen sitpostuur en adolessente BKMP te ondersoek, geregverdig is.

ACKNOWLEDGEMENTS

I wish to extend my sincere gratitude to the following individuals, who provided assistance and support that enabled me to complete this research project:

Prof. Quinette Louw, the principal supervisor, who provided continuous support and guidance, encouraging me to improve the quality of my work;

Prof. Kristiaan Schreve, the associate supervisor, who contributed to the development of the 3D-PAT and who provided technical advice and support related to the implementation of the 3D-PAT;

Dr Ronald Cornelissen, the Research Director from the Western Cape Education Department, for granting permission for the studies to be conducted in the Western Cape province;

The **learners, teachers and principals** of the high schools that participated in this research project, without whose participation this project would not have been possible;

Esme Jordaan, from the Medical Research Council, for her professional assistance and advice with the statistical analysis of the data;

The **Medical Research Council of South Africa,** the **National Research Fund** and the **Division of Research Development and Support of Stellenbosch University,** for their financial support of this project;

Prof. Karen Grimmer-Somers, from the Centre of Allied Health Evidence, University of South Australia, for advice and support during the course of the research project;

Gareth van der Westhuizen, the master's student who, in collaboration with Prof. Schreve, developed the 3D-PAT and who provided continuous technical support;

The **research assistants,** for their time and diligence during the data collection period;

To **my extended family,** for their love, encouragement and support;

Most importantly, to my husband, **Francois** and daughter **Jani** for their love, continuous encouragement, unwavering support and tireless patience, providing me with an environment that was conducive to me fulfilling my dream.

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LIST OF ABBREVIATIONS

2D:	two-dimensional
3D:	three-dimensional
3D-PAT:	Three-Dimensional Posture Analysis Tool
AOJ:	atlanto-occipital joint
CAT:	Critical Appraisal Tool
CI:	confidence interval
CNS:	central nervous system
CV:	coefficient of variation
CUQ:	Computer Usage Questionnaire
DNF:	deep neck flexors
EMDC:	Education Management and Development Centres
FHP:	forward head posture
ICC:	intraclass correlation coefficient
IV:	intervertebral
OC1	occiput cervical joint
OR	Odds ratios
QUADAS:	Quality Assessment of Diagnostic Accuracy Studies
QUAREL:	Quality Appraisal of Reliability Studies
SD:	standard deviation
SE:	standard error
SP:	spinous process
UQMP:	upper quadrant musculoskeletal pain
WCED:	Western Cape Education Department

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ETHICAL APPROVAL

Approval for this project was obtained from the Committee for Human Research of Stellenbosch University (Addendum 1). The project was conducted according to internationally accepted ethical standards and guidelines of the international Declaration of Helsinki, the South African Guidelines for Good Clinical Practice and the Medical Research Council (MRC) Ethical Guidelines for Research.

CHAPTER 1

INTRODUCTION

1.1 ADOLESCENT MUSCULOSKELETAL PAIN AND SITTING POSTURE

Upper quadrant musculoskeletal pain (UQMP) in adolescents is a global health concern (Siivola, Levoska, Latvala, Hoskio, Vanharanta & Keinanen-Kiukaanniemi, 2004; Stahl, Mikkelsson, Kautiainen, Hakkinen, Ylinen & Salminen, 2004; Smith, Louw, Crous & Grimmer-Somers, 2009; Syazwan, Azhar, Anita, Azizan, Shaharuddin, Hanafiah, Muhaimin, Nizar, Rafee, Ibthisham & Kasani, 2011). The monthly prevalence for adolescent UQMP can be up to 30% (Straker, O'Sullivan, Smith, Perry & Coleman, 2008a; Smith *et al*., 2009; Rees, Smith, O'Sullivan, Kendall & Straker, 2011; Hakala, Saarni, Punamaki, Wallenius, Nygard & Rimpela, 2012). This high occurrence of adolescent UQMP is alarming, as musculoskeletal pain increases with age and usually persists into adulthood (Brattberg, 2004; Siivola *et al*., 2004; Paananen, Taimela, Auvinen, Tammelin, Kantomaa, Ebeling, Taanila, Zitting & Karppinen, 2010).

The aetiology of UQMP in both children and adolescents is complex and multifactorial (Vikat, Rimpela, Salminen, Rimpela, Salvolainen, & Virtanen, 2000; Diepenmaat, Van der Wal & De Vet, 2006; Murphy, Buckle & Stubbs, 2007; Prins, Louw & Crous 2008). Well reported factors associated with UQMP include psychosocial elements, life-style, physical activity, postural elements, joint hypermobility, environmental elements, motor competence and gender (Mikkelsson, El-Metwally, Kautiainen, Auvinen, Macfarlane & Salminen, 2008; Briggs, Smith, Straker & Bragge, 2009a; O'Sullivan, Beales, Jensen, Murray and Myers, 2011a). UQMP in children and adolescents may also be related to monotonous sitting for

prolonged periods or to sitting at an ergonomically deficient workstation (Murphy, Buckle & Stubbs, 2004; Auvinen, Tammelin, Taimela, Zitting & Karppinen, 2007; Geldhof, De Clercq, De Bourdeaudhuij & Cardon, 2007a; Murphy et al., 2007; Kelly, Dockrell & Galvin, 2009). In contrast less research has described any association between sitting postural angles and UQMP in adolescents (Prins *et al.,* 2008). Therefore it is unclear whether postural alignment, in terms of postural angles, is a risk factor for adolescent UQMP.

Good postural alignment is recognised when the centre of gravity of each spinal segment is vertically aligned above the segment below, thus requiring minimum muscular effort to maintain (Griegel-Morris, Larson, Meuller-Klaus & Oatis, 1992). It is, therefore, assumed that sitting with a neutral spinal posture (good posture) will prevent or reduce musculoskeletal pain symptoms, as adopting such posture benefits the supporting musculoskeletal structures, (Barrero & Hedge, 2002; Geldhof *et al*., 2007a) as there is then minimal resistance from passive structures (Falla, Jull, Russell, Vincenzino & Hodges, 2007). Such an assumption has not changed among researchers investigating posture and pain (Geldhof *et al.*, 2007a; Caneiro, O'Sullivan, Burnett, Barach, O'Neil, Tveit & Olafsdottir, 2010). Postural re-education or training is typically aimed at optimising the neutrally aligned skeletal system to reduce any unfavourable stress on both active and passive structures (O'Sullivan, Grahamshaw, Kendell, Lapenskie, Moller & Richards, 2002). Two types of 'poor sitting postures', in terms of postural alignment, for children, adolescents and adults are described in the literature. Forward head posture (FHP), which is present when the head is displaced anteriorly in relation to the theoretical plumb line (Griegel-Morris *et al*., 1992; Yip, Chio & Poon, 2008; Silva, Punt, Sharples, Vilas-Boas & Johnson, 2009), generally, but not necessarily, encompasses upper cervical extension and flexion of the lower cervical spine (Raine & Twomey, 1994; Silva *et al.*, 2009). Slump sitting, which is defined by excessive thoracic flexion, lumbar flexion and posterior pelvic

tilt, can also incorporate a FHP (Kendall, McCreary & Provance, 1993; Caneiro *et al.*, 2010; O'Sullivan, Smith, Beales & Straker, 2011b). The evidence for such 'poor sitting postures' to be associated with musculoskeletal pain in adolescents is controversial. Further research is warranted to identify which sitting alignments contribute to adolescent UQMP.

The evidence for angular differences in sitting posture, in terms of postural angles, between adolescent groups, with and without UQMP, is limited (Brink, Crous, Louw, Grimmer-Somers & Schreve 2009a; Straker, O'Sullivan, Smith & Perry, 2009a). Furthermore, there is conflicting evidence as to whether 'poor-seated postures' or 'poor spinal alignment' is associated with musculoskeletal pain in adolescents, since related research has also found no association between FHP, slump sitting postures or postural angles, and adolescent musculoskeletal pain (Straker *et al*., 2008a; Weber Hellstenius, 2009; Astfalck, O'Sullivan, Straker, Smith, Burnett & Caneiro, 2010; O'Sullivan *et al*., 2011b; Straker, Smith, Bear, O'Sullivan & De Klerk, 2011). On the other hand, O'Sullivan *et al*. (2011a) reported that the habitual sitting posture of adolescents with non-specific musculoskeletal pain significantly resembled their slump sitting postures, and that the pain group revealed significantly greater neck flexion angles. These findings were in contrast to Straker *et al*., (2009a)'s results, who illustrated that increased lumbar lordosis with anterior pelvic tilt was more related to adolescent UQMP; however, assumption of an increased lumbar lordosis with anterior pelvic tilt posture contradicts the typical slump posture. The contradiction implies that certain sitting postures, or postural angles, might, for adolescents, be more related to musculoskeletal pain symptoms in specified anatomical areas. All studies, bar one, that investigated the relationship between sitting postural angles and adolescent musculoskeletal pain were cross-sectional. Such studies do not meet the temporality criteria for causation, so that the findings of the studies concerned

could not shed light on whether the 'poor' sitting postural angles were predictive of adolescent UQMP, since the exposure did not necessarily precede the outcome (pain).

The findings of prospective cohort studies enhance our understanding of a potential causal relationship between sitting postural angles and adolescent UQMP. To the researcher's knowledge, Brink *et al*.'s (2009a) study is the only published one that was aimed at evaluating the sitting postural angles of asymptomatic adolescents and which measured UQMP prospectively. The authors identified extreme cervical, and the combination of extreme cervical and thoracic spinal angles as significant predictors of UQMP; however, the study measured postural angles, using two-dimensional (2D) photography. A three-dimensional (3D) measurement of sitting posture would provide a more comprehensive assessment of sitting posture, as the spine is a 3D anatomical structure and seated activities also incorporate non-sagittal plane postures (Straker, Burgess-Limerick, Pollock, Coleman, Skoss & Maslen, 2008b).

1.2 POSTURE MEASUREMENT

Postural assessment is an essential component of the physical examination of patients with musculoskeletal pain. The methods used in clinical practice are often not objective (Griegel-Morris *et al*., 1992; Cho, 2008). There are two important psychometric prerequisites for any objective measurement instrument that should be established. The psychometric properties concerned relate to the reliability and validity of an instrument (Portney & Watkins, 2009). The objective assessment of postural variables depends on the use of the most appropriate posture measurement instrument, based upon the reliability and validity properties of the instrument used. Three-dimensional (3D) quantitative biomechanical measures are the preferred method for accurately describing sitting posture, although the use of such time consuming and costly instruments generally

results in too small study samples being used (Veira & Kumar, 2004; Prins, 2008). Static photographic analysis is currently the most cost-effective, practical and less time-consuming method for measuring several postural angles simultaneously (Perry, Smith, Straker, Coleman & O'Sullivan, 2008a). However, no research reporting has yet been undertaken into the 3D assessment of adolescent sitting posture and pain. Although four published studies were found that reported on the 3D sitting postures of children, none of the four studies also assessed the relationship between the 3D sitting posture and musculoskeletal pain (Geldhof, Cardon, De Bourdeaudhuij, Daneels, Coorevits, Vanderstraeten & De Clerq, 2007b; Straker *et al*., 2008b; Straker, Maslen, Burgess-Limerick & Pollock, 2009b; Straker, Burgess-Limerick, Pollock & Maslen, 2009c). The lack of evidence to support the existence of sitting posture as a risk factor for adolescent UQMP could be due to limitations in reliable and valid posture measurement instruments.

1.3 SIGNIFICANCE OF THE RESEARCH PROJECT

Information computer technology has come to be increasingly used by learners in South Africa (Smith *et al.,* 2009; Curriculum development: WCED, 2012). During adolescence, the increase in sitting height has been found to be significant in comparison to standing height, as adolescence is accompanied by a critical period of skeletal growth in the vertebral column (Howell, Mahood & Dickson, 1992). Adolescents using computers for prolonged periods are, therefore, at an increased risk of developing pain, as strain to the neuromusculoskeletal system may have lasting effects (Harris & Straker, 2000; Ramos, James & Bear-Lehman, 2005).

Prolonged time spent sitting while using the computer is associated with adolescent UQMP (Auvinen *et al*., 2007; Kelly *et al*., 2009; Smith *et al*., 2009; Hakala, Saarni, Ketola, Rahkola, Salminen & Rimpela, 2010), whereas other studies have found no such

association (Diepenmaat *et al*., 2006; Adamson, Murphy, Shelvin & Buckle, 2007; Briggs, Straker, Bear & Smith, 2009b; Brink *et al*., 2009a). However, these studies did not describe sitting posture three-dimensionally. Straker *et al.* (2009b), who measured sitting postural angles three-dimensionally, despite reporting more monotonous sitting postures for children when using computers than with paper-based tasks, did not measure the relationship of such posture to musculoskeletal pain. Straker, O'Sullivan, Smith and Perry (2007), who measured 2D postural angles, reported small angular differences (with angles not reported) between the habitual sitting posture of adolescent computer and non-computer users, and also noted that small angular differences existed between the groups experiencing pain and those that did not in the sample. However, due to the cross-sectional study design used, computer use was not implicated as being the cause of the habitual postural changes or the source of the musculoskeletal pain concerned. South African high school students (adolescents), who tend to use computers for about nine hours per week, are significantly at risk of developing neck pain (Smith *et al.,* 2009), and, since such students are exposed to poor ergonomically designed workstations, they could be exposed to the negative effects of adopting a poor posture on a regular basis and for a prolonged period of time (Smith, 2007).

The lack of association between sitting posture and UQMP for adolescents might be due to two factors. Firstly, most studies report the sitting posture that is adopted in an artificial environment (in a laboratory set-up), which does not reflect the habitual sitting postures of adolescents in a classroom set-up (Straker *et al*., 2008a). Secondly, there is a the need for postural measurement in longitudinal studies to determine whether a causal relationship exists between sitting posture and UQMP in adolescents, as cross-sectional study designs are not conducive to identifying the physical risk factors that are predictive of musculoskeletal pain (Murphy *et al*., 2004; Grimmer, Nyland & Milanese, 2006). Since

school-based programmes, which are aimed at encouraging favourable sitting postures with or without the use of computers, have been unable to report consequent reduction in musculoskeletal pain prevalence (Cardon, De Clercq, De Bourdeaudhuij & Breithecker, 2004; Geldhof, Cardon, De Bourdeaudhuij & De Clerq, 2007c; Hakala et al., 2010; Syazwan *et al*., 2011), it is imperative for the health practitioner to learn more about the possible causal relationship between posture and pain, so that future preventative or management strategies for adolescent UQMP can be evidence-based.

As a result of the above, the aim of the current research project was to develop, build and determine the reliability and validity of a new portable posture measurement instrument, which was then utilised to establish whether sitting postural angles, measured in a real-life setting, were predictive of UQMP in computing South African high school students. Figure 1.1 below is a graphical illustration of the presentation of the dissertation, showing a time-line indicating when the respective studies comprising the research were conducted.

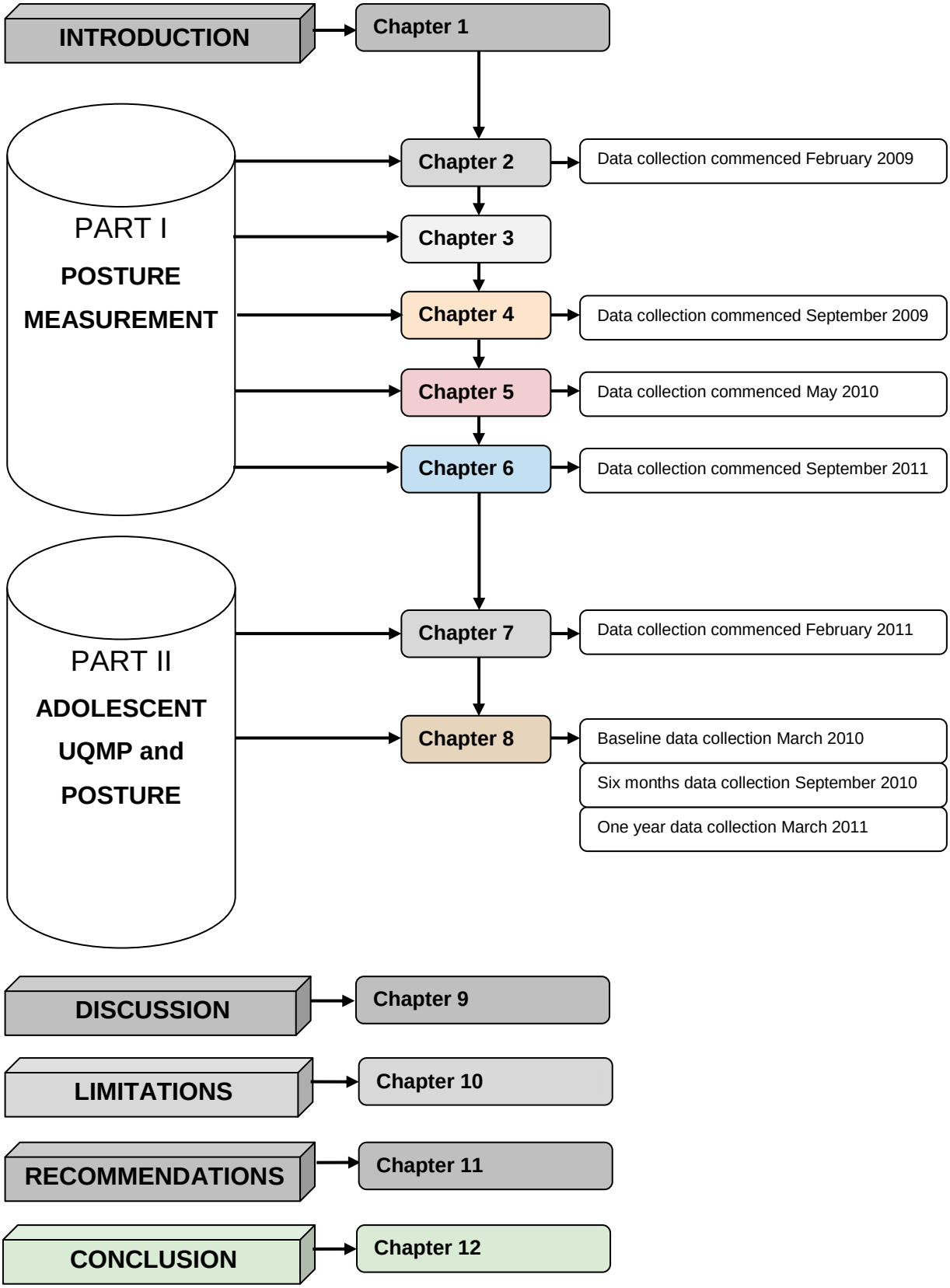


Figure 1.1: Graphical visualisation of the presentation of the dissertation

PART I

POSTURE MEASUREMENT

Preface

Postural assessment is a standard and essential component of examining individuals with neuromusculoskeletal disorders (Bullock-Saxton, 1993; Sheeran, Sparkes, Busse & Van Deursen, 2010). As no uniform definition for 'ideal' posture exists, researchers and clinicians continue to seek the best way of assessing and describing posture. Although ideal spinal posture is proposed as a neutral spinal alignment, the relationship between spinal segments in a normal population remains unknown (Li & Buckle1999; Barrero & Hedge, 2002). The spine is a complex 3D anatomical structure, whose segmental position in space should be described in all three planes (sagittal, frontal and transverse) (Vieira & Kumar, 2004; Hay, Hershkovitz & Rivlin, 2009; Vrtovec, Pernus & Likar, 2009). Precise positional data can be derived from a number of biomechanical measurement instruments, of which non-invasive 3D instruments are preferred (Vieira & Kumar, 2004).

Establishing the psychometric properties of spinal posture measurement instruments is not a trivial task, given the complex nature of human posture. Psychometric testing, which consists of crucial stepping-stones to be followed in terms of the application of posture measurement instruments, should be a rigorous and continuous process that requires a series of experiments to be conducted under different conditions. An important requirement for the psychometric testing of posture measurement is that the instrument used be tested under a given set of conditions on a specific population within the context of the instrument's intended use. Therefore, it is essential that posture measurement

instruments be tested on humans at some stage of their development, and that they are not just tested using inanimate objects (Portney & Watkins, 2009).

Part I of the current dissertation presents a stepwise process that included a secondary synthesis study that was aimed at gaining an understanding of the procedure of reliability and validity testing of posture measurement instruments, and three primary interlinked studies to ascertain the reliability and validity of the 3D Posture Analysis Tool (3D-PAT). Chapter 2 presents the published systematic review (Brink, Louw & Grimmer-Somers, 2011) (Addendum 2): *The quality of evidence of psychometric properties of three-dimensional spinal posture-measuring instruments,* which explores the psychometric testing of recently developed 3D posture measurement instruments. Chapter 3 explains the design and development of the 3D-PAT in a research setting, and Chapters 4 to 6 present the three phases of psychometric testing. The testing was aimed at assessing the concurrent validity of the 3D-PAT when using the Vicon motion analysis system as the reference standard, and at establishing the test-retest reliability of the 3D-PAT. The three consecutive phases of psychometric testing of the 3D-PAT emphasise the importance of critically analysing the testing procedures and the results of each phase, improving the instrument as required, and adapting the testing procedures, before retesting the instrument. Limited rater reliability was tested, because the 3D-PAT is a new instrument that has not yet either been tested or used in a clinical or research setting. Furthermore, the tested variable (sitting posture) must be stable before rater reliability can be tested (Portney & Watkins, 2009), and it was not feasible to have more than one rater in a school setting, because of the time constraints imposed on the study.

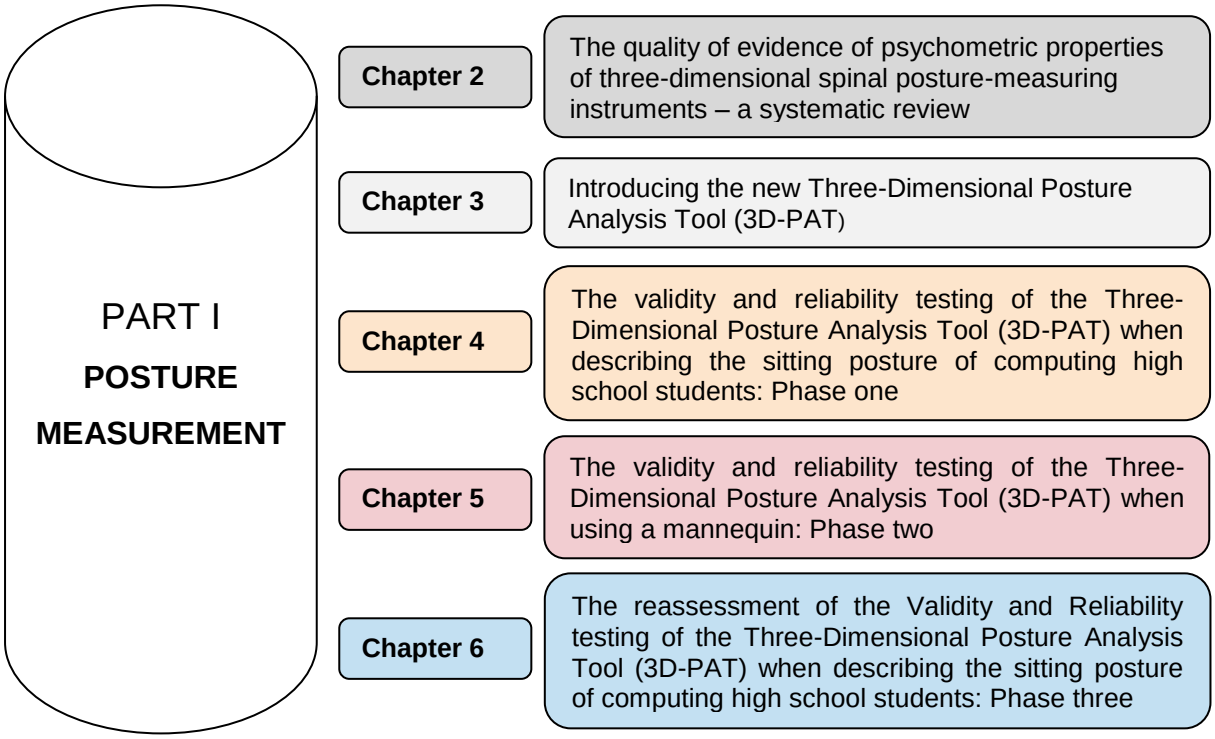


Figure Part I Preface: Graphical visualisation of the presentation of the dissertation – Part I

PART I

CHAPTER 2

The quality of evidence of psychometric properties of three-dimensional spinal posture-measuring instruments

2.1 INTRODUCTION

It is essential that a spinal posture measurement instrument be shown to be reliable and valid. Without such assurance, use of the instrument cannot facilitate diagnosis, chart variability in 'usual' posture, or assist the objective monitoring of patient progress with treatment (Bullock-Saxton, 1993). Researchers and clinicians should, therefore, be familiar with the psychometric properties of spinal posture-measuring instruments, so that they can choose those with the best evidence of performance (White & Van den Broek, 2004).

Two core elements of psychometric properties are reliability and validity (Karanicolas, Bhandari, Kreder, Moroni, Richardson, Walter, Norman & Guyatt, 2009). A measurement instrument cannot be recommended with confidence if there is a lack of evidence about its reliability and validity (Portney & Watkins, 2009). Reliability and validity are interlinked, with reliability and validity being prerequisites to the trustworthiness of an instrument. Reliability refers to an ability to estimate the inherent variability of posture, as well as to estimate the amount of error that can be blamed on the rater and on the measurement instrument (Portney & Watkins, 2009). Error can relate to the consistency with which measurements are taken by the same or different raters, or over multiple occasions of testing (Karanicolas *et al.*, 2009). Reliability is classified as test-retest reliability and inter- and intra-rater reliability. Test-retest reliability describes the stability of the measurement instrument in

obtaining the same results with repeated measurements, using the identical test on two or more separate occasions, and keeping all testing conditions as constant as possible (Portney & Watkins, 2009). Intra-rater reliability is defined as the stability of data recorded by one observer across two or more test occasions, of which the variables being rated are fixed and time the only factor that varies between administrations (Karanicolas *et al.*, 2009; Portney & Watkins, 2009). Inter-rater reliability is the extent to which two or more observers obtain similar scores when using the same instrument, rating the same individuals (Bannigan & Watson, 2009; Karanicolas *et al*., 2009; Portney & Watkins, 2009). Inter-rater reliability is best assessed when the raters concerned can measure the variable simultaneously.

Validity is the extent to which an instrument measures what it is intended to measure (Brink, 2006). Criterion-related validity is the ability of one test (index test) to predict results obtained on an external criterion (gold standard / reference standard) that is assumed to be valid. When both tests are performed on the same subjects, the scores from the index test are correlated with those achieved by means of the criterion measure (Portney & Watkins, 2009). Two types of criterion-related validity exist. Concurrent validity is evaluated when the index test and the criterion measure are taken simultaneously so that the findings reflect the same incident of behaviour, whereas predictive validity is tested when the index test is performed and measured prospectively, so as to ascertain the relationship between the index test and the criterion scores, which allows for determination of whether the index test is a valid predictor of the outcome concerned (Portney & Watkins, 2009).

Thus, convincing evidence of reliability and validity of any posture measurement instrument can only be established by assessing the methodological quality of the

underpinning developmental studies. Specific psychometric study design features are, therefore, essential to establish and to assess, for instance, controls that are put in place for systematic bias, non-systematic bias and inferential error.

The purpose of the systematic review undertaken during the current study was 1) to identify the non-invasive 3D instruments that measure human static sitting or standing spinal posture, and 2) to review the quality of the evidence of reliability and validity of the identified 3D posture measurement instruments.

2.2 METHODS

2.2.1 Search strategies

Two inter-related search strategies (A and B) were implemented to ensure that all eligible papers were included. Strategy A sought to identify any primary research studies that reported the use of 3D non-invasive instruments measuring static sitting or standing spinal posture. Strategy B sought to identify primary research into the psychometric testing of said instruments. In the search, one reviewer trawled the following six electronic databases; BioMed Central; CINAHL; PEDRO; PROQUEST; PUBMED and SCIENCE DIRECT. The publication date was restricted to full-text papers published in English from 1980 to June 2010. MESH terms were used for searching PUBMED. (Refer to Addendum 3 for a detailed description of the database searches conducted.)

In addition, secondary searching was performed through the reference list of the included papers. Experts in the field of research concerned, and authors, who failed to provide references to studies that tested an instrument's psychometric properties, were contacted.

2.2.2 Keywords and synonyms

The following keywords were used: three-dimensional; measurement tool; assessment tool; instrument; measurement; assessment; spinal posture; posture; validity; reliability; accuracy and reproducibility.

2.2.3 Inclusion and exclusion criteria for paper selection

Papers were included if they reported testing an instrument's psychometric properties, specifically reliability and/or validity, using humans, or the instrument's validity, using objects. A core inclusion criterion was that static standing or sitting spinal posture had to be evaluated using an instrument that could quantitatively calculate 3D spinal posture without using a baseline reference value, such as zero. The evaluation had to take place in this way because a reference value requires that the subject be required firstly to assume a neutral or resting posture, at which point the instrument is zeroed, before it can be used to measure the static spinal posture. For the purpose of the current review, static posture was assessed instantaneously, without any guiding from the rater.

Papers were excluded if they (1) reported neither reliability nor validity testing; (2) did not report on static spinal posture (e.g. reported on the 3D motion of the spine, scapulo-humeral girdle or pelvis); or (3) reported on the validity testing of an instrument using motion (as motion was not incorporated in this review, and we argue that validity be evaluated within the context of the instrument's intended use). In addition papers were excluded if (4) the instrument concerned only measured cadaver or in vitro spinal posture; (5) the instrument was invasive (e.g. biplanar radiography or stereoradiography); and if (6) only an algorithm or a mathematical formula were reported.

2.2.4 Study selection

One reviewer excluded papers by screening all the titles and reading their abstracts, after which two independent reviewers selected the eligible papers, after reading the full-text version of the remaining papers. Figure 2.1 below describes the procedures of study selection used for each of the two search strategies concerned.

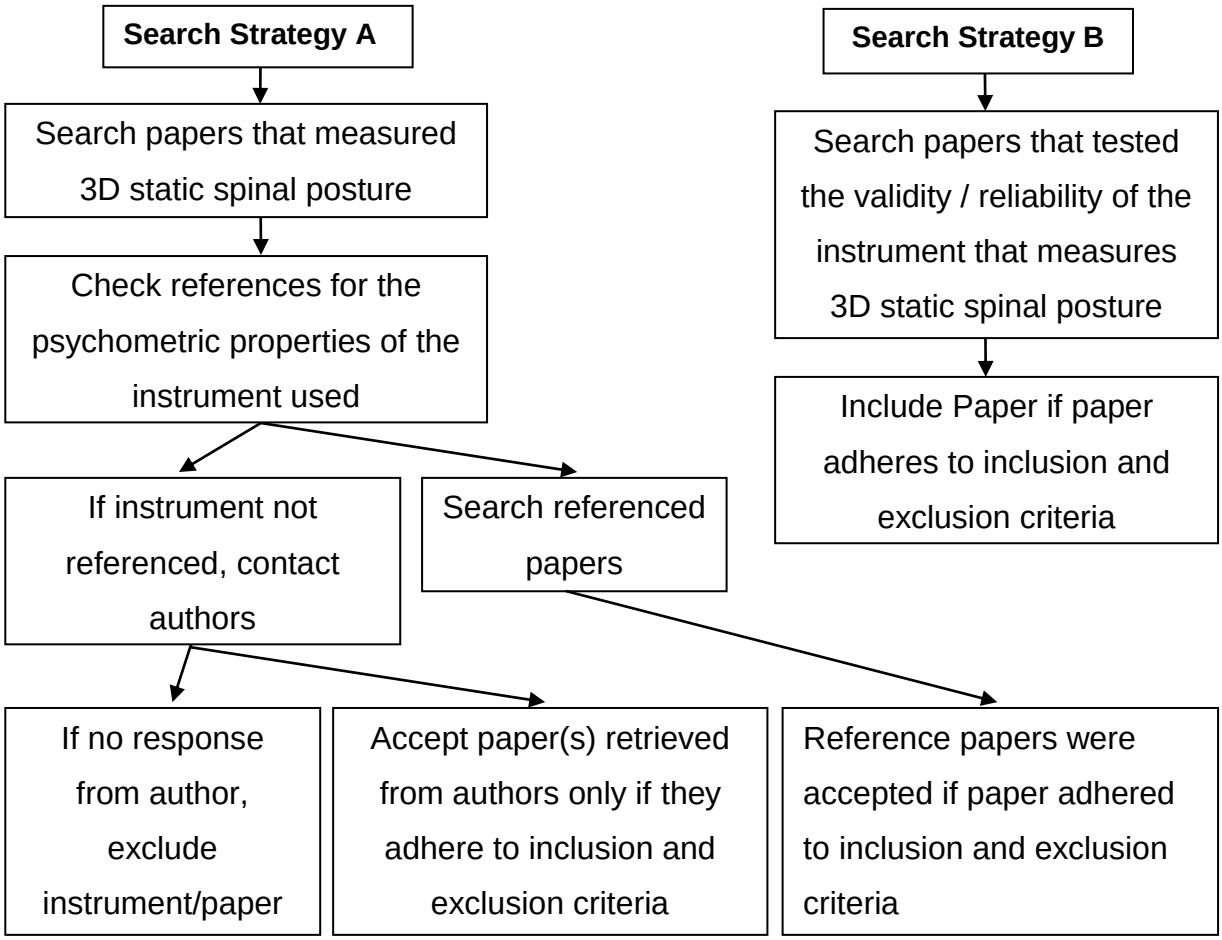


Figure 2.1: A flowchart to demonstrate the procedures followed for study selection

2.2.5 Methodological quality appraisal

The full-text eligible papers were subjected to methodological critical appraisal. The Critical Appraisal Tool (CAT) applied in the review was purpose-built, in the absence of any other relevant CAT. The tool was adapted from the Quality Assessment of Diagnostic Accuracy Studies (QUADAS) (Whiting, Rutjes, Reitsma, Bossuyt & Kleijnen, 2003) and from the

Quality Appraisal of Reliability Studies (QAREL) (Lucas, Macaskill, Irwig & Bogduk, 2010). Although the purpose-built CAT consisted of 13 items, its data were not designed to be reported as a composite quality score (see Addendum 4). The CAT was designed to assess the impact of each individual item on the quality of the methodological procedures implemented in each paper. The development of the CAT, is described in the paper *Clinical Instruments: Reliability and validity critical appraisal* (Brink & Louw, 2012) (Addendum 5). Prior to the critical appraisal of the included papers, three papers were randomly selected and assessed independently by three reviewers using the purpose-built CAT. Disagreements were discussed in order to ensure that the interpretation of the CAT items was consistent.

2.3 RESULTS

2.3.1 Results from the search strategies

Of the 130 possible papers considered, only 30 were deemed eligible for inclusion in the study. Nine additional papers were identified after searching the reference lists of latter papers. Two further papers were included after experts and authors had been contacted. Figure 2.2 below provides a consort diagram to demonstrate the selection of papers.

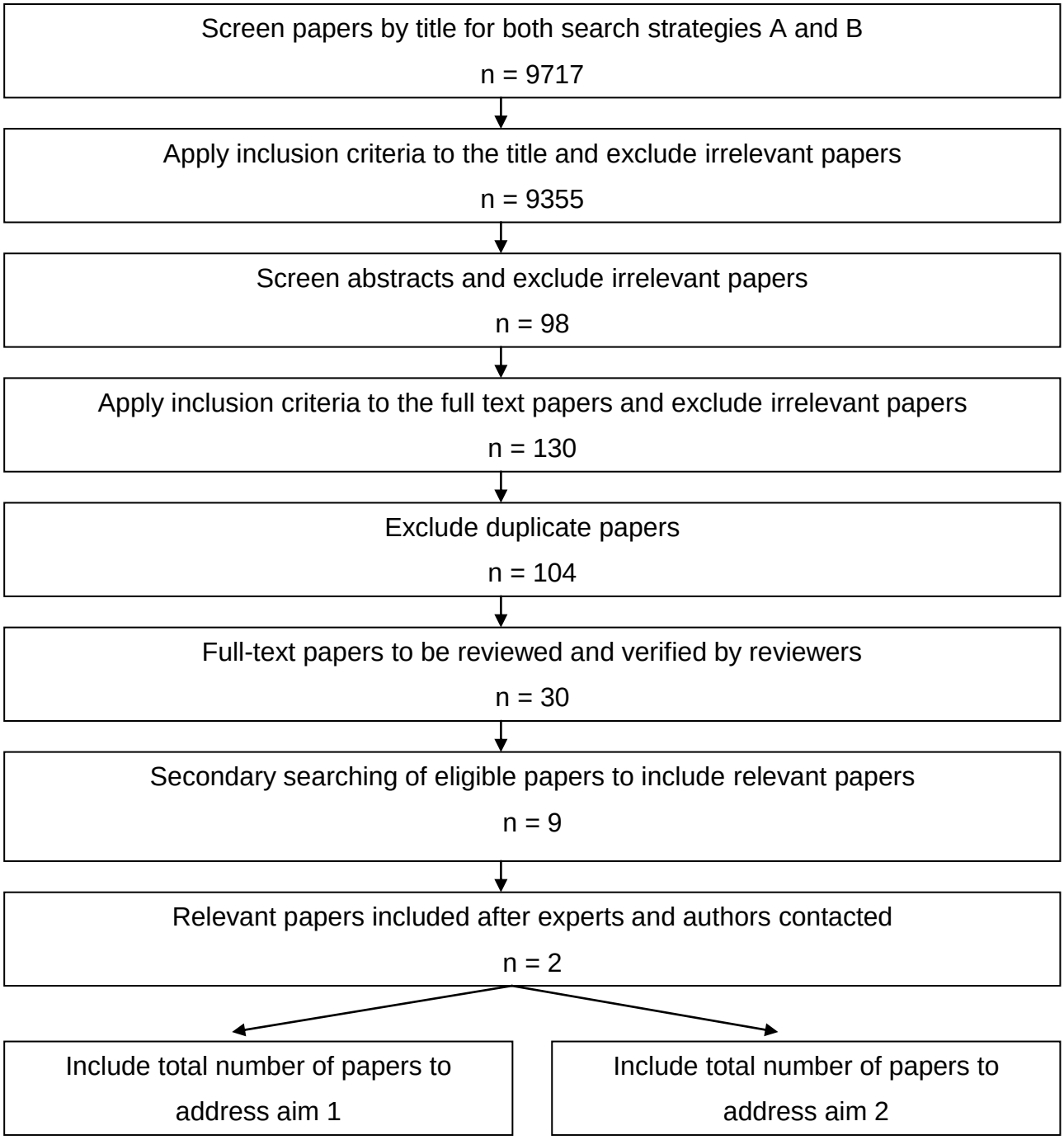


Figure 2.2: Consort diagram to demonstrate the selection of papers

2.3.2 Volume of literature

Of the 18 instruments identified from the two literature searches, 15 were retrieved by way of Search A, one by way of Search B, and two by way of author contacts. The instruments identified as being of relevance to the current study are listed in the first column of Table 2.1 below, with the papers addressing Aim One appearing in the second column and those

addressing Aim Two appearing in the third column. The papers reporting on the above instruments are identified by bold script if identified through strategy A, in italics if through strategy B, in normal script if through author search, and with an asterisk if through secondary searching. The Automatic Scoliosis Analyser System (Auscan) (Italy), the Elite system (Italy), the Optotrak 3020 (Canada), the Peak Motus (USA), the PosturePrint (Canada), the Qualysis Proreflex Motion Capture Unit system (Sweden), the Vicon 370 (England) and an Optoelectronic camera system (Canada) are optoelectronic analysis systems. The Fonar upright positional MRI (USA) uses magnetic resonance imaging. The INSPECK (Canada) is an optical 3D digitiser. The Lumbar Motion Monitor (LMM) (USA) is an electrogoniometer. The Metrecom (USA), the Articulated Arm for Computerised Surface Measurement (BACES) (Italy) and the Microscribe 3DX Digitizer (USA) are computerised electromechanical 3D digitisers. Rasterstereography is a photogrammetric method based on triangulation. The 3 Space Isotrak or Fastrak (USA) and the Electromagnetic tracking system (USA) are electromagnetic devices. The Zebris (Germany) is an ultrasound analysis system.

Table 2.1: Recent 3D instruments used to measure static spinal posture

Instrument	Addresses Aim 1: Used to measure posture	Addresses Aim 2: Reports on psychometric properties	N
BACES	**D'Osualdo, Schierano, Soldano & Isola (2002)**		
AUSCAN	*Negrini & Negrini (2007)*		
Electromagnetic tracking system	**Claus, Hides, Moseley & Hodges (2009)**		
Elite optoelectronic system	**Lissoni, Caimmi, Rossini & Terenghi (2001); Naslund, Jesinkey, Sundelin, Von Wendt & Hirschfeld (2005)**		
Inspek		Pazos, Cheriet, Song, Labelle & Dansereau (2005*); **Pazos, Cheriet, Dansereau, Ronsky, Zernicke & Labelle (2007)**	2
Lumber Motion Monitor (LMM)	**Jang, Karwowski, Quesadas, Rodrick, Sherehiy, Cronin & Layer (2007)**		
FONAR Upright positional MRI	**Morl & Blickhan (2006); Cargill et al. (2007); Lafon, Smith & Beillas (2010)**		
Metrecom	Franklin , Chenier, Brauninger, Cook & Harris (1995*) ; **Black, McClure & Polansky (1996); Gram & Hasan (1999)**	Smidt, McQuade & Wei (1992*); Norton & Ellison (1993*)	2
Microscribe 3DX Digitizer		Warren, Bettany-Saltikov, Van Schaik & Papastefanou (2005)	1
Optoelectronic camera system	**Duong, Mac-Thiong & Labelle (2009)**		
Optotrak 3020	Rempel, Barr, Brafman & Young (2007)		
Peak Motus	**Straker et al. (2009b)**		
Postureprint		**Normand, Harrison, Calliet, Black, Harrison & Holland (2002)**; *Harrison, Janik, Calliet, Harrison, Normand, Perron & Ferrantell (2007)*; **Janik, Harrison, Calliet, Harrison, Normand & Perron (2007)**; *Normand, Descarreaux, Harrison, Harrison, Perron, Ferrantelli & Janik (2007)*	4
Qualysis Proreflex Motion Capture Unit system	**Grip, Sundelin, Gerdle & Karlsson (2007); Neiva, Kirkwood & Godinho (2009)**		
Rasterstereography		Stokes, Armstrong & Moreland (1988*); **Hackenberg, Hierholzer, Potzl, Gotze & Liljenqvist (2003a)**; *Hackenberg, Hierholzer, Potzl, Gotze & Liljenqvist (2003b)*; Drerup & Hierholzer (1994*, 1996*)	5

Table 2.1: Recent 3D instruments used to measure static spinal posture (cont.)

Instrument	Addresses Aim 1: Used to measure posture	Addresses Aim 2: Reports on psychometric properties	N
3 Space Isotrack / Fastrak	O' Sullivan et al. (2006*); **Caneiro et al. (2010); Astfalck et al. (2010)**	Pearcy & Hindle (1989*)	1
Vicon three-dimensional kinematic system	**Levine & Whittle (1996)**; **Szeto, Straker & O'Sullivan (2005); Skalli, Zeller, Miladi, Bourcereau, Savidan, Lavaste & Dubousset (2006)**	**Whittle & Levine (1997)**	1
Zebris CMS70P; Zebris CMS20	**Theisen, Van Wagensveld, Timmesfeld, Efe, Heyse, Fuchs-Winkelmann & Schofer (2010)**	**Geldhof et al. (2007b)**	1

N: Number of papers addressing aim 2; Bold script: Papers from search A; Italic script: Papers from search B;: Papers from secondary search; Normal script: Papers from author search.*

The 17 papers that reported on the reliability and/or the validity of the included instruments were thus assessed in order to address the second aim (see Table 2.1, third column). One paper by Smidt, McQuade and Wei (1992) reported on both reliability and validity, and was therefore reviewed as if it was two separate papers, due to the nature of the review. Drerup and Hierholzer (1996) tested a new algorithm for processing data presented in a previous paper (Drerup & Hierholzer, 1994). The papers were reviewed as if they were one paper, because the previous paper reported on the study procedure in relatively great detail, whereas the latter paper discussed the latest improvement made in the data processing procedure.

2.3.3 Aim of the reliability studies

The aim of six studies was to test the reliability of a 3D instrument in assessing the spinal posture of humans (Smidt *et al*., 1992; Whittle & Levine 1997; Warren, Bettany-Saltikov, Van Schaik & Papastefanou, 2005; Geldhof et al., 2007b; Normand, Descarreaux, Harrison, Harrison, Perron, Ferrantelli & Janik, 2007; Pazos, Cheriet, Dansereau, Ronsky, Zernicke & Labelle, 2007).

2.3.4 Aim of the validity studies

The aim of 11 studies was to test the validity of a 3D posture instrument. Four studies (Stokes, Armstrong and Moreland, 1988; Drerup & Hierholzer, 1996; Hackenberg, Hierholzer, Potzl, Gotze & Liljenqvist, 2003a; Hackenberg, Hierholzer, Potzl, Gotze & Liljenqvist, 2003b) used human subjects to measure 3D spinal posture and to compare the results with those obtained from a reference standard. The other seven studies used mannequins (Pazos, Cheriet, Song, Labelle, & Dansereau, 2005; Harrison, Janik, Calliet, Harrison, Normand, Perron & Ferrantelli, 2007; Janik, Harrison, Calliet, Harrison, Normand & Perron, 2007), wooden wedges (Pearcy & Hindle, 1989), a steel frame (Smidt et al., 1992), parallelograms (Normand, Harrison, Calliet, Black, Harrison & Holland, 2002) or other objects with known parameters (Norton & Ellison, 1993) to test the validity of an instrument that could be used to assess the 3D spinal posture of humans in future.

2.3.5 Study design for reliability and validity studies

The type of reliability and validity tested, as well as the time interval for the reliability studies and the reference standard for the validity studies, are reported in Table 2.2 below.

Table 2.2: The type and time interval for reliability studies and the type and reference standard for validity studies

Author	Type of reliability	Time interval	Type of validity	Reference standard
Stokes et al. (1988)	N/A	N/A	Criterion-related validity	Stereoradiography
Pearcy & Hindle (1989)	N/A	N/A	Concurrent validity	Precision optical inclinometer
Smidt et al. (1992)	N/A	N/A	Concurrent validity	Not specified
	Intra- and interrater reliability	On the same day	N/A	N/A
Norton & Ellison (1993)	N/A	N/A	Concurrent validity	Type measure or ruler
Drerup & Hierholzer (1996)	N/A	N/A	Criterion-related validity	Stereoradiography
Normand et al. (2002)	N/A	N/A	Concurrent validity	Not specified
Hackenberg et al. (2003a, 2003b)	N/A	N/A	Criterion-related validity	Stereoradiography
Pazos et al. (2005)	N/A	N/A	Concurrent validity	Coordinate measuring machine
Harrison et al. (2007); Janik et al. (2007)	N/A	N/A	Concurrent validity	Not specified
Whittle & Levine (1997)	Intrarater reliability	On the same day	N/A	N/A
Warren et al. (2005)	Intrarater reliability	One minute	N/A	N/A
Geldhof et al. (2007b)	Intrarater reliability	One week	N/A	N/A
Pazos et al. (2007)	Test retest reliability	30 seconds	N/A	N/A
Normand et al. (2007)	Intra- and interrater reliability	One day	N/A	N/A

N/A: Not applicable.

2.3.6 Statistical analysis

Table 2.3 summarises the statistical procedures implemented in the reliability and validity studies. Comparing the findings in the table with the types of reliability and validity testing

reported in Table 2.2 highlights the variability in choice and application of statistical tests to assess the same constructs.

Table 2.3 Statistical procedures of the reliability and validity studies

Author	Statistical analysis
Stokes et al. (1988)	Linear regression analysis and Pearson correlation coefficient ®
Pearcy & Hindle (1989)	Means; estimate of error, regression analysis and intra-class correlation coefficient (ICC)
Smidt et al. (1992)	Dunnett's comparison test
Norton & Ellison (1993)	Pearson product moment correlation coefficient ® and repeated measures t-test
Drerup & Hierholzer (1996); Hackenberg et al. (2003a, 2003b)	Root mean square (RMS) deviations of the surface curves from the radiographic curves
Whittle & Levine (1997)	ICC and Pearson correlation coefficient
Normand et al. (2002)	Means, SD, SEM, 95% confidence intervals (CIs) and mean differences
Pazos et al. (2005)	Multiway ANOVA
Warren et al. (2005)	Pearson correlation coefficient and ICC
Harrison et al. (2007); Janik et al. (2007)	Error analyses of mean differences and SD
Geldhof et al. (2007b)	ICC for test-retest reliability
Pazos et al. (2007)	Bivariate ANOVA; typical error of measurement (TEM); 95% CI of the TEM; smallest detectable difference (SDD) and multivariate ANOVA
Normand et al. (2007)	Mean absolute values of differences within and between examiner measurements; ANOVA; Shapiro-Wilk test and SEM for conservative and liberal ICC methods

2.3.7 Methodological quality appraisal

Table 2.4 below reports the findings from the critical appraisal of the papers, which is related to reliability and validity testing.

Table 2.4: Summary of the methodological quality appraisal results of the studies (n = 17)

Authors	Item 1	Item 2	Item 3	Item 4	Item 5	Item 6	Item 7	Item 8	Item 9	Item 10	Item 11	Item 12	Item 13
Stokes et al. (1988)	√	x	√	n/a	n/a	n/a	√	n/a	√	√	√	√	√
Pearcy & Hindle (1989)	n/a	x	√	n/a	n/a	n/a	n/a	n/a	√	√	√	n/a	√
Smidt et al. (1992) (validity)	n/a	x	x	n/a	n/a	n/a	n/a	n/a	x	√	x	n/a	√
Smidt et al. (1992) (reliability)	√	√	n/a	√	√	x	n/a	√	n/a	√	n/a	x	√
Norton & Ellison (1993)	n/a	x	x	n/a	n/a	n/a	n/a	n/a	√	√	√	n/a	x
Drerup & Hierholzer (1994, 1996)	x	x	√	n/a	n/a	n/a	√	n/a	√	√	√	√	√
Whittle & Levine (1997)	√	x	n/a	n/a	x	x	n/a	√	n/a	√	n/a	√	√
Normand et al. (2002)	n/a	x	x	n/a	n/a	n/a	n/a	n/a	x	√	x	n/a	√
Hackenberg et al. (2003a)	√	x	√	n/a	n/a	n/a	√	n/a	√	x	√	x	√
Hackenberg et al. (2003b)	√	x	√	n/a	n/a	n/a	√	n/a	√	x	√	x	√
Warren et al. (2005)	√	x	n/a	n/a	X	x	n/a	√	n/a	√	n/a	x	√
Pazos et al. (2005)	n/a	x	√	n/a	n/a	n/a	n/a	n/a	√	√	√	n/a	√
Harrison et al. (2007)	n/a	x	x	n/a	n/a	n/a	n/a	n/a	x	√	x	n/a	√
Janik et al. (2007)	n/a	x	x	n/a	n/a	n/a	n/a	n/a	x	√	x	n/a	√
Geldhof et al. (2007b)	√	x	n/a	n/a	√	x	n/a	√	n/a	√	n/a	√	√
Pazos et al. (2007)	√	x	n/a	n/a	n/a	n/a	n/a	√	n/a	√	n/a	x	√
Normand et al. (2007)	√	√	n/a	√	√	√	n/a	√	n/a	√	n/a	√	√

Item 1: If human subjects were used, did the authors give a detailed description of the sample of subjects used to perform the (index) test?

Nine papers (Stokes *et al*., 1988; Whittle & Levine, 1997; Smidt *et al*., 1992; Hackenberg *et al.,* 2003a, 2003b; Warren *et al*., 2005; Geldhof *et al*., 2007b; Normand *et al*., 2007; Pazos *et al*., 2007) scored 'yes' because a detailed description of the sample characteristics was given. Drerup and Hierholzer (1996) scored 'no', as the authors did not mention how their subjects were recruited and merely stated that only scoliosis patients were included. Seven papers (Pearcy & Hindle, 1989; Smidt *et al*., 1992; Norton & Ellison, 1993; Normand *et al*., 2002; Pazos *et al*., 2005; Harrison *et al*., 2007; Janik *et al.,* 2007) scored 'not applicable' because the studies covered used inanimate objects.

Item 2: Did the authors clarify the qualification or competence of the rater(s) who performed the (index) test?

Eleven validity studies (Stokes *et al.,* 1988; Pearcy & Hindle, 1989; Smidt *et al.,* 1992; Norton & Ellison, 1993; Normand et al., 2002; Drerup & Hierholzer, 1996; Hackenberg *et al.*, 2003a, 2003b; Pazos *et al*., 2005; Harrison *et al.,* 2007; Janik *et al.,* 2007) and 4 reliability studies (Whittle & Levine, 1997; Warren *et al*., 2005; Geldhof *et al*., 2007b; Pazos *et al*., 2007) scored 'no'. The qualifications of the operators of the instruments concerned were not reported, as their past experience with operating these instruments was not described. The reliability studies of Smidt *et al*. (1992) and of Normand *et al*. (2007) scored 'yes' as they stated that the operators were 'familiar and competent' in the instrument's use.

Item 3: Was the reference standard explained?

Stokes *et al*. (1988), Drerup and Hierholzer (1996) and Hackenberg et al. (2003a, 2003b) scored 'yes' as they provided references for the methods used to digitise the radiographs.

Pearcy and Hindle (1989) and Pazos *et al*. (2005) scored 'yes' because the authors named the instruments used and stated their accuracy. Norton and Ellison (1993) scored 'no' because a ruler or tape measure was inappropriately used as a reference standard for calculating 3D-coordinates of a point in space. The studies by Smidt *et al.* (1992), Normand *et al*. (2002), Harrison *et al*. (2007) and Janik *et al*. (2007) scored 'no' because the authors used an object with known 3D parameters as reference standards, but the methods of measuring the 3D locations, angles or distances concerned were not explained.

Item 4: If inter-rater reliability were tested, were the raters blinded to the findings of other raters?

Smidt *et al*. (1992) and Normand *et al*. (2007) scored 'yes' because subjects were evaluated separately by the different raters. As Whittle and Levine (1997), Warren *et al*. (2005) and Geldhof *et al*. (2007b) only tested intra-rater reliability, their studies scored 'not applicable'. The study of Pazos *et al*. (2007) scored 'not applicable' because, instead of evaluating rater reliability, test-retest reliability of the instrument, when using different postures, was evaluated.

Item 5: If intra-rater reliability were tested, were raters blinded to their own prior findings of the test under evaluation?

Smidt *et al*. (1992), Geldhof *et al*. (2007b) and Normand *et al*. (2007) scored 'yes' because the raters concerned were sufficiently blinded to their own prior measurements, as repeated digitising of the anatomical landmarks took place one week apart, all photographs were numbered and were not identifiable by subject name, occasion or characteristics, or no skin markings were made on the subjects involved. Whittle and Levine (1997) and Warren *et al*. (2005) scored 'no' because passive and skin markings

respectively were placed only once on the subject and were not removed between repeated measurements. Pazos *et al*. (2007) scored 'not applicable', because they did not test rater reliability.

Item 6: Was the order of examination varied?

Normand *et al*.'s (2007) paper scored 'yes', because the subjects were evaluated in random order. The studies of Whittle and Levine (1997) and Warren *et al*. (2005) scored 'no', because repeated measurements were performed consecutively without changing the order of subjects during testing. Geldhof *et al*.'s (2007b) paper scored 'no', as the order of testing was kept the same for the repeated measurements that were made one week apart. Smidt *et al*.'s (1992) research scored 'no', as insufficient information was provided. Pazos *et al*.'s (2007) study scored 'not applicable', because no rater reliability was tested.

Item 7: If human subjects were used, was the time period between the reference standard and the index test short enough to be reasonably sure that the target condition did not change between the two tests?

The studies of Stokes *et al*. (1988), Drerup and Hierholzer (1996) and Hackenberg *et al*. (2003a, 2003b) scored 'yes', because the radiographs and the rasterstereographs were taken on the same day. The other seven articles (Pearcy & Hindle, 1989; Smidt *et al*., 1992; Norton & Ellison, 1993; Normand *et al*., 2002; Pazos *et al*., 2005; Harrison *et al*., 2007; Janik *et al*., 2007) scored 'not applicable', because inanimate objects that cannot deform with the passage of time were used.

Item 8: Was the stability (or theoretical stability) of the variable being measured taken into account when determining the suitability of the time-interval between repeated measures?

Six papers scored 'yes', because repeated measurements of posture were either taken on the same day (Smidt *et al*., 1992; Whittle & Levine, 1997; Warren *et al.,* 2005; Pazos *et al.,* 2007), one week (Geldhof *et al*., 2007b) or one day apart (Normand *et al*., 2007).

Item 9: Was the reference standard independent of the index test?

Seven papers (Stokes *et al*., 1988; Pearcy & Hindle, 1989; Norton & Ellison, 1993; Drerup & Hierholzer, 1996; Hackenberg *et al*., 2003a, 2003b; Pazos *et al*., 2005) scored 'yes', because the index test and the reference standard were independant instruments. The papers of Smidt *et al*. (1992), Normand *et al*. (2002), Harrison *et al*. (2007) and Janik *et al*. (2007) scored 'no', due to insufficient information being provided.

Item 10: Was the execution of the (index) test described in sufficient detail to permit replication of the test?

Nine validity (Stokes *et al*., 1988; Pearcy & Hindle, 1989; Smidt *et al*., 1992; Norton & Ellison, 1993; Drerup & Hierholzer, 1996; Normand *et al*., 2002; Pazos *et al*., 2005; Harrison *et al*., 2007; Janik *et al*., 2007) and six reliability papers (Smidt *et al*., 1992; Whittle & Levine, 1997; Warren *et al*., 2005; Geldhof *et al*., 2007b; Normand *et al*., 2007; Pazos *et al*., 2007) scored 'yes', because clear descriptions of how the instruments were applied to the subjects or to the inanimate objects were provided. Hackenberg *et al*. (2003a, 2003b) scored 'no', as the authors neither explained how raterstereographs were performed on the subjects, nor provided any citations for the methodology.

Item 11: Was the execution of the reference standard described in sufficient detail to permit its replication?

Seven papers scored 'yes', because clear descriptions of how the reference standard was used on the subjects (Stokes *et al*., 1988; Drerup & Hierholzer, 1996) or on the inanimate objects (Pearcy & Hindle, 1989; Norton & Ellison, 1993; Pazos *et al*., 2005) or citations for the methodology (Hackenberg *et al*., 2003a, 2003b) were provided. The studies of Smidt *et al*. (1992), Normand *et al*. (2002), Harrison *et al*. (2007) and Janik *et al*. (2007) scored 'no' for the reasoning provided for item 3.

Item 12: Were withdrawals from the study explained?

The research papers of Stokes *et al*., (1988), Whittle and Levine (1997), Drerup and Hierholzer (1996), Geldhof *et al*. (1997) and Normand *et al.* (2007) scored 'yes', because the number of subjects who participated in the studies was reflected in the results sections of the studies. The studies of Hackenberg *et al*. (2003a, 2003b) scored 'no', as the authors did not explain why 48 instead of 52 and 24 instead of 25 subjects participated in the pre-operative evaluations respectively. Smidt *et al*. (1992), Warren *et al*. (2005) and Pazos *et al*. (2007) scored 'no', due to insufficient information being provided. Seven papers (Smidt *et al*., 1992; Pearcy & Hindle, 1989; Norton & Ellison, 1993; Normand *et al*., 2002; Pazos *et al.,* 2005; Harrison *et al*., 2007; Janik, *et al*., 2007) scored 'not applicable', because the studies concerned used inanimate objects.

Item 13: Were the statistical methods appropriate for the purpose of the study?

All but one paper by Norton and Ellison (1993) implemented appropriate statistical analysis, which thus scored 'no'. Although the other sixteen papers reported conducting appropriate statistical analysis, only five papers (Drerup & Hierholzer, 1996; Hackenberg

et al., 2003a, 2003b; Warren *et al*., 2005; Normand *et al*., 2007) provided a justification of, or motivation for, using their chosen statistical measures.

2.4 SUMMARY

The review identified eighteen 3D human posture measurement instruments, in relation to which papers describing the psychometric property testing of only eight instruments were found (see Table 2.1, column C). The psychometric properties of the 3D spinal posture measurement instruments were either not well conducted or not well reported. The current review highlights four methodological shortcomings: rater qualification; reference standard; blinding for intra- or inter-rater reliability; and statistical analysis. The shortcomings identified are discussed below.

2.4.1 Rater qualification

Both reliability and validity studies should provide descriptions of the qualifications of the rater(s) used in the studies, because the professional background, expertise and prior training of the rater(s) operating the instruments affect psychometric property assessment.

2.4.2 Reference standard

In order to test validity, it is important that the psychometric properties of the reference standard be known to confirm that the reference standard is suitable (Bossuyt, Reitsma, Bruns, Gatsonis, Glasziou, Irwig, Moher, Rennie, De Vet & Lijmer, 2003).

2.4.3 Blinding for intra- or inter-rater reliability

When repeated measurements are performed one week apart, it is important to vary the order of the subjects, otherwise it enhances the possibility of the raters recalling the test outcomes of the previous measurements and of them potentially incurring increased bias.

When testing intra-rater reliability, the anatomical markers should be removed before replacement between repeated measurements, otherwise the raters will not be blinded to their previous measurements of the same subjects. Consequently, failure to follow the correct procedure could introduce bias and could compromise the quality of the study findings obtained.

2.4.4 Statistical analysis

Given the complexity of posture measurement and interpretation, no statistical strategy for psychometric property testing is without its disadvantages. Therefore it seems sensible to report the findings of two or more different statistical analysis approaches in order to validate findings and in order to justify the reason for a particular statistical test being chosen (Lucas *et al.*, 2010).

The review concludes that further research into the reliability and validity testing of the instruments concerned is required to improve the quality of reliability and validity evidence of 3D posture measurement instruments. Improving the methodological rigor of reliability and validity testing, would enhance the users' confidence in static human 3D sitting or standing spinal posture measurement in clinical and research settings.

The review also highlighted the need for a cost-effective portable 3D posture measurement instrument that has undergone the appropriate psychometric testing. Therefore the following chapter describes the design of the 3D-PAT that was developed to measure the sitting postural angles of high school students in a computer classroom set-up.

PART I

CHAPTER 3

Introducing the new Three-Dimensional Posture Analysis Tool (3D-PAT)

3.1 BACKGROUND

A collaborative research project was conducted with mechanical engineers from the Department of Mechanical and Mechatronic Engineering of Stellenbosch University. The engineers concerned were responsible for the design and development of the new 3D-PAT, and the researcher was responsible for testing the reliability and validity of the measurement instrument involved.

The 3D-PAT needed to be inexpensive and portable, as it would be taken to various schools to assess the students' sitting posture in their own computer classrooms while working on desktop computers. The layout of the measurement instrument also needed to be easily configurable in order to allow for adaptation to various (spacious versus confined) classroom settings and dimensions. Certain parts of the 3D-PAT, such as the Point Grey research cameras; software development kit and camera tripods, were decided upon based on the need for easy accessibility by the research team, thus keeping costs to a minimum. The estimated cost of the 3D-PAT was R30 000.00 (US $3 600.00). The 3D-PAT was to be a basic implementation of stereovision, serving as an early-level measurement instrument upon which further improvements would be made once it had been used in the field. This chapter describes the 3D-PAT in detail and explains the improvements already made to the measurement instrument during the course of the research project.

3.2 THREE-DIMENSIONAL POSTURE ANALYSIS TOOL (3D-PAT)

3.2.1 Equipment

The 3D-PAT consists of:

- Five 0.3 MP CMOS FireFly MV – 640 × 480 (Point Grey Research) cameras;
- 6 mm fixed focal-length lenses (Point Grey Research);
- Five- and three- port IEEE hubs;
- a IEEE 1394b Firewire bus expansion card;
- a power supply for the required voltages to the expansion card;
- Firewire (IEEE-1394b) cables;
- a computer equipped with the Windows operating system;
- two steel cross-bars;
- two steel clamps;
- two camera tripods;
- black cloth; and
- a calibration object.

Two and three cameras were mounted on each steel cross-bar respectively, which were fastened to the tripod head using a clamp. The black cloth was draped from the cross-bar downwards, in order to create a uniform backdrop for the photographic images. The cameras could individually rotate horizontally, whereas the metal bar could rotate horizontally and tilt vertically using the adjustable tripod head, and the camera unit (cameras, steel cross-bar, steel clamp, tripod, and black cloth) could be moved in any direction – thus increasing the flexibility of camera positioning. Figure 3.1(a)–(c) below demonstrates the camera unit of the 3D-PAT.

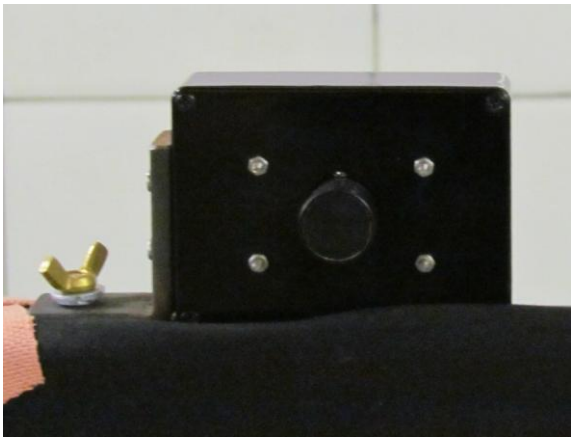


Figure 3.1(a): A 0.3 MP CMOS FireFly MV – 640 × 480 camera

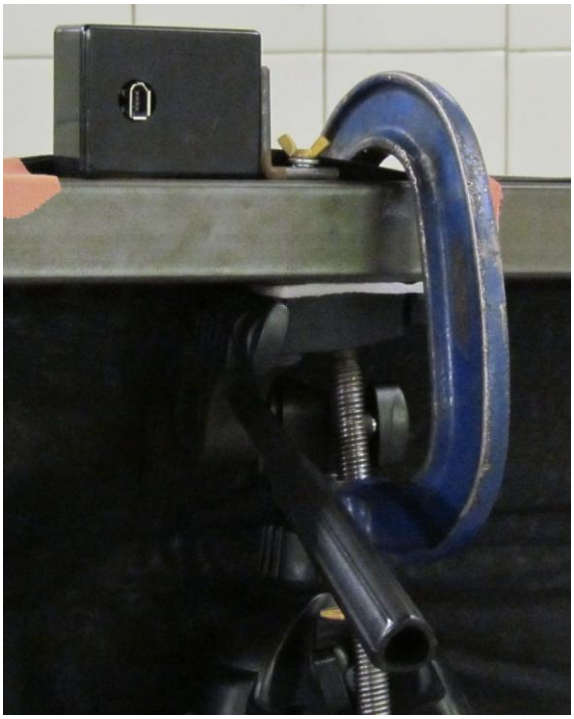


Figure 3.1(b): A close-up photograph of the camera unit, showing a centre camera, with the steel clamp keeping the cross-bar firmly on the tripod

Figure 3.1(c): A full-length photograph of the camera unit of the 3D-PAT

The five cameras were connected via the two- and three-port hubs to a single IEEE bus. The IEEE 1394b Firewire bus expansion card connected the single IEEE bus to the computer. Figure 3.2 below demonstrates the system connections used.

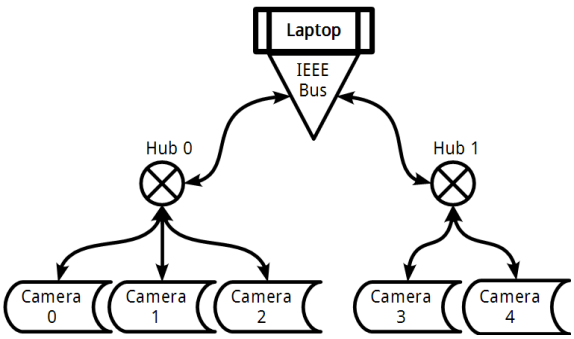


Figure 3.2: Schematical presentation of the system connections

Source: Van der Westhuizen (2011:14)

3.2.2 Calibration objects

Two forms of calibration objects were designed for the project. The first object was an aluminium corner-shaped object with 48 black dots on the outer surface on two orthogonal planes, XZ and YZ, with the centres of each fiducial marker accurately known. The origin of the object was in the bottommost corner, where the two planes met (Van der Westhuizen, 2011). The dimensions of the object were 300 mm × 300 mm × 300 mm, as are shown in Figure 3.3 below.

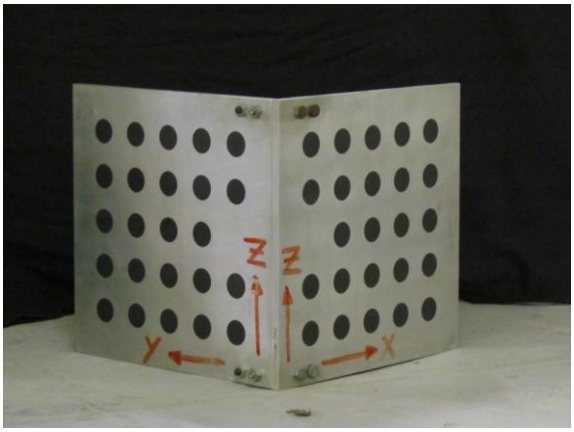


Figure 3.3: The aluminum corner-shaped calibration object

When a subject was captured from a 360° view, the object required rotating once, so that all cameras the cameras concerned had a chance to capture the 48 fiducial markers used. When the object moved, the origin of the calibration object's reference frame changed, therefore the cameras needed to be grouped into two sets, which a coordinate transformation was used to align.

The 48 fiducial markers were arranged from (y_0,z_0) to (y_4,z_4) on the left side and from (x_0,z_0) to (x_4,z_4) on the other. No fiducial marker was provided for (y_2,z_0) on the left or for (x_0,z_2) on the right. Figure 3.4 below demonstrates the labelling of each fiducial marker used.

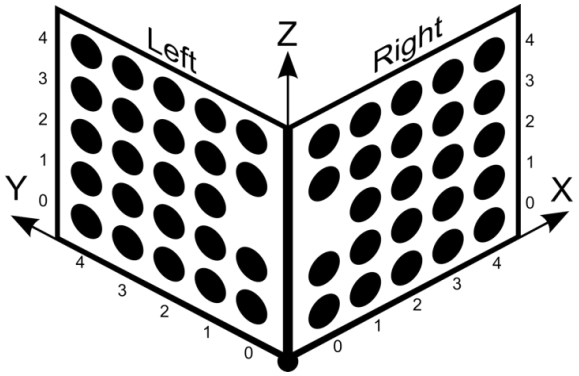
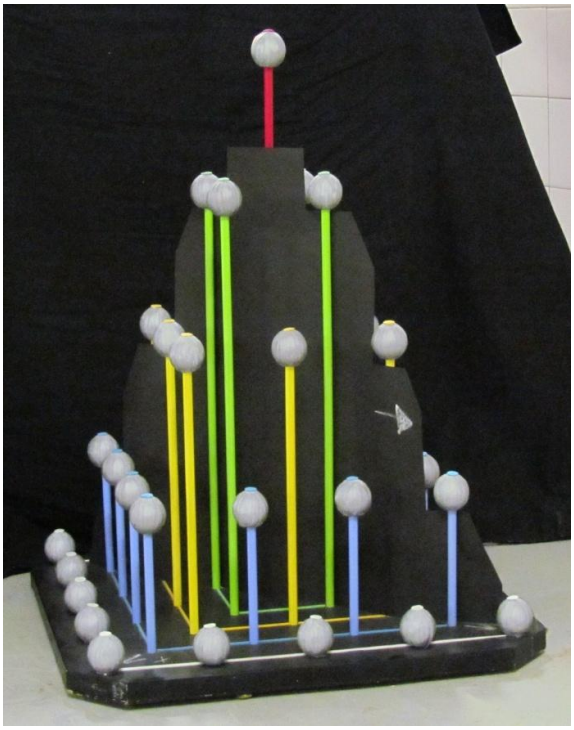
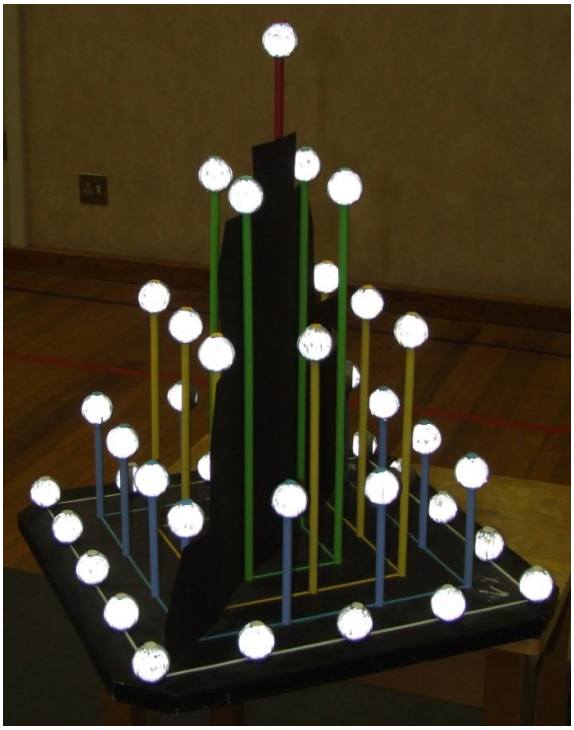


Figure 3.4: The fiducial marker labelling of the corner calibration object

The second object was a pyramid object that consisted of four rows of 25 wooden dowels of varying lengths, with a reflective sphere mounted at the head of each dowel. The dowels were fastened to a wooden board. The fifth row of 16 reflective spheres was attached to the top surface of the wooden board. A black sheaf of paper was inserted diagonally across the wooden board, effectively separating the pyramid object into two identical halves, as is shown in Figure 3.5(a) and (b) below. The cameras were able to capture sufficient fiducial markers without moving the object concerned, thus no transformation process was needed, and the cameras all shared the same world coordinate system.



(a) The dowels without illuminated reflective spheres



(b) The dowels with illuminated reflective spheres

Figure 3.5(a-b): The pyramid calibration object

The spheres were arranged from level A (lowest) to level E (highest), with A00 starting at the +Y-axis moving counter-clockwise to A15, as is shown in Figure 3.6 below. The x-axis was defined by a line stretching from A04 to A12, whereas the y-axis was perpendicular to the x-axis, passing through A00, and the z-axis, which was perpendicular to the x- and y-axes, passed through the intersection of X and Y (Van der Westhuizen, 2011).

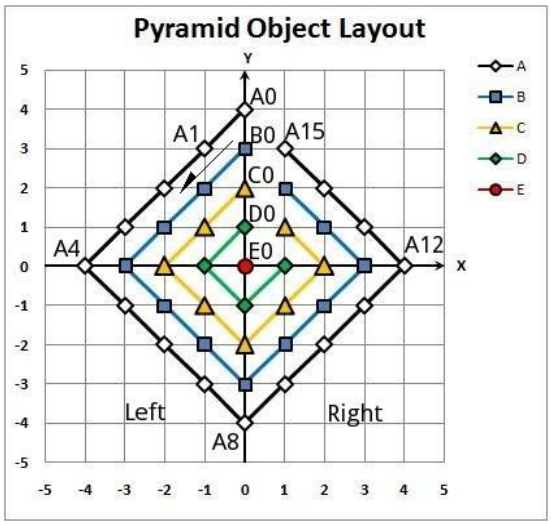


Figure 3.6: The fiducial marker labelling of the pyramid calibration object

Source: Van der Westhuizen (2011:34)

The positions in the world coordinate system (i.e. the world points) of the fiducial markers on the objects were known, as measured by a coordinate measurement machine. The values concerned were used in the calibration algorithm.

3.2.3 Software

The software system was implemented in Python (version 2.6) programming language, with the interface being command-line driven. Input data included images, world points and marker definitions, the number of active cameras and the identifying student names and the capture calibration. The data output were presented in comma-separated values text files. The Point Grey FirePro software development kit incorporated the hardware drivers in order to interface the operating system with the cameras and in order to synchronise all active cameras across multiple IEEE buses that were present on the computer (Van der Westhuizen, 2011).

3.2.4 Marker placement models

Two marker placement models were written for the reflective markers, with one being for the placement of the reflective markers on the students (n = 9) and the other being for placement on a mannequin (n = 14). The following abbreviations were used in the software program to describe the anatomical landmarks:

List of markers for student

Lcanth: Left canthus of the eye

Rcanth: Right canthus of the eye

Ltrach: Left trachus of the ear

Rtrach: Right trachus of the ear

C_7: C_7 spinous process

T_5: T_5 spinous process

Strn: Superior border of sternum

Lhip: Left greater trochanter

Rhip: Right greater trochanter

List of markers for mannequin

Lcanth: Left canthus of the eye

Rcanth: Right canthus of the eye

Ltrach: Left trachus of the ear

Rtrach: Right trachus of the ear

LAC: Left acromioclavicular joint

RAC: Right acromioclavicular joint

LSh: Left midpoint of the shoulder

RSh: Right midpoint of the shoulder

C_7: C_7 spinous process

T_5: T_5 spinous process

T_8: T_8 spinous process

Strn: Superior border of sternum

Lhip: Left greater trochanter

Rhip: Right greater trochanter

Two marker placement models were also written for each of the calibration objects concerned.

3.3 IMPROVEMENTS TO THE INSTRUMENT

3.3.1 Calibration object

The pyramid object described above was designed to replace the corner object. The dimensions of the calibration object were changed, with the calibration volume being enhanced to cover the full working volume of a sitting subject, as the accuracy of stereovision systems decreases outside the calibration volume (Fitzpatrick, West & Maurer, 1998). All cameras were, thus, calibrated to a single-world coordinate system. The pyramid object was first introduced during the baseline measurements of the cohort study that is presented in Chapter 8, subsection 8.1.6.1(a).

3.3.2 Lens distortion

The radial distortion for a given camera and calibration was corrected during the calibration procedure using the calibration world and image points. The parameters were stored in a text file, along with the calibration files (Van der Westhuizen, 2011). The improvement was incorporated during the data processing of the phase one study that is presented in Chapter 4, subsection 4.1.6.1(c).

3.3.3. Sub-pixel accuracy of marker selection

The pixel depth of the image was artificially increased by means of zooming a square portion around the desired reflective marker in the original image (640 × 480 px). The zoomed portion was scaled to fit the zoomed window (600 × 600 px) displayed alongside the original image window. After circle-fitting the reflective marker in the zoomed window, the image was scaled back to the original image window pixel scale, due to the scale difference between the original and zoomed windows (Van der Westhuizen, 2011). The improvement was incorporated during the data processing of the phase one study, which is presented in subsection 4.1.6.1(a).

The thesis by Van der Westhuizen, (2011), the implementer of such improvements, gives a detailed account of the magnitude of the improvement made in the accuracy of the 3D-PAT.

The following three chapters present the three phases of psychometric testing that were implemented to test the reliability and validity of the 3D-PAT.

PART 1

CHAPTER 4

The validity and reliability testing of the Three-Dimensional Posture Analysis Tool (3D-PAT) when describing the sitting posture of computing high school students: Phase one

The 3D-PAT was designed to measure the sitting posture of high school students as they work on desk top computers at school, therefore the first phase of psychometric testing was performed under similar conditions. The current chapter presents the first psychometric testing of the 3D-PAT, with the objectives being to determine: 1) the concurrent validity of the 3D-PAT's measurements of nine sitting postural angles, namely head flexion, neck flexion, cranio-cervical angle, cervico-thoracic angle, trunk flexion, head lateral bending, neck lateral bending, head rotation, and thoracic trunk rotation of high school students, when compared to the reference standard using the Vicon motion analysis system, and 2) the test-retest reliability of the 3D-PAT's measurements when repeated measurements are taken of the sitting postural angles of high school students.

4.1 METHODOLOGY

4.1.1 Study design

Two studies, namely a correlation study for validity testing and a repeated-measures observational study for reliability testing, were conducted.

4.1.2 Study population

The study population consisted of Grade 10 and 11 high school students in the Cape metropolitan region of the Western Cape province. Boys and girls aged between 15 to 18 years old, who had Computer Application Technology as a school subject, participated in the study.

4.1.3 Sampling method

4.1.3.1 *Sample size*

A sample size calculation was performed, based on the results from a previous study of a similar sample population (Brink et al., 2009a). The null hypothesis$\boldsymbol{H}_0$: $\rho = 0.85$ at $\propto = \beta = 0.05$, gives an estimated sample size of 31 subjects, with two repeated measurements, level of significance α, and power (1-β) = 95% (Shoukri, Colak, Kaya & Donner, 2008). Therefore, at least 96 students had to be screened in order to obtain 31 asymptomatic students with informed, written consent.

4.1.3.2 *Sampling of schools*

The government schools of the Cape metropolitan region were, at the time of the current study, divided into four Education Management and Development Centres (EMDCs). A list of the names of all the high schools that were part of the Khanya project[1] was pooled. Computer-generated randomisation was performed, with one school per EMDC being required to participate in the study.

[1] *A project launched by the Western Cape Education Department as a means of increasing computer literacy among educators and school students.*

The high schools offering Computer Application Technology as a school subject that headed the four EMDC-supplied lists were selected. The principals of the selected schools were invited to participate in the study and received a summary of the proposed research via fax or e-mail during April and May 2009. The principals were followed up on telephonically. If a school declined the invitation, the next school on the list was selected. Figure 4.1 below demonstrates the selection procedure used for the high schools. The selected schools, which represented the high school population of the Cape metropolitan region, spanned the geographical spectrum of the Cape metropolitan region.

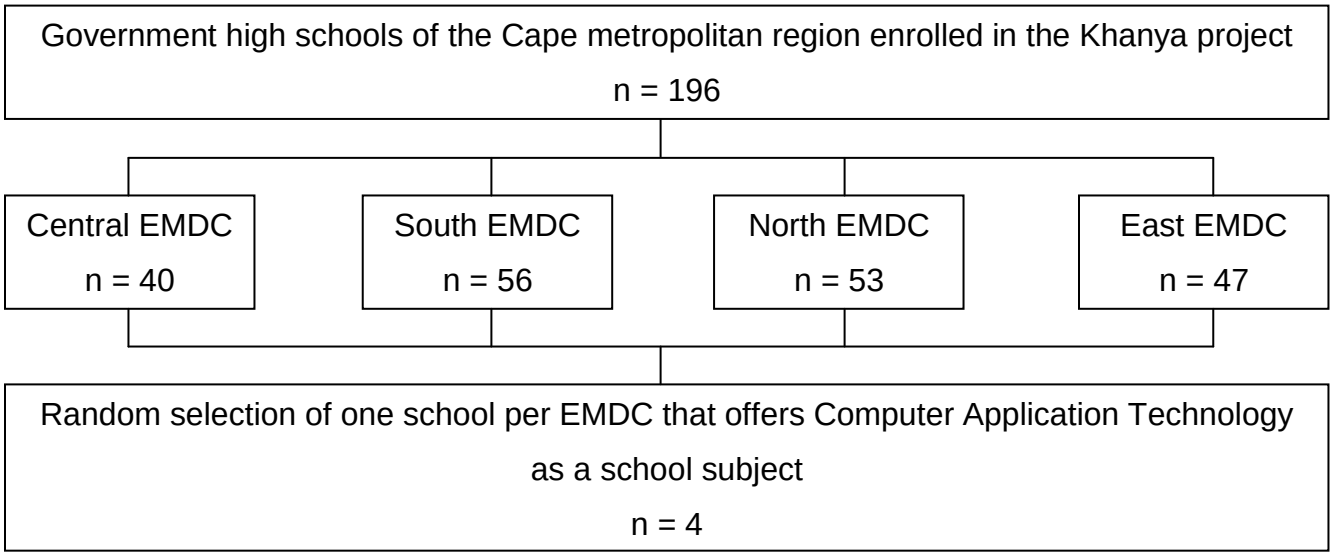


Figure 4.1: Recruitment of schools for study

4.1.3.3 *Sampling of students*

On visiting each selected high school during July and August 2009, the researcher presented the research project to those Grade 10 and 11 students who had Computer Application Technology as a subject. The students concerned were screened for the presence of musculoskeletal pain by means of being required to complete the pain-related component of

the Computer Usage Questionnaire (CUQ) (Addenda 6 and 7, questions 35 and 36) (Smith, 2007). The screening tool only incorporated the first two questions from the pain-related component of the original questionnaire. This instrument has been shown to be a stable, reliable and valid tool for assessing musculoskeletal dysfunction among a South African high school student population and has also been shown to determine associative factors related to the dysfunction concerned (Smith, 2007). The participants completed the questionnaire in about ten minutes. Once the inclusion and exclusion criteria, as described in subsections 4.1.3.4 and 4.1.3.5, were applied, the asymptomatic students were invited to participate in the study.

Even if a school had more than ten eligible students, only ten were selected to participate in the study. The researcher selected the students in such a way as to ensure an equal distribution of students by gender and age. Therefore, if a school had more than ten eligible students, the age and gender distribution of the other schools were determined before said school's participants were selected. A potential sample of 40 students was selected to participate in both the validity and reliability testing procedures of the current study.

4.1.3.4 *Inclusion criteria*

The criteria for inclusion of students in the study were as follows:

- They had to be male or female Grade 10 and 11 students aged 15 to 18 years old.
- They had to have Computer Application Technology as a school subject.
- They had to have had no history of musculoskeletal pain symptoms during the preceding month.

- They had to be students from whose parental / legal guardian consent had been obtained for their participation in the study.

4.1.3.5 *Exclusion criteria*

The criteria for exclusion of students from the study were as follows:

- Students diagnosed with movement disorders or with severe fixed skeletal abnormalities, were excluded, as an investigation into disease and into severe postural abnormalities was omitted from the study.
- Students absent on the day of testing were not included in the study.

4.1.3.6 *Ethical considerations*

Written permission was obtained from the Western Cape Education Department (WCED) (Addendum 8) and from the school principals (Addendum 9) prior to conducting the study in the selected schools. Written informed consent letters were completed by the parents / legal guardians and the students. The informed consent letters were available in English, Afrikaans and isiXhosa (Addenda 10, 11 and 12). If any questions from the parents arose, then an intermediate person (a computer teacher or a school principal), who was fluent in isiXhosa and who was knowledgeable concerning the study, was asked to assist the researcher in answering them. No questions or concerns were, however, raised by either the parents or the students concerned.

4.1.4 Instrumentation

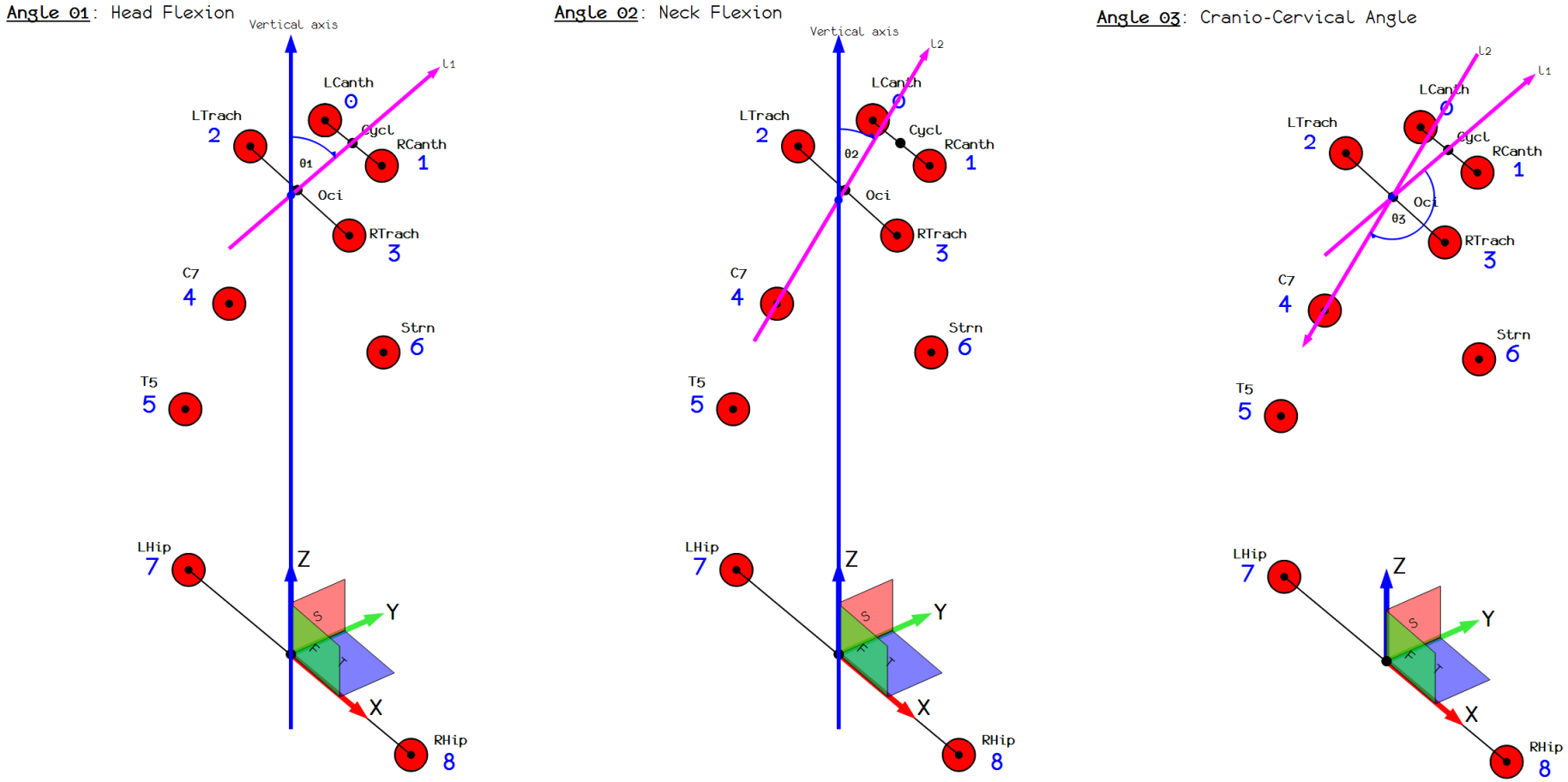
4.1.4.1 *Three-Dimensional Posture Analysis Tool (3D-PAT)*

The 3D-PAT was designed to measure nine 3D postural angles assumed while the subjects were sitting. (The instrument has been described in detail in Chapter 3.) The following nine angles were measured (Straker, Burgess-Limerick, Pollock, Murray, Netto, Coleman & Skoss, 2008c) (refer to Figure 4.2 (a-i) for their schematic illustrations):

- Head flexion: The angle is that made by a line drawn from the Cyclops[2] to the occiput cervical joint (OC1)[3] and the vertical axis.
- Neck flexion: The angle is that made by a line drawn from the OC1 to the C_7 spinous process (SP) and the vertical axis.
- Cranio-cervical angle: The angle is that made by a line drawn from the Cyclops to the OC1 to the C_7 SP.
- Cervico-thoracic angle: The angle is that made by a line drawn from the OC1 to the C_7 SP to the T_5 SP.
- Trunk flexion: The angle is that made by a line drawn from the C7 SP to the mid-point of the greater trochanters and the vertical axis.
- Head lateral bending: The lateral angle is that made by a line drawn from the OC1 to the trachus of the ear, with the vertical line going through the OC1 (negative to the left).
- Neck lateral bending: The angle is that made by a line drawn from the OC1 to the C7 SP, with the vertical axis going through C7 in the frontal plane.
- Head rotation: The angle is that made by a line drawn from the OC1 to the Cyclops, with the anterior axis in the transverse plane (negative to the left).

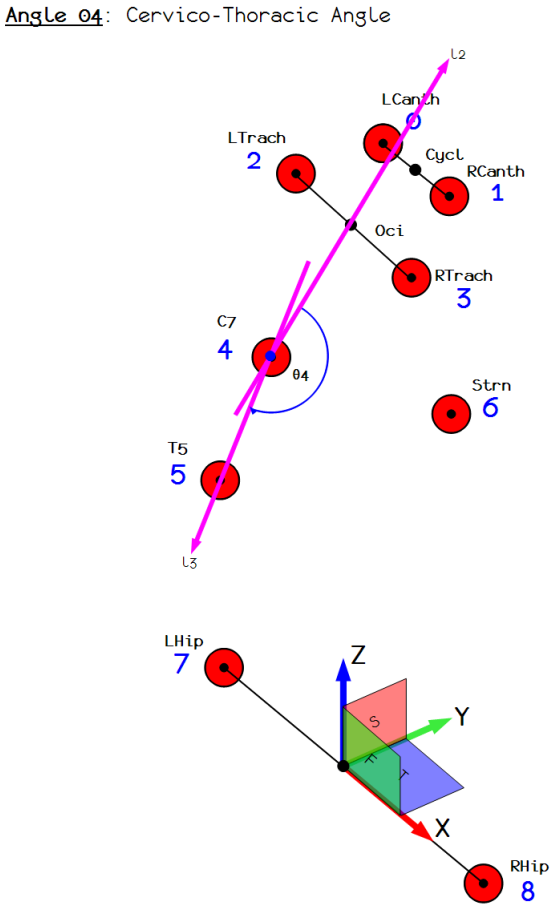
[2] *Midway between the left and right canthus.*
[3] *Midway between the left and right trachus.*

- Thoracic trunk rotation: The angle is that made by a line drawn from the sternum to the T5 SP, with the anterior axis in the transverse plane (negative to the left).

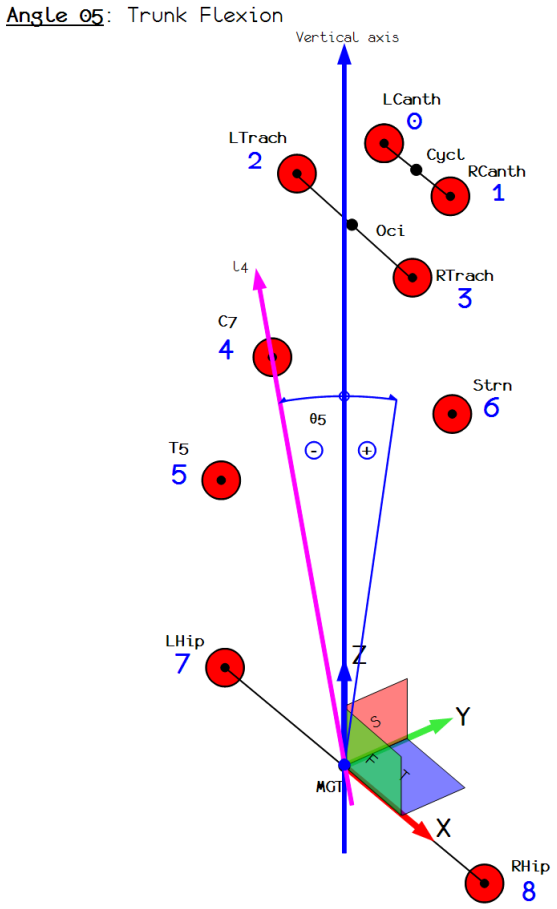


(a) Head flexion (b) Neck flexion (c) Cranio-cervical angle

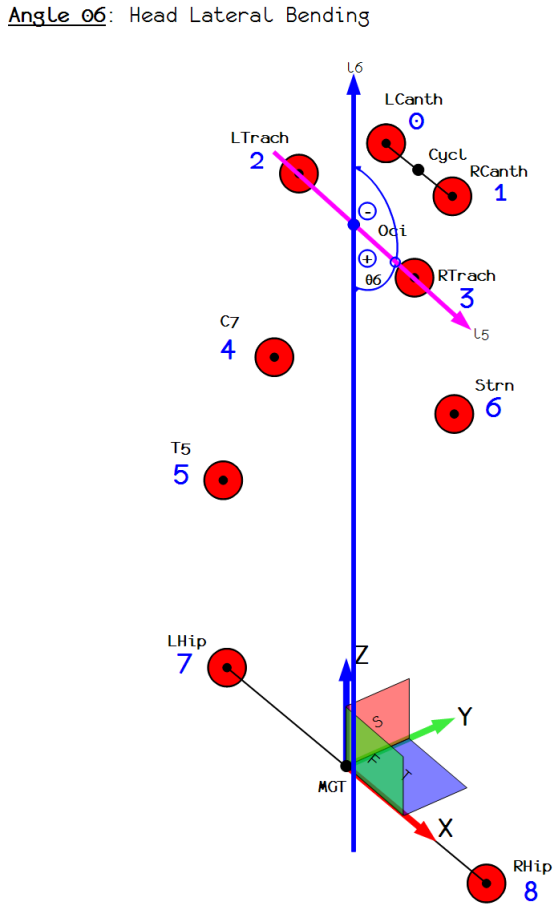
Figure 4.2 (a-i): Schematic illustrations of the postural angles concerned



Cervico-thoracic angle

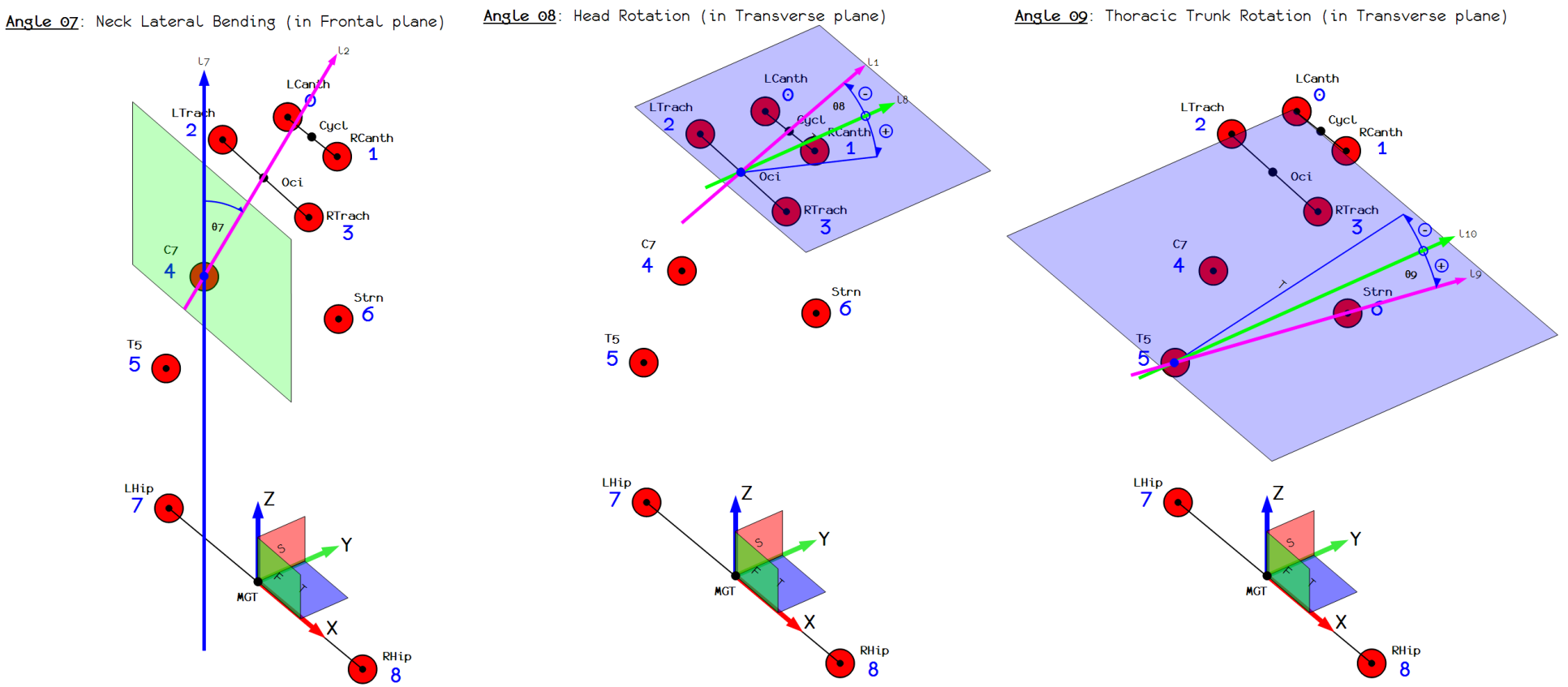


(e) Trunk flexion



(f) Head lateral bending

Figure 4.2 (a-i): Schematic illustrations of the postural angles concerned (cont)



(g) Neck lateral bending (h) Head rotation (i) Thoracic trunk rotation

Figure 4.2 (a-i): Schematic illustrations of the postural angles concerned (cont)

4.1.4.2 *Vicon motion analysis system*

The Vicon T-series motion analysis system (Vicon Motion Systems (Ltd) (Oxford, UK), which is hereafter referred to as 'the Vicon system', is a 3D system that is used for digital and optical motion measurement and analysis. The Vicon system was used to measure the same nine postural angles as those that are measured by the 3D-PAT and which, therefore, represented the reference standard for 3D posture measurement in the current study.

Six infrared Vicon T-10 cameras with Nexus 1.4 116 software and giganet were used in the study. The T-10 system has a unique combination of high speed accuracy and resolution. In the current study, the system captured 200 frames per second at 250 Hz. The retro-reflective markers placed on the anatomical landmarks of the students provided a full-frame 'true' shutter. The Vicon lens has been custom-built for motion capture, and has a large field of view to ensure that the entire image is evenly illuminated. Figure 4.3 below is a photograph of the T10 infrared camera used.

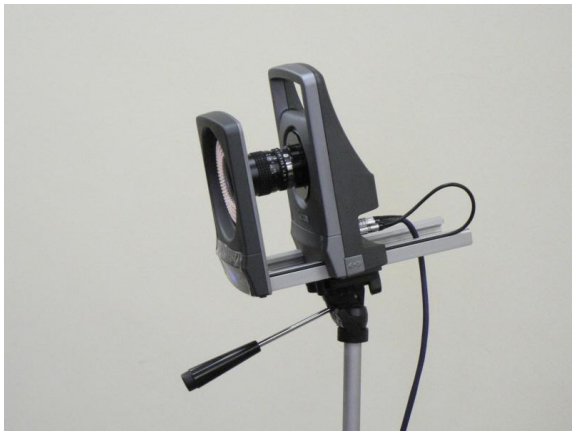


Figure 4.3: The T10 infrared camera

The Vicon system has demonstrated a high degree of accuracy and reliability (Ehara, Fujimoto, Miyazaki, Mochimaru, Tanaka & Yamamoto, 1997). For the current study, the output from the Vicon was the X-, Y- and Z-coordinates of the reflective markers on the students.

4.1.5 Study procedure

4.1.5.1 *Preparation of the laboratory for validity testing*

The researcher, with assistance from the four representative teachers from each high school, arranged for the students to travel to the Tygerberg Campus of Stellenbosch University where the testing laboratory was set up for the validity testing. Data capture was conducted during September 2009. The University transported the students from three schools to the Tygerberg Campus, and one school provided their own transport. Two research assistants accompanied the researcher to the Tygerberg Campus.

Both the 3D-PAT and the Vicon system's measurements were captured simultaneously in the laboratory for the validity testing. The new Vicon system was set up in a temporary room in the Physiotherapy Division for the study. Six infra-red T10 Vicon cameras were positioned in the laboratory in such a way that the reflective markers were visible on the computer monitor at all times. A standard dynamic calibration procedure was performed to enable automatic calibration of the Vicon system. The calibration procedure followed ensured that the Vicon cameras accurately detected the orientation of the reflective markers with respect to each other and within the capture volume.

The two steel cross-bars from the 3D-PAT, which were each fitted with either two or three cameras with draped black cloth, remained attached at all times. Therefore, the set-up of the camera unit entailed that the steel cross-bar be fastened to the tripod head and that the camera unit be connected to the computer via the IEEE hubs, cabling and the IEEE 1394b Firewire bus expansion card. The two tripods were positioned parallel to the frontal plane (facing the lateral aspect) of the student, on either side, but closer to the student than the Vicon system cameras, so that any reflective marker could be seen by at least two cameras. Once the camera unit was set up, the cameras were connected to the computer, as well as focused and synchronised on the system. A research assistant was responsible for the setting up of the 3D-PAT in the laboratory.

The corner calibration object was used in the current study to perform the calibration procedure. The calibration object was captured within the capture volume, as the system captured 100 synchronised frames from each of the five cameras surrounding the object. Each camera had to be able to capture the entire calibration object during one capture trial. The calibration procedure produced a camera matrix per camera. From the images, the image coordinates (image points) of the fiducial markers on the object were determined through semi-automated image processing. The image point values concerned were used together with the world point (fiducial) values in the calibration algorithm. The coordinate system of the calibration object is also the coordinate system of all the reflective markers on the subject. Figures 4.4 and 4.5 below are presentations of the 3D-PAT and Vicon system that were set up for the validity testing.

Figure 4.4: The set-up of the 3D-PAT and Vicon system for validity testing

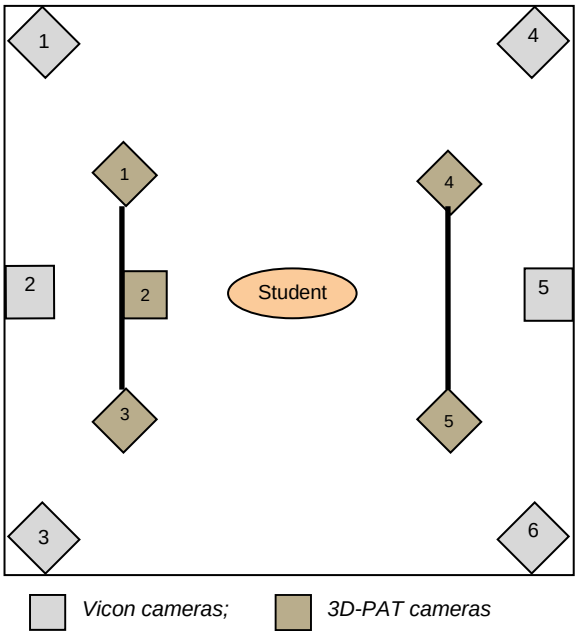


Figure 4.5: The 3D-PAT and Vicon system set-up in the laboratory

The student was given a chair and desk that were similar in height and shape to the furniture used in the school computer laboratories that he or she customarily used (Smith, 2007). After a computer monitor was positioned on the desk, the student was required to sit behind the desk facing the computer monitor while the relevant data were captured. No specific instructions regarding the distance of the chair from the desk or sitting posture were given.

4.1.5.2 *Preparation of the students for validity testing*

The researcher explained the study procedure to the students on their arrival at the laboratory. The latter students wore black t-shirts and grey school pants (supplied by the researcher) in order for the reflective markers to be clearly visible on the digital photographs taken. A research assistant measured their height and weight prior to the validity testing. Their height was measured with a steel tape measure (Panamedic stature meter) that was mounted against the wall and their weight was measured with a calibrated digital scale (Terrailon Electronic Scale).

Reflective markers were placed on each student's left and right canthus of the eye, left and right trachus of the ear, C_7 SP and T_5 SP, the left and right greater trochanters and the superior border of the sternum, in order to allow for the 3D-PAT to measure the nine postural angles concerned. The reflective markers for the canthus and the trachus were attached to the skin using double-sided tape. The anatomical landmarks for the left and right greater trochanters were identified while the student was standing, but the markers were only attached to the grey school pants using double-sided tape, once the student had sat down, in order to ensure that the marker did not move from the anatomical landmark with his or her movement. The markers for C_7 SP, T_5 SP and the sternum had magnets mounted on the base of the marker. A flat magnet plate was fastened to the skin at C_7 SP, T_5 SP and the sternum using sticking plaster. The reflective markers were kept in position via the magnets used. Following the method concerned allowed for the student to remain dressed to assure comfort, which might have facilitated the assumption of his or her habitual sitting posture during the data capture. The researcher was responsible for the placement and removal of

the reflective markers used. Figure 4.6 below illustrates the placement of the reflective markers, as seen from the student's right side.

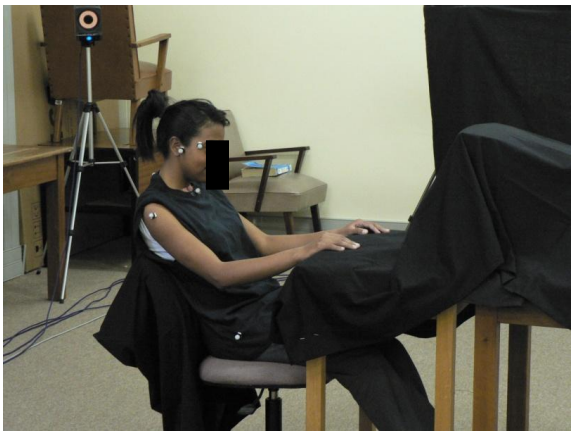


Figure 4.6: The placement of the reflective markers for validity testing

4.1.5.3 *Measurements with the 3D-PAT and Vicon system for validity testing*

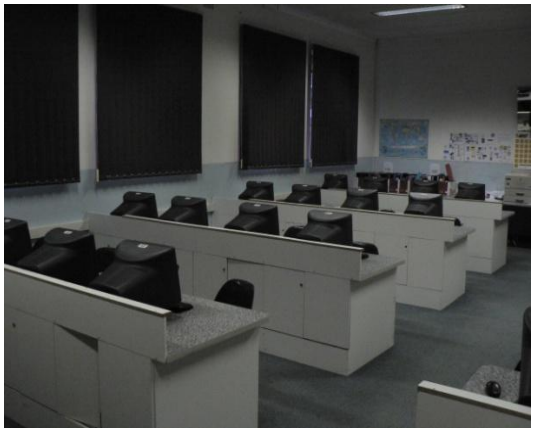
The student, with reflective markers, was positioned within the capture volume of the 3D-PAT and Vicon system. One student was measured per trial. Data capture commenced once the student had settled in behind the desk and was making no more conspicuous postural adjustments. One research assistant operated the Vicon system and another the 3D-PAT. The data capture trial lasted for approximately 15 seconds, during which time the Vicon system and the 3D-PAT, which captured 100 synchronised frames from each of the five cameras, simultaneously captured it. The capture frame rate of the 3D-PAT was influenced by the frame rate of the camera sensor and by the maximum data transfer speed of the connected Firewire bus. Since a static sitting posture was measured, of which only one frame per camera was selected for analysis, it was considered sufficient for the needs of the study. The data capture trial was successful if all nine reflective markers were clearly visible on the

digital photographs, as well as on the computer monitor of the Vicon system. Figure 4.7 below is an example of a photograph taken during one of the validity data capture trials.

Figure 4.7: A data capture trial for validity testing

4.1.5.4 *Preparation of the classroom for reliability testing*

Reliability testing was performed in the computer classroom of each school. The researcher scheduled the dates on which to travel to the schools for purposes of data capture. Data capture was conducted during September and October 2009. One research assistant accompanied the principal researcher to the participating high schools. Figure 4.8(a-d) below consists of photographs of the computer classrooms of the four participating high schools.



(a) Central EMDC

(b) South EMDC

(c) North EMDC

(d) East EMDC

Figure 4.8(a-d): The computer rooms of the selected four schools

The researcher was responsible for the setting up of the 3D-PAT at the schools. The two tripods of the 3D-PAT were positioned on either side of the student, as was done for the validity testing. Figure 4.9 below shows the positioning of the cameras in the school computer room, with the student visible in the centre of the capture volume. The computing set-up was standardised across the different schools in terms of the student seated in front of and facing the computer monitor but not in terms of the chair and desk height. The 3D-PAT was calibrated in the computer room, as was described in subsection 4.1.5.1.

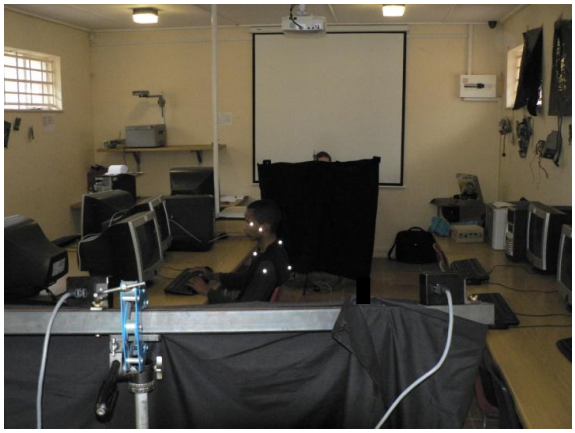


Figure 4.9: 3D-PAT set-up in the school computer classroom, showing the placement of the cameras in relation to the student

4.1.5.5 *Preparation of the students for reliability testing*

During the preparation of the exercise, the researcher explained the study procedure to each student in turn in the school computer classroom. The reflective markers were then placed on the student, as has been was done for the validity testing (Figure 4.10).

Figure 4.10: Marker placement for reliability testing

4.1.5.6 *Measurements with the 3D-PAT for reliability testing*

One student was measured per data capture trial. Each student in turn was asked to sit behind a desk-top computer and to perform five minutes of typing while the digital photographs were taken. One set of photographs per camera was taken after five minutes of typing, in order to give the student concerned enough time in which to settle down behind the computer, so that they could assume their relaxed or habitual sitting posture that they usually took up during class when the eyes are focussed on the computer monitor (Briggs, Straker & Grieg, 2004). The research assistant operated the 3D-PAT for the reliability testing.

The same procedure was followed two weeks later in order to capture repeated measurements of the sitting posture of the students concerned (Bullock-Saxton, 1993). The students used the same chair, desk and computer height settings as previously and the same testing procedure was followed. Figure 4.11 below shows a student during the reliability testing data capture trial.

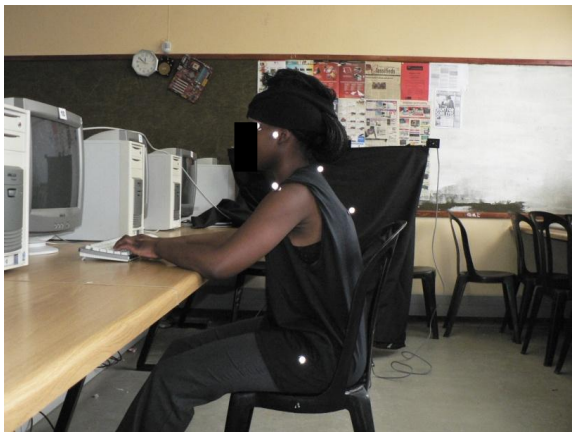


Figure 4.11: A data capture trial for reliability testing

4.1.5.7 *Time period for data collection per school*

Students from one school were measured during the morning of each day of the study during school hours for both the validity and reliability testing. Four days were utilised for the validity testing and eight days for the reliability testing. Validity testing per student took approximately three minutes to complete. For the reliability testing, the data capture duration was approximately seven minutes per student. Said duration allowed for enough time for the placement and removal of reflective markers by the researcher concerned. Figure 4.12 below summarises the sample recruitment and study procedures.

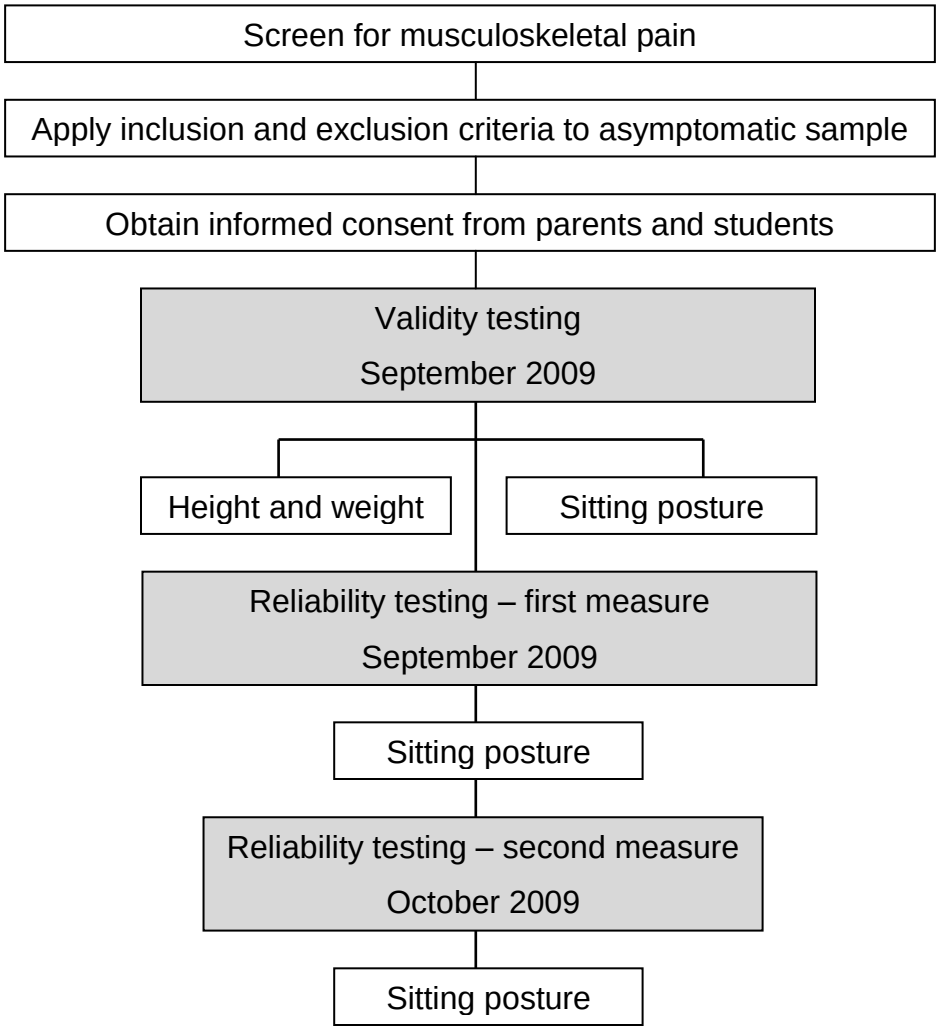


Figure 4.12: A flow chart to demonstrate the sample recruitment and study procedures

4.1.6 Data processing

4.1.6.1 *3D-PAT*

The software program converted all captured images to JPEG format in order to reduce file size. For all trials, the researcher selected one frame per camera for processing. The five images concerned were then imported into the software program and processed. The researcher then performed processing of the 3D-PAT data.

(a) *Marker selection of the reflective markers placed on the students*

The frame closest to the fiftieth one (at 100 frames per camera per trial) (Straker, Briggs & Greig, 2002), in which the student's eyes were focused on the computer screen, was selected to form a set of five photographs, with one per camera. The same was done for 102 trials (consisting of 38 validity and 64 reliability trials). A square section of the original image containing the desired reflective markers was zoomed and displayed alongside the original image window. In the zoomed window, the centre of each reflective marker was manually selected, according to the marker placement model for the subjects (refer to Chapter 3, subsection 3.2.4). The program allowed for a marker not to be selected if it was not clearly visible on the image, in which case it was assigned a 'none' value. In this way, the image coordinate value for each reflective marker was recorded. Five control markers, additional to the nine anatomical landmarks, had to be identified prior to the marker selection phase, because the corner calibration object was used. The five control markers were prominent points, namely the tip of the nose and the chin or knuckles, and had to be visible on all five digital photographs. The control markers were circle-fitted, as was done for the reflective markers. Doing so was necessary in order to increase the accuracy of the digitisation procedure.

(b) *Marker selection of the calibration object*

The first frame from each of the five cameras of the corner calibration object was selected. The same procedure was followed as had been for the marker selection of the subject. The sequence of marker selection was according to the marker placement model for the corner calibration object (refer to chapter 3, subsection 3.2.4).

(c) *Reconstruction of the X-, Y-, Z-coordinates and postural angle calculation*

The marker selection files for both the corner calibration object and the students were imported into the reconstruction section of the software program. The image point coordinates, world point (fiducial) coordinates of the calibration object and the camera matrix were used to triangulate the X-, Y- and Z-coordinates of each reflective marker. If a reflective marker was not triangulated, the program reported an error message that indicated that the reflective marker was not captured by at least two cameras. Once the process was completed, the program wrote the coordinates concerned to a text file that was used for the postural angle calculation. The software program automatically calculated the nine postural angles from the 3D coordinates, using linear algebra and the 'dot-product-cosine rule', according to the definition of each angle, as was described in subsection 4.1.4.1. The coordinate system for the raw data of the reflective markers was the same as for the calibration object. Thereafter a local coordinate system for each subject was defined as follows: from the left to the right greater trochanter defined the *x*-axis, the *z*-axis was vertically upward and the *y*-axis was perpendicular to the *x*- and *z*-axes. The software program generated a *.csv* file containing the postural angles concerned.

4.1.6.2 *Vicon system*

A research assistant performed the data processing of the Vicon system's data. Each data capture trial was processed using the Vicon Nexus 1.4 116 software program to produce X-, Y- and Z-coordinates of the nine reflective markers. All the captured frames were processed. The coordinate data were imported into the designed software program of the 3D-PAT. The nine postural angles were calculated using the software from the 3D-PAT. The data were exported as text files for analysis in Microsoft Excel (Microsoft Corporation). As the capture rate of the Vicon system differed from the 3D-PAT, and since the 50th frame of the 3D-PAT data was chosen, it was decided to select the frame of Vicon data that closest resembled the postural angles that had been calculated from the 3D-PAT.

4.1.7 Statistical analysis

4.1.7.1 *Test–retest reliability*

The concordance correlation coefficient was calculated. In the current study, the index was based on the difference between measurements made by one rater, using one instrument, on two occasions and on the same subjects. Said instrument evaluated the agreement between two readings by measuring the variation from the 45° line through the origin. The concordance correlation coefficient reflected the degree of accuracy (i.e. measured how far the best fit line deviated from the 45° line) and precision (i.e. measured how far each measurement deviated from the 45° line) between the repeated measurements. The concordance correlation coefficient, r_c , for measuring agreement between continuous variables X and Y (both approximately normally distributed), was an estimate of the population concordance correlation coefficient ρ_c. The concordance correlation satisfied -1 ≤ r_c ≤ +1. A value of r_c = +1 corresponded to perfect agreement. A value of r_c = - 1

corresponded to perfect negative agreement, and a value of r_c = 0 corresponded to no agreement (Lin, 1989). The concordance correlation coefficient r_c, was calculated as follows:

$$r_c = \frac{2S_{XY}}{S_{XX} + S_{YY} + (\overline{X} - \overline{Y})^2}$$

The upper and lower 95% confidence intervals (CIs) for r_c were also calculated.

4.1.7.2 *Concurrent validity*

The Bland-Altman method, based on graphical techniques and simple calculations, was used for the validity analysis. The method used calculated the differences between the measurements of the same student by two methods. The mean difference (***d***) was the estimated bias and reflected the systematic difference between the methods and the variation about the mean obtained was estimated by calculating the standard deviation (SD; ***s***) of the differences. Approximately 95% of the differences between the two methods lay between $d - 1.96s$ to $d + 1.96s$. The data were graphically displayed using Bland-Altman plots, where the difference between the measurements by the two methods for each subject was plotted against their mean. The presentation of the 95% limits of agreement was for visual judgment of how well the two methods of measurement were in agreement. The smaller the range between said two limits and the closer the spread of the scores around the zero point, the better the agreement was between the two measures (Bland & Altman 1990, 1999; Portney & Watkins, 2009).

Since no literature was available to determine the clinical cut-off point where the estimated bias was acceptable, so that the two instruments could be used interchangeably, the following guideline was used:

- If the bias was found to be less than 1.5°, the difference concerned was considered to be small.
- If the bias was found to be less than 3.0°, the difference concerned was considered to be moderate and therefore acceptable.
- If the bias was found to be greater than 3.0°, the difference concerned was considered to be large and was, therefore to be interpreted with caution.

To assist in the interpretation of the bias, it was decided to include the relative bias (i.e. the bias relative to the mean of the Vicon system values) and the width of the limits of agreement. The estimated bias is used as a means to report the amount of agreement between the two measures, of the individual postural angles relative to one another.

4.2 RESULTS

4.2.1 Sample composition

In the current study, 112 Grade 10 and 95 Grade 11 students were screened for musculoskeletal pain symptoms. After the inclusion and exclusion criteria were applied, two Grade 10 boys were randomly excluded from one school, in order to allow for the maximum of 40 students to participate in the project. The students participating in the validity and reliability testing numbered 38 and 32 respectively. Table 4.1 below illustrates the sample characteristics of the participating students.

Table 4.1: Sample characteristics of the students participating in the validity and reliability testing procedures

	School A		School B		School C		School D	
	Boys	Girls	Boys	Girls	Boys	Girls	Boys	Girls
Screened Grade 10	31	15	8	8	13	11	12	14
Screened Grade 11	24	11	3	9	13	11	16	8
Asymptomatic students	9	3	4	7	14	10	8	14
Excluded due to age	0	0	0	0	1	2	1	1
Consent obtained	4	3	4	6	11	6	3	5
Randomly excluded	0	0	0	0	2	0	0	0
Absent on day of validity testing	0	0	0	1	0	1	0	0
Students in validity study (n=38)	4	3	4	5	9	5	3	5
16 years old	3	1	4	4	2	3	0	4
17 years old	0	2	0	1	5	2	2	0
18 years old	1	0	0	0	2	0	1	1
Absent on day of reliability testing	0	0	0	1	1	2	1	1
Students in reliability study (n=32)	4	3	4	4	8	3	2	4
16 years old	3	1	4	3	1	2	0	3
17 years old	0	2	0	1	5	1	1	0
18 years old	1	0	0	0	2	0	1	1

4.2.2 Height and weight measurements

The mean age for the group was 16.6 years (SD 0.7), the mean height was 1.64 m (SD 0.1) and the mean weight was 58.1 kg (SD 12.6).

4.2.3 Validity findings

4.2.3.1 *Postural angles from the 3D-PAT and Vicon system*

Table 4.2 below summarises the mean, the SD, the maximum and the minimum values obtained for each instrument for the nine postural angles. A large difference in the means for cervico-thoracic angle, neck lateral bending and thoracic trunk rotation, as indicated with an asterisk in the table, was noted.

Table 4.2: The mean, the SD, the maximum and the minimum values for each instrument for the nine postural angles (n = 38)

		Head flexion (°)	Neck flexion (°)	Cranio-cervical angle (°)	Cervico-thoracic angle (°)	Trunk flexion (°)	Head lateral bending (°)	Neck lateral bending (°)	Head rotation (°)	Thoracic trunk rotation (°)
VICON	Mean	69.2	55.7	165.3	154.0*	-18.3	1.0	1.6*	1.9	-0.2*
	SD	7.5	6.9	7.2	7.8	10.8	4.5	8.2	6.8	3.1
	Max	86.9	70.10	179.3	170.2	-2.6	12.6	20.1	23.5	8.7
	Min	50.2	44.4	154.5	130.3	-45.3	-9.8	-15.5	-10.6	-5.7
3D-PAT	Mean	67.0	57.7	159.9	126.7*	-21.9	2.2	10.8*	4.0	31.4*
	SD	6.5	11.3	20.0	37.2	18.6	12.7	31.5	15.7	44.0
	Max	81.7	95.3	178.5	168.3	60.8	37.5	95.5	26.8	138.3
	Min	50.2	32.8	78.2	11.9	-52.2	-25.2	-67.6	-45.3	-35.7

*Indicates a large difference in the mean values obtained from the Vicon system and the 3D-PAT.

4.2.3.2 *Differences between two measurements from two instruments*

The amount of agreement between the measurements from the 3D-PAT and the Vicon system for the nine postural angles was estimated and interpreted by examining the difference between the two (Vicon – 3D-PAT) per angle per student. Table 4.3 below presents the estimated bias (mean difference), the variability of the scores (SD of the differences) and the upper and lower levels of the limits of agreement within which 95% of the differences between the measurements, by the two instruments, would lie. The table also presents the relative bias, the coefficient of variation (CV), and the width of the limits of agreement. The standard error (SE) of the limits of agreement is also shown.

Addendum 13 shows the Bland-Altman plots, visualising the relationship between the measurements from the two instruments. In the graphs concerned, the difference between the measurements is plotted against the mean score for each student.

Table 4.3: The estimated bias, the variability of the scores and the limits of agreement for the nine postural angles (n = 38)

		Head flexion	Neck flexion	Cranio-cervical angle	Cervico-thoracic angle	Trunk flexion	Head lateral bending	Neck lateral bending	Head rotation	Thoracic trunk rotation
DF	*n-1*	37	37	37	37	37	37	37	37	37
Estimated bias	*Mean difference (d)*	2.15°	-1.99°	5.35°	27.39°	3.61°	-1.2°	-9.29°	-2.13°	-31.62°
Variation	*SD of the differences (s)*	4.46°	9.97°	19.32°	36.53°	13.18°	11.49°	32.24°	15.02°	43.59°
VICON	*Mean*	69.2°	55.7°	165.3°	154.0°	-18.3°	1.0°	1.6°	1.9°	-0.2°
Relative bias	*d / Vicon mean*	0.03	-0.04	0.03	0.18	-0.20	-1.20	-5.81	-1.12	158.10
CV	*s/d*	2.07	5.01	3.61	1.34	3.65	9.58	3.47	7.05	1.40
SE of bias	s^2/n	0.72	1.62	3.13	5.97	2.14	1.86	5.23	2.44	7.16
95% limits of agreement	*Upper limit (UL) (d+1.96s)*	10.9°	17.5°	43.22°	99.5°	29.4°	21.3°	53.9°	27.3°	54.9°
	Lower limit (LL) (d-1.96s)	-6.6°	-21.5°	-32.5°	-44.7°	-22.2°	-23.7°	-72.5°	-31.6°	-118.2°
Width	*UL – LL*	17.5°	39.0°	75.7°	144.2°	51.6°	45.0°	126.4°	58.9°	173.1°
SE of limits of agreement	$\sqrt{(3*s^2/n)}$	1.25	2.80	5.43	10.34	3.70	3.23	9.06	4.22	12.41

The Bland-Altman method revealed small bias (< 1.5°) for head lateral bending (-1.2°), moderate biases (< 3.0°) for head flexion (2.15°), neck flexion (-1.99°) and head rotation (-2.13°), and large biases (>3.0°) for the remaining angles, as indicated by the criteria set out in subsection 4.1.7.2 and shown in Table 4.3 above. The largest biases were seen for the cervico-thoracic angle and thoracic trunk rotation. The relative bias was high for neck lateral bending and thoracic trunk rotation. The limits of agreements were found to be the widest for the cervico-thoracic angle, neck lateral bending and thoracic trunk rotation.

4.2.4 Reliability findings

4.2.4.1 *Postural angles from the 3D-PAT*

The mean scores for the first measurement (mean 1) and for the repeated measurement (mean 2), for each of the nine postural angles, are reported in Table 4.4 below.

Table 4.4: The mean and SD for repeated measurements from the 3D-PAT (n = 32)

	Mean 1 (°)	**Mean 2 (°)**
Head flexion	71.53 (± 8.0)	70.33 (± 11.0)
Neck flexion	58.64 (± 8.3)	62.79 (± 11.6)
Cranio-cervical angle	161.65 (± 9.8)	165.15 (± 8.8)
Cervico-thoracic angle	147.98 (± 17.2)	143.49 (± 19.4)
Trunk flexion	-12.31 (± 14.2)	-11.57 (± 16.9)
Head lateral bending	5.54 (± 8.1)	-0.52 (± 12.9)
Neck lateral bending	15.25 (± 26.8)	13.08 (± 38.1)
Head rotation	17.59 (±18.1)	9.82 (± 59.0)
Thoracic trunk rotation	0.42 (±34.8)	8.36 (± 53.2)

4.2.4.2 *Agreement between repeated measurements*

Table 4.5 below reports the calculated concordance correlation coefficient (r_c), which reflects the degree of agreement between the repeated measurements for the nine postural angles. The upper and lower CIs are also reported per postural angle. The results indicate poor agreement between the repeated measurements and negative agreement for head lateral bending, head rotation and thoracic trunk rotation. Relatively stronger agreement was found for head flexion, cervico-thoracic angle and trunk flexion, as indicated with an asterisk in the table.

Table 4.5: The upper and lower CIs and the concordance correlation coefficient (r_c) per postural angle (n = 32)

	Concordance correlation lower CI	**Concordance correlation upper CI**	**Concordance correlation (r_c)**
Head flexion	-0.028	0.587*	0.312
Neck flexion	-0.158	0.455	0.164
Cranio-cervical angle	-0.326	0.339	0.008
Cervico-thoracic angle	-0.095	0.554*	0.258
Trunk flexion	-0.057	0.589*	0.300
Head lateral bending	-0.291	0.273	-0.009
Neck lateral bending	-0.319	0.355	0.021
Head rotation	-0.248	0.156	-0.048
Thoracic trunk rotation	-0.389	0.255	-0.075

**Relatively stronger agreement.*

4.3 SUMMARY

The current chapter described the first attempt that was made to assess the reliability and validity of the 3D-PAT. The findings illustrated poor agreement between the measurements from the 3D-PAT and the Vicon system for all angles, except for head flexion, neck flexion, head rotation and head lateral bending. The reliability testing revealed poor agreement between the repeated measurements and negative agreement for head lateral bending, head rotation and thoracic trunk rotation angles.

In the light of the findings, the 3D-PAT required modifications and further psychometric testing, as the 3D-PAT did not compare well with the reference standard for, in its current form, measuring the nine postural angles. The variable, ‘static sitting posture’, was also not stable enough to satisfy the requirement for testing of the validity and reliability of a new measurement instrument, thus the next chapter presents the second phase of psychometric testing, using a mannequin.

PART I

CHAPTER 5

The validity and reliability testing of the Three-Dimensional Posture Analysis Tool (3D-PAT) when using a mannequin: Phase two

The current chapter presents the second psychometric testing procedure that was conducted with the 3D-PAT. Once the shortcomings of the 3D-PAT had been addressed, the phase of testing was introduced that incorporated the use of a mannequin, which guaranteed a very stable variable for measurement that would minimise the error due to the variability of sitting posture. The objectives were to determine: 1) the concurrent validity of the X-, Y- and Z-coordinates of the reflective markers, placed on a mannequin, by comparing the data from the 3D-PAT to the reference standard data obtained using the Vicon system, and 2) the test-retest reliability of the X-, Y- and Z-coordinates of the reflective markers, by comparing the repeated measures from the 3D-PAT. From an engineering perspective, it was essential that the validity of the coordinate data be determined separately from the postural angle calculation process, as the latter process could have introduced further error in measurement, resulting in only the X-, Y- and Z-coordinate data being compared.

5.1 METHODOLOGY

5.1.1 Study design

A correlation study for validity testing and a repeated measures observational study for reliability testing were conducted.

5.1.2 Ethical considerations

As no subjects were used in this part of the study, no informed consent was required.

5.1.3 Instrumentation

5.1.3.1 *Three-Dimensional Posture Analysis Tool (3D-PAT)*

The same instrument was used as that which had been used in the phase one study. (Refer to Chapter 3 for a description of the instrument.) The instrument measured the X-, Y- and Z-coordinates of 14 reflective markers on a mannequin.

5.1.3.2 *Vicon motion analysis system*

The same Vicon T-series motion analysis system (Vicon Motion Systems (Ltd) (Oxford, UK) as had been used in the phase one study was used (see subsection 4.1.4.2). Five infrared Vicon T-10 cameras were used. The output from the Vicon system was the X-, Y- and Z-coordinates of the reflective markers on the mannequin.

5.1.4 Study procedure

5.1.4.1 *Preparation of the laboratory for validity and reliability testing*

The study was performed in the Motion Analysis and Physiotherapy Clinic on the Tygerberg campus of Stellenbosch University. Data capture was conducted during May 2010. The Vicon system is a permanent fixture in the laboratory concerned, and only the dynamic calibration procedure, as described in subsection 4.1.5.1 for the phase one study, was performed. Five T-10 infrared Vicon cameras were used. The research assistant operated the Vicon system.

The 3D-PAT was set up in the same manner as for the phase one study (refer to subsection 4.1.5.1), so that the 14 reflective markers on the mannequin could be photographed by two or more of the 3D-PAT cameras. The two tripods with the 3D-PAT cameras were positioned as shown in Figure 5.1 below. The researcher was responsible for the setting-up of the 3D-PAT and for operating the instrument. The pyramid calibration object was used for the study. (Refer to subsection 4.1.5.1 for a description of the calibration procedure for the 3D-PAT.) Figure 5.1 below is a schematic demonstration of the Vicon system and 3D-PAT set-up in relation to the mannequin.

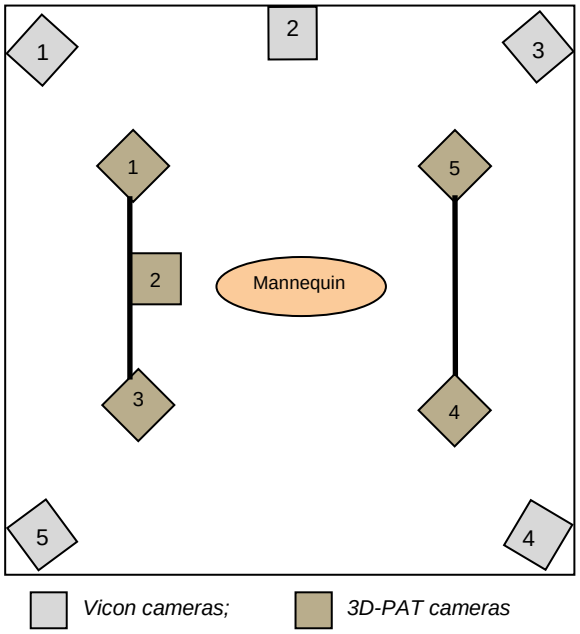


Figure 5.1: The 3D-PAT and Vicon system set-up in the laboratory

5.1.4.2 *Preparation of the mannequin for validity and reliability testing*

The *'Choking Charlie' Heimlich Abdominal Thrust Manoeuvre Training mannequin* was used. The mannequin was positioned on a wooden table in the centre of the Vicon system's capture volume to ensure that each marker was visible by two or more of the Vicon and 3D-

PAT cameras. The researcher placed the reflective markers on the surface of the mannequin, using double-sided tape.

Reflective markers were placed on the mannequin's left and right canthus of the eyes, left and right trachus of the ears, SPs of C_7, T_5 and T_8, the left and right acromioclavicular joints, the left and right midpoint of the shoulders, the superior border of the sternum and the left and right hips, using double-sided tape.

5.1.4.3 *Measurements with the 3D-PAT and Vicon system for validity testing*

Measurements with the 3D-PAT and the Vicon system were taken simultaneously for the validity testing. Once the reflective markers were placed on the mannequin, they were not removed until the validity testing was complete. Seven different mannequin positions were captured by means of the Vicon system and the 3D-PAT. Each of the seven positions was captured once, except for position one, which was captured three times, so that there were nine validity trials in all. The seven positions concerned are shown in Figure 5.2 (a-g) below.

A capture commenced once the mannequin was in position and lasted until the 3D-PAT had successfully captured 100 synchronised frames from each of the five cameras used.

(a) On a flat surface, facing the y plane

(b) On a flat surface, facing the x plane

(c) On a flat surface, rotated 180° clockwise from the y plane

(d) On a flat surface, rotated 135° counter clockwise from the y plane

(e) Facing the y plane, tilted forward

(f) Rotated 45° from the y plane, tilted forward to the left

(g) Facing the y plane, tilted forward to the left

Figure 5.2 (a-g): The mannequin positions captured by the Vicon system and the 3D-PAT

5.1.4.4 *Measurements with the 3D-PAT for reliability testing*

Two repeated measurements of mannequin position one (on a flat surface, facing the y-plane), were performed for the reliability testing. The researcher removed all the reflective markers before replacing them, prior to capturing trial eight by both the 3D-PAT and the Vicon system. The same procedure was repeated immediately thereafter for trial nine, without moving the mannequin's position. No traces of the markers remained before replacing them for the next trial. The reflective markers were removed in order to test the reliability of the researcher's marker placement. Thus, there were two sets of repeated measurements of which the reflective markers were replaced after each captured trial (trials eight and nine).

5.1.5 Data processing

5.1.5.1 *3D-PAT*

The researcher performed the data processing of the 3D-PAT.

(a) *Marker selection of the reflective markers on the mannequin*

For each of the nine captured trials, the first frame from each of the five cameras was selected. A marker selection procedure for the mannequin was followed, which was similar to the procedure for the marker selection of the reflective markers on the students, as was described in subsection 4.1.6.1(a), except that each reflective marker was manually selected according to the marker placement model for the mannequin (refer to subsection 3.4.2).

(b) *Marker selection of the calibration object*

The first frame from each of the five cameras of the pyramid calibration object was selected, after which the same procedure was followed as for the marker selection of a subject. The sequence of marker selection was according to the marker placement model for the pyramid calibration object (refer to subsection 3.2.4).

(c) *Reconstruction of the X-, Y-, Z-coordinates*

The marker selection files for both the pyramid calibration object and the mannequin were imported into the reconstruction section of the software program. The same procedure as described in subsection 4.1.6.1(c) was implemented to triangulate the X-, Y- and Z-coordinates of each reflective marker. The completed 3D-PAT data set reported nine sets of data (one set per data trial), containing the X-,Y- and Z-coordinates of each of the 14 reflective markers.

5.1.5.2 *Vicon system*

A research assistant performed the data processing of the Vicon system's data. The same process, as described in subsection 4.1.6.2 for the phase one study, was implemented. The Vicon's software program produced the X-, Y- and Z-coordinates of the 14 reflective markers. The data were exported as text files for analysis in Microsoft Excel (Microsoft Corporation).

5.1.6 Statistical analysis

5.1.6.1 *Test-retest reliability*

The concordance correlation coefficient (r_c) and the upper and lower 95% CI were calculated as was done for the phase one study (refer to subsection 4.1.7.1).

5.1.6.2 *Concurrent validity*

The Bland-Altman method was used as for the phase one study (see subsection 4.1.7.2).

5.2 RESULTS

5.2.1 X-, Y- and Z-coordinate data from the 3D-PAT and Vicon system

Since 14 reflective markers were placed on the mannequin, the maximum number of coordinates per trial for each set of X-, Y- and Z-coordinates was 14. However, due to the positioning of the mannequin, not all 14 reflective markers were equally visible in all three planes. Hence, the number of coordinate data sets displayed in Table 5.1 below varies.

Table 5.1: The captured and uncaptured reflective marker per trial

Trial	Instrument	Captured reflective markers (n = 121)	Uncaptured reflective markers
1	Vicon system / 3D-PAT	14/14	
2	Vicon system	13	Right trachus
	3D-PAT	12	Left and right trachus
3	Vicon system	13	Left trachus
	3D-PAT	14	
4	Vicon system / 3D-PAT	14/14	
5	Vicon system / 3D-PAT	14/14	
6	Vicon system / 3D-PAT	14/14	
7	Vicon system	13	T_8 SP
	3D-PAT	14	
8	Vicon system	13	Right acromioclavicular joint
	3D-PAT	13	Right acromioclavicular joint
9	Vicon system / 3D-PAT	14/14	

After the X-, Y- and Z-coordinates from both the 3D-PAT and the Vicon system were plotted on method comparison graphs, four Y-coordinates from trial one were indicated as outliers and not plotted on, or close to, the 45° line (see Figure 5.3 below). Thus, it was decided to exclude trial one from further analysis.

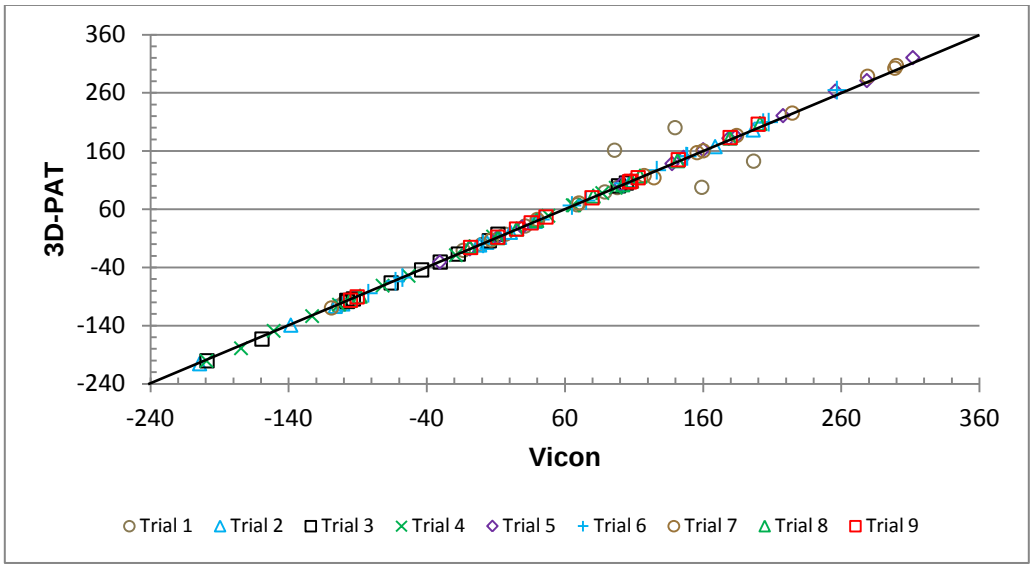


Figure 5.3: Method comparison plot for the Y-coordinates (n = 121)

5.2.2 Validity findings

5.2.2.1 *Differences between the measurements from the two instruments*

The agreement between the measurements from the 3D-PAT and the Vicon system for the X-, Y- and Z-coordinates was estimated and interpreted by means of examining the difference between the two measurements (Vicon – 3D-PAT) per coordinate. Table 5.2 below presents the estimated bias (the mean difference), the variability of the scores (the SD of the differences) and the upper and lower levels of the limits of agreement within which 95% of the differences between the measurements, by the two instruments, would lie. The table also

presents the CV and the width of the limits of agreement. The SE of the limits of agreement is also shown.

Table 5.2: The estimated bias, the variability of the scores and the limits of agreement for the X-, Y- and Z-coordinates for trials two to nine

		X-coordinates (n = 107)	**Y-coordinates (n = 107)**	**Z-coordinates (n = 107)**
DF	*n - 1*	106	106	106
Estimated bias	*Mean difference (d)*	1.98mm	-0.77mm	0.71mm
Variation	*SD of the differences (s)*	10.0mm	2.7mm	1.9mm
CV	*s/d*	5.07	3.45	2.73
SE of bias	s^2/n	0.97	0.26	0.19
95% limits of agreement	*Upper limit (d+1.96s)*	21.64mm	4.44mm	4.51mm
	Lower limit (d-1.96s)	-17.68mm	-5.98mm	-3.09mm
Width	*UL - LL*	39.32mm	10.42mm	7.60mm
SE of limits of agreement	$\sqrt{(3*s^2/n)}$	1.68	0.45	0.32

Figures 5.4 to 5.9 are method comparison plots and Bland-Altman plots for the X-, Y- and Z-coordinates visualising the relationship between the measurements from the two instruments. In the Bland-Altman plots, the difference between the measurements was plotted against the mean score for each coordinate pair. The red line in the figures represents the *estimated bias* and the two blue lines the *upper and lower 95% limits of agreement.*

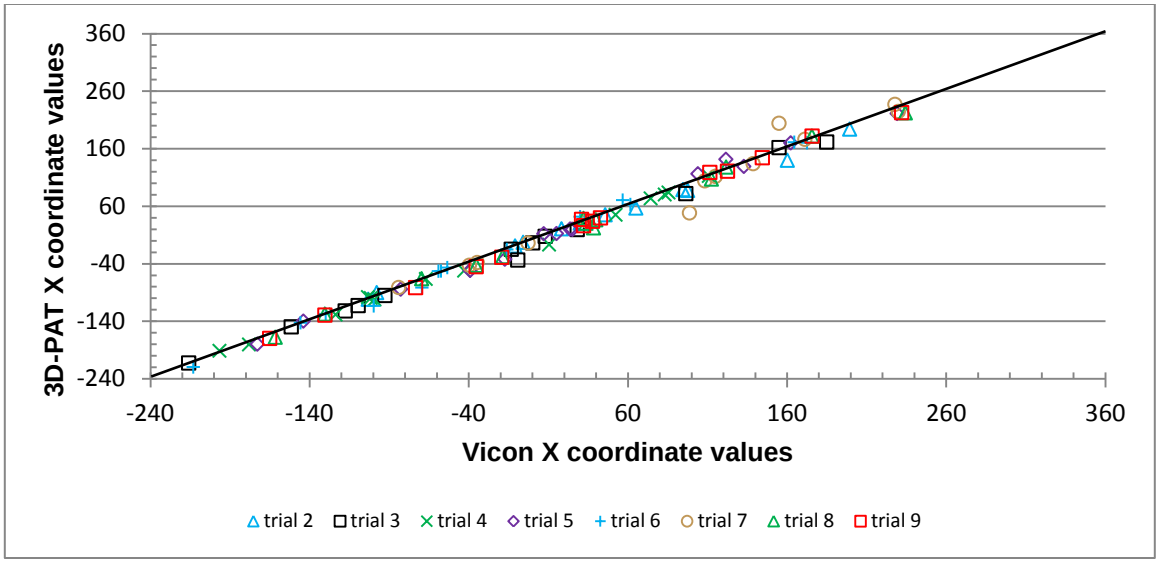


Figure 5.4: Method comparison plot for the X-coordinates

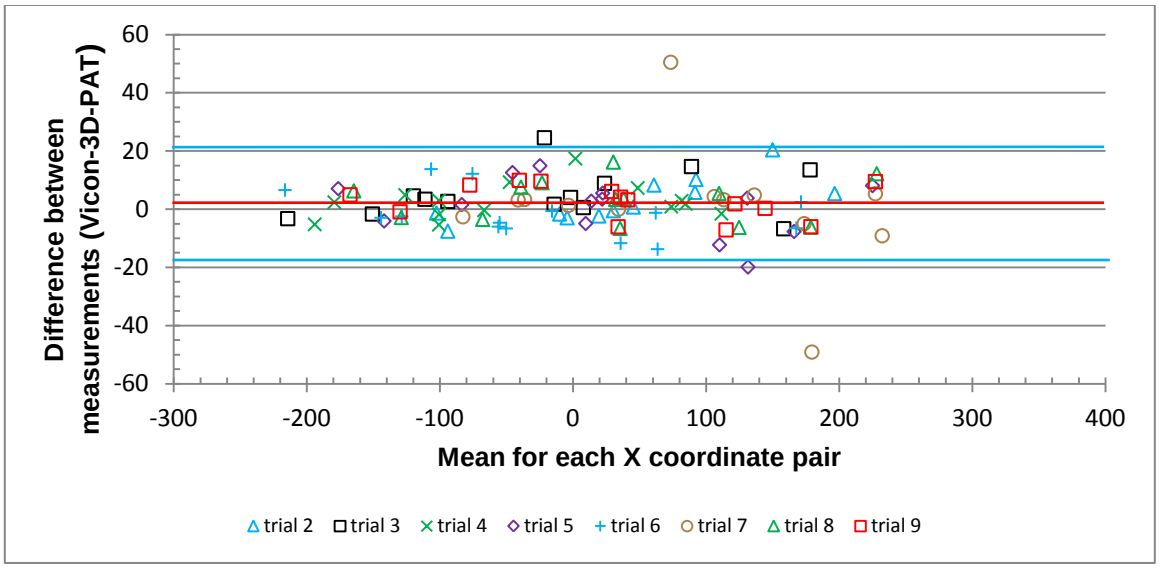


Figure 5.5: Bland-Altman plot for the X-coordinates

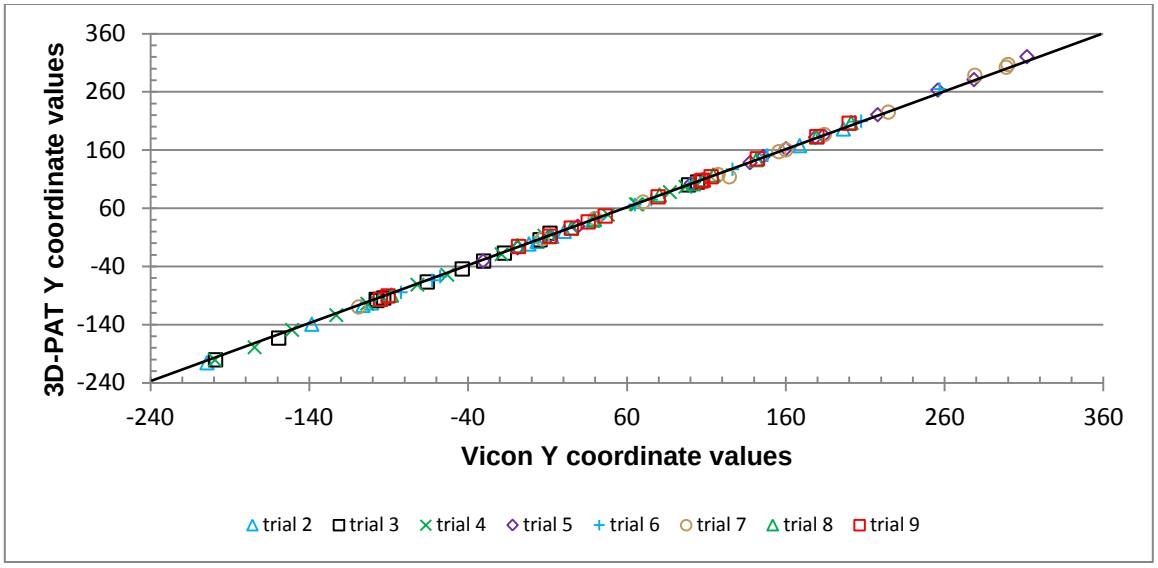


Figure 5.6: Method comparison plot for the Y-coordinates

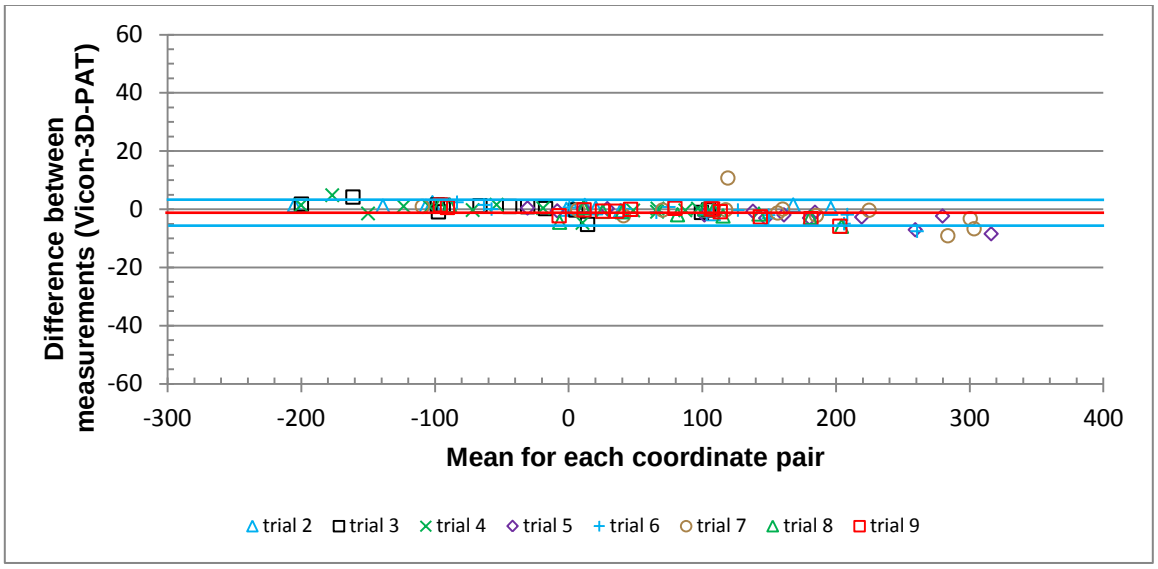


Figure 5.7: Bland-Altman plot for the Y-coordinates

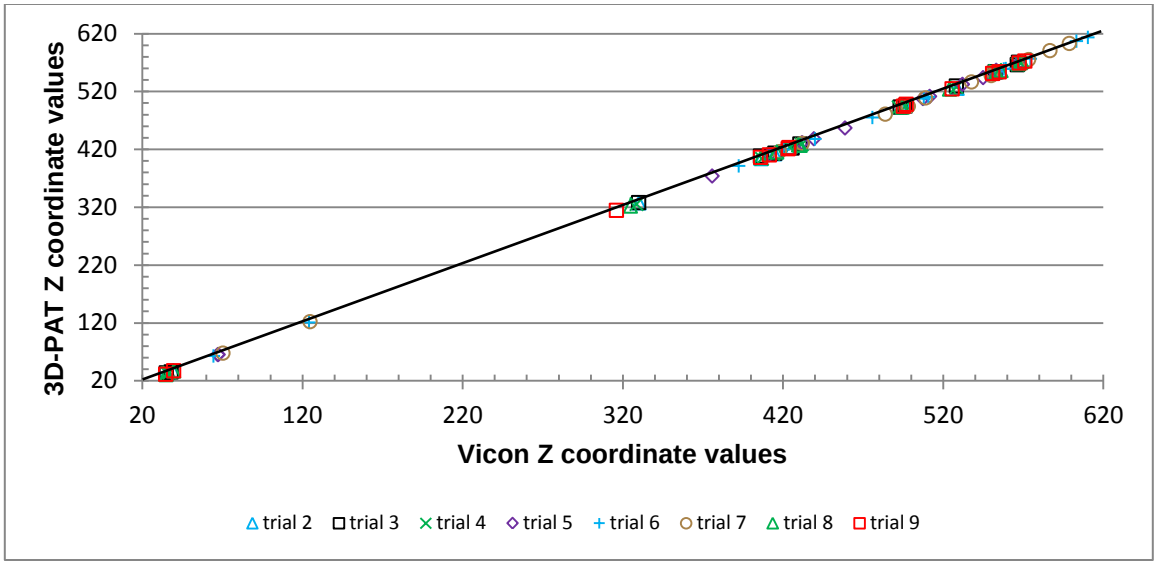


Figure 5.8: Method comparison plot for the Z-coordinates

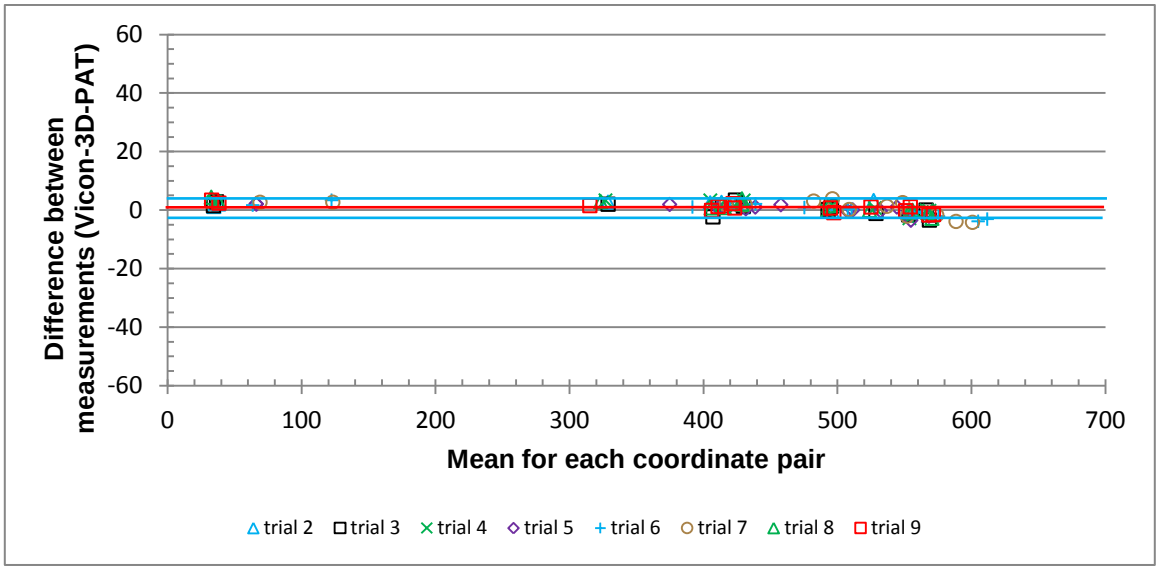


Figure 5.9: Bland-Altman plot for the Z-coordinates

The Bland-Altman method revealed small biases for the Y- and Z-coordinates with little variation, as all scores were spread closely around the zero point. The bias for the X-coordinate was larger, being approximately 2.5 times the bias for the X- and Z-coordinates, as was shown in Table 5.2 above. The limits of agreement were the widest for the X-coordinates.

5.2.2.2 *Outliers of the X-, Y- and Z-coordinates*

For mannequin position seven, the mannequin was facing the Y-plane and was tilted forward towards the left. The X-coordinates of the left canthus and left trachus were observed as outliers. Table 5.3 below shows the estimated bias, the variability of the scores and the upper and lower levels of the limits of agreement for the X-coordinate once the two outliers were excluded.

Table 5.3: The estimated bias, the variability of the scores and the limits of agreement for the X-coordinates for trials two to nine excluding the outliers

		X-coordinates (n = 105)
DF	*n - 1*	104
Estimated bias	*Mean difference (d)*	2.00mm
Variation	*SD of the differences (s)*	7.4mm
CV	*s/d*	3.70
SE of bias	s^2/n	0.52
95% limits of agreement	*Upper limit (d+1.96s)*	16.52mm
	Lower limit (d-1.96s)	-12.52mm
Width	*UL - LL*	29.04mm
SE of limits of agreement	$\sqrt{(3*s^2/n)}$	1.25

After excluding the outliers, the variation was reduced by 2.6mm and the width of the limits of agreement was reduced by 10mm.

5.2.3 Reliability findings

5.2.3.1 *Agreement between repeated measurements (trials eight and nine)*

Trials eight and nine were considered for the test-retest reliability analysis. Table 5.4 below shows the calculated concordance correlation coefficients that reflect the reproducibility of the measurements for the X-, Y- and Z-coordinates. The upper and lower 95% CI were also reported. The results indicated very good reproducibility for all three coordinate systems.

Table 5.4: The concordance correlation coefficients and the upper and lower CIs, per coordinate system (n = 13)

	Concordance correlation coefficient	**Lower 95% CI**	**Upper 95% CI**
X-coordinates	0.99	0.99	0.99
Y-coordinates	0.99	0.99	0.99
Z-coordinates	0.99	0.99	0.99

Figures 5.10 to 5.12 are scatterplot graphs that illustrate the degree of agreement between the repeated measurements in trials eight and nine.

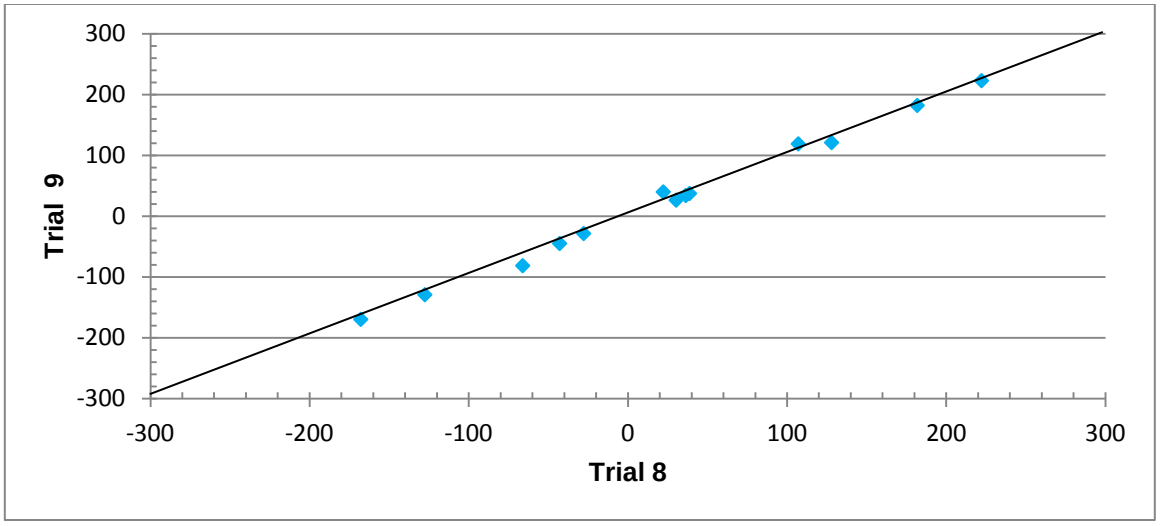


Figure 5.10: Scatterplot graph illustrating agreement for the X-coordinates

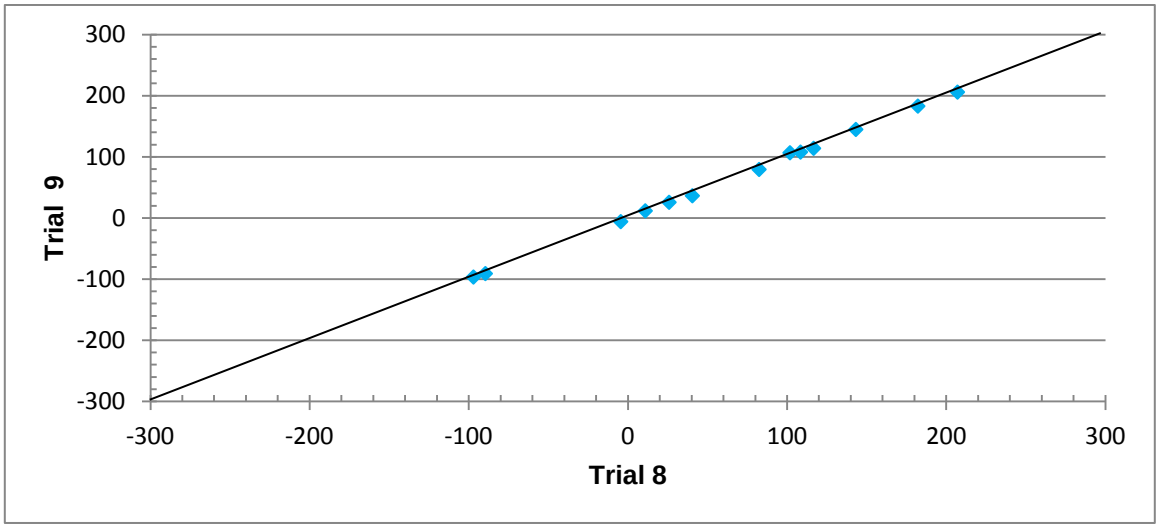


Figure 5.11: Scatterplot graph illustrating agreement for the Y-coordinates

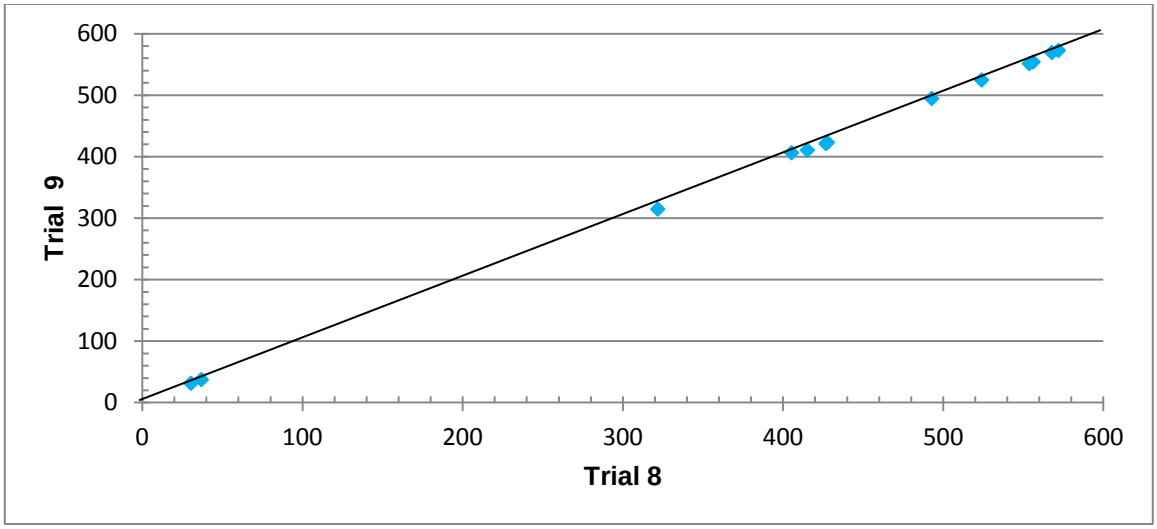


Figure 5.12: Scatterplot graph illustrating agreement for the Z-coordinates

5.3 SUMMARY

The current chapter described the second assessment of the reliability and validity of the 3D-PAT when using an inanimate object (a mannequin). The findings illustrated very good agreement between the measurements from the 3D-PAT and the Vicon system for the Y- and Z-coordinates of the reflective markers, and good agreement for the X-coordinate values. The reliability testing revealed very good reproducibility for the X-, Y- and Z-coordinates.

The results of phase two of the validity and reliability testing procedures indicated that the 3D-PAT compared very well with the reference standard for measurement of the X-, Y- and Z-coordinates of the reflective markers. However, it was imperative that the 3D-PAT be tested under similar conditions, as it would be used in clinical practice, thus the next chapter presents the third phase of psychometric testing of the 3D-PAT. The chapter reassesses the instrument's ability to measure the nine postural angles of high school students under consideration in the phase one study.

PART I

CHAPTER 6

The reassessment of the validity and reliability testing of the Three-Dimensional Posture Analysis Tool (3D-PAT) when describing the sitting posture of computing high school students: Phase three

The current chapter presents the third psychometric testing of the 3D-PAT, of which the findings reflect the improvements made to the instrument after the first phase of testing. The methodology and study procedure were adapted from the phase one study, due to time constraints experienced (convenience sampling), and in order to address the variability of sitting posture over time (with reliability being tested on the same day in a laboratory set-up). The objectives were to determine: 1) the concurrent validity of the 3D-PAT's measurements of nine sitting postural angles of high school students, when compared to the reference standard using the Vicon motion analysis system; and 2) the test-retest reliability of the 3D-PAT's measurements, when repeated measures were taken of the sitting postural angles of high school students.

6.1 METHODOLOGY

6.1.1 Study design

A correlation study for validity testing and a repeated measures observational study for reliability testing were conducted.

6.1.2 Study population

The study population consisted of Grade 10 and 11 high school students from one high school in the Cape metropolitan region of the Western Cape Province. Boys and girls aged between 15 to 18 years old were eligible to participate in the study.

6.1.3 Sampling method

6.1.3.1 *Sample size*

No sample size calculation was performed for the current study, since the study was not included in the original proposal and a convenience sample of high school students from one school was included, due to the time constraints experienced. The researcher collaborated with a researcher who had already contacted a high school for another research project, and the same high school students who were participating in the other study were also invited to participate in the current study.

6.1.3.2 *Sampling of students*

The researcher invited the students from one school in the Western Cape metropolitan region to participate in the study. The students completed the pain-related component of the CUQ, as had been done in the phase one study (refer to subsection 4.1.3.3).

6.1.3.3 *Inclusion and exclusion criteria*

The same inclusion and exclusion criteria were applicable to the current study as were applicable for the phase one study, except that both asymptomatic and symptomatic students were eligible to participate in the study, as the 3D-PAT was also required to be capable of

accurately measuring the sitting postural alignment of both groups (refer to subsections 4.1.3.4 and 4.1.3.5).

6.1.3.4 *Ethical considerations*

Permission was obtained from the WCED for students to participate in this study. Written informed consent letters were completed by the parents/legal guardians and the students. The informed consent letters were available in English and Afrikaans (Addenda 14 and 15). No questions or concerns were raised by the parents or students.

6.1.4 Instrumentation

6.1.4.1 *Three-Dimensional Posture Analysis Tool (3D-PAT)*

The same instrument was used, and the same nine postural angles were measured, as for the phase one study that was previously described in subsection 4.1.4.1.

6.1.4.2 *Vicon motion analysis system*

The same Vicon T-series motion analysis system (Vicon Motion Systems (Ltd) (Oxford, UK), was used to measure sitting postural alignment as for the phase one study, as was described in subsection 4.1.4.2. were used. The output from the Vicon system, consisting of eight infrared Vicon T-10 cameras, was the X-, Y- and Z-coordinates of the reflective markers that were placed on the students.

6.1.5 Study procedure

6.1.5.1 *Preparation of the laboratory for the validity and reliability testing*

The testing laboratory was set up at the Motion Analysis and Physiotherapy Clinic on the Tygerberg Campus for both the validity and reliability testing of the 3D-PAT. Stellenbosch University transported the students to the laboratory. Data capture was conducted during September 2011.

Eight T-10 infrared Vicon cameras were used in the current study, and the same standard calibration procedure was performed for the Vicon system as was described in subsection 4.1.5.1. The same set-up and calibration procedure for the 3D-PAT was followed, as described in subsection 4.1.5.1. The pyramid calibration object was used for the study. The 3D-PAT was positioned as is shown in Figure 6.1 below. The researcher was responsible for the setting-up of the 3D-PAT.

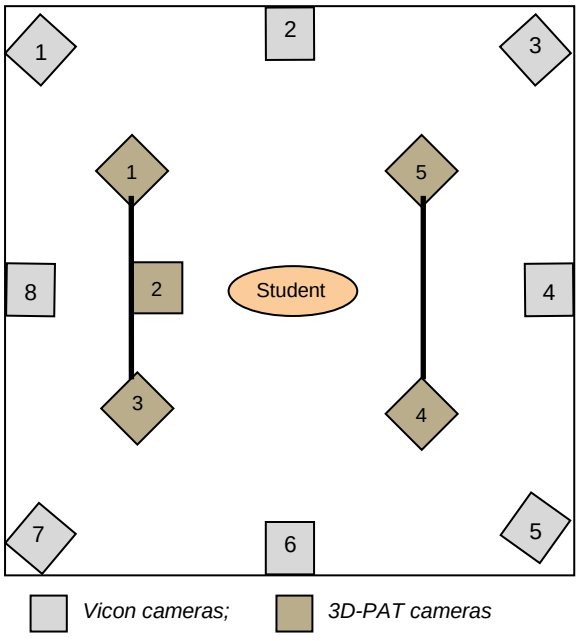


Figure 6.1: The 3D-PAT and Vicon system set up in the laboratory

Measurements with the 3D-PAT and the Vicon system were taken simultaneously for purposes of the validity and reliability testing. Each student in turn was given a chair and desk that were similar in height and shape to the furniture used in the school computer laboratories (Smith, 2007). After a computer monitor was positioned on the desk, the student concerned was required to sit behind the desk, facing the login window, which was displayed in the centre of the computer monitor while the data were captured.

6.1.5.2 *Preparation of the students for the validity and reliability testing*

The researcher explained the study procedure to the students on their arrival at the laboratory. The students wore black t-shirts and grey school pants in order for the reflective markers to be clearly visible on the digital photographs. Height and weight measurements were measured by a research assistant prior to the validity testing. The same instruments for height and weight measurements were used as for the phase one study. The reflective markers were placed on the students by the researcher, as was described in subsection 4.1.5.2. Figure 6.2 below illustrates the placement of the reflective markers as seen from the student's back, left side and front.

(a) From the back (b) From the side (c) From the front

Figure 6.2(a-c): The placement of the reflective markers for validity testing

6.1.5.3 *Measurements with the 3D-PAT and Vicon system for validity and reliability testing*

The student, with reflective markers, was placed within the capture volume of the 3D-PAT and Vicon system. Validity and reliability testing were performed simultaneously by means of capturing three trials per student with both the 3D-PAT and Vicon system. One student was measured per trial. Data capture commenced once the student was settled in behind the desk and there was no more conspicuous postural adjustments. One research assistant operated the Vicon system and another the 3D-PAT. The data capture trial lasted for approximately 15 seconds, while the Vicon system and the 3D-PAT, which captured 100 synchronised frames from each of the five cameras, simultaneously captured one trial. The data capture trial would have been successful if all nine reflective markers had been clearly visible on the digital photographs, as well as on the computer monitor of the Vicon system. Figure 6.3 below is a photograph that was taken during one of the validity data capture trials.

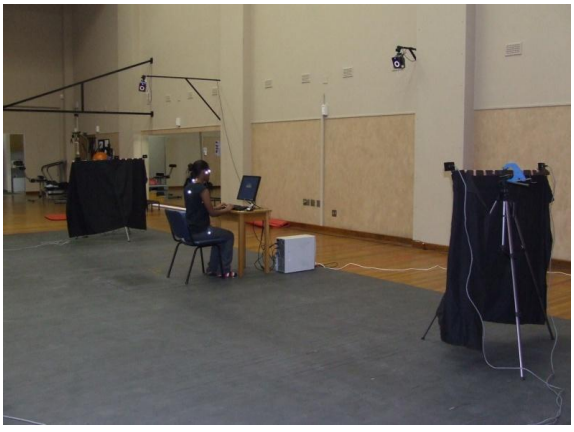


Figure 6.3: A data capture trial for validity / reliability testing

For repeated measurements, each student was asked in turn to stand after the first trial was captured and then immediately to sit down in the same position as previously, before the second trial was captured. The same procedure was repeated for the third measurement.

6.1.5.4 *Time period for data collection*

The students came in three groups. Measurements were taken in the morning during school hours. The data capture duration was approximately 10 minutes for the validity and reliability testing per student.

Figure 6.4 summarises the sample recruitment and study procedure.

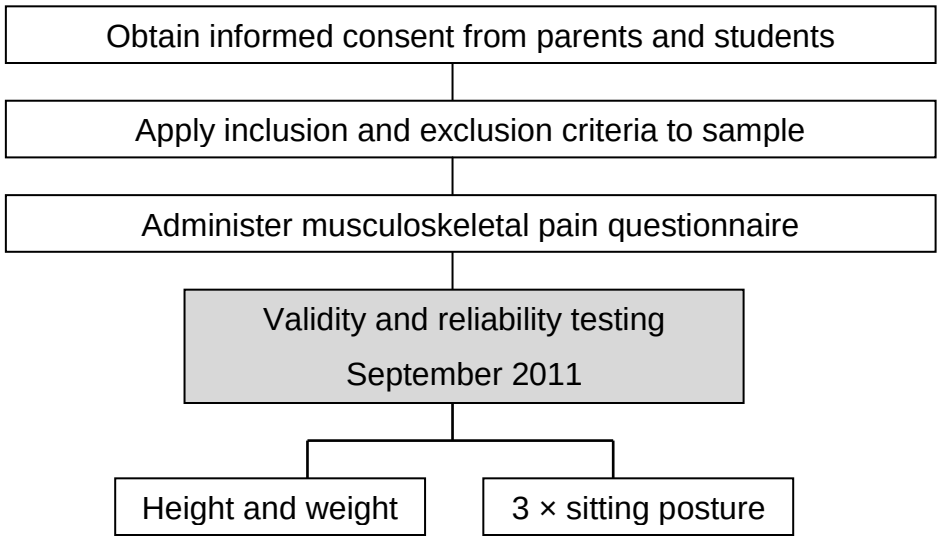


Figure 6.4: A flow chart demonstrating the sample recruitment and study procedures

6.1.6 Data processing

6.1.6.1 *3D-PAT*

The researcher performed the data processing of the 3D-PAT.

(a) *Marker selection of the reflective markers placed on the students*

For the validity and reliability testing, the total number of trials was 81 (27 × 3). For the validity testing, the first frame per camera was selected to form a set of five photographs per

trial. The set of photographs concerned was saved in a separate folder. For the reliability testing, the first frame per camera per trial was selected, provided that the frames in question resembled a similar posture. If the first frame of a trial did not match the posture from the previous trial, a different frame with closest resemblance to the posture was selected. The marker selection was performed as described in subsection 4.1.6.1(a). No additional control markers were necessary.

(b) *Marker selection of the calibration object*

The first frame from each of the five cameras of the pyramid calibration object was selected and saved in a separate folder. A marker selection procedure for the pyramid calibration object, which was described in subsection 5.1.5.1(b), was followed.

(c) *Reconstruction of the X, Y, Z coordinates and postural angle calculation*

The reconstruction section of the software program compiled the data from the files with the marker selection of the student and the marker selection of the pyramid calibration object. The same process, as was described in subsection 4.1.6.1(c) was followed, in order to calculate the nine postural angles. The complete 3D-PAT data set contained 28 and 66 successful validity and reliability trials, respectively. If all nine postural angles were within acceptable ranges after digitisation and postural angle calculation, it was regarded as constituting a successful trial.

6.1.6.2 *Vicon system*

A research assistant performed the data processing of the Vicon system's data. The same process as was described in subsection 4.1.6.2 for the phase one study was implemented.

6.1.7 Statistical analysis

6.1.7.1 *Test-retest reliability*

The ICC and the upper and lower 95% CI were calculated to measure the reproducibility of two or three repeated measurements of the nine postural angles. The index reflected both correspondence and agreement between measurements (Li Lu & Nawar, 2007; Portney & Watkins, 2009).

6.1.7.2 *Concurrent validity*

The Bland-Altman method was used, as in the phase one study, was described in subsection 4.1.7.2.

6.2 RESULTS

6.2.1 Sample composition

The number of students with written informed consent letters who arrived at the laboratory for testing was 36. After the inclusion and exclusion criteria were applied, three boys and six girls were excluded from the study, due to their age not falling within the required age limit for the study, leaving 27 participants. Of the 27 students, 15 students complained of UQMP. Due to technical problems occurring with both the Vicon system and the 3D-PAT, only 28 validity trials from ten students and 66 reliability trials from 24 students were successful. Eighteen students with three repeated measurements and six students with two repeated measurements constituted the 66 trials. Thus, only the data from 24 students could be used for either both validity and reliability analysis or for only the reliability analysis. Figure 6.5 below outlines how the validity and reliability data sets were obtained.

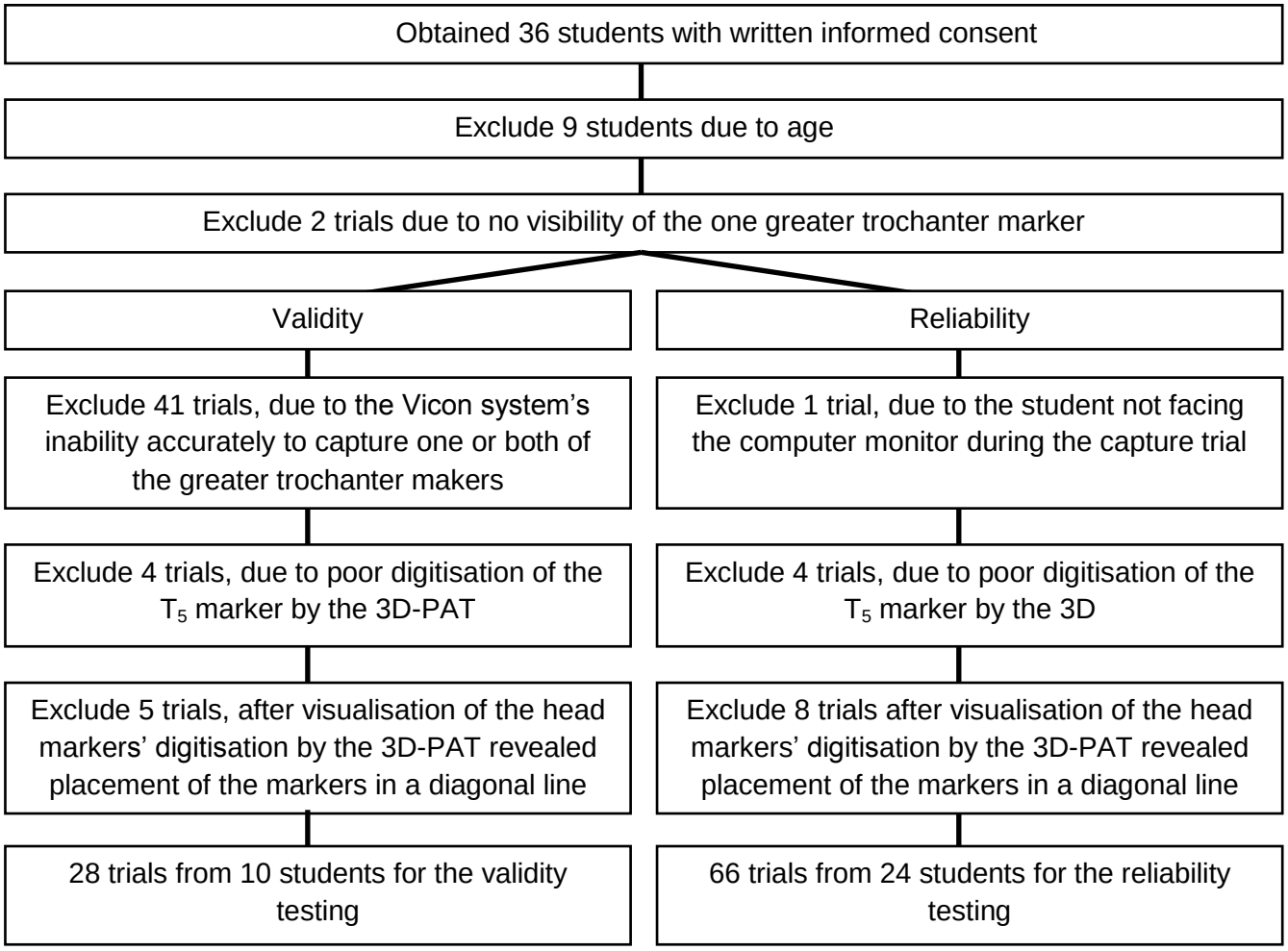


Figure 6.5: Flow diagram illustrating the exclusion of trials from the validity and reliability testing

Table 6.1 below illustrates the sample characteristics of the participating students.

Table 6.1: Sample characteristics of the students participating in the validity and reliability testing procedures

	Asymptomatic students		Symptomatic students	
	Male	**Female**	**Male**	**Female**
Students in validity study (n = 10)	3	2	1	4
15 years old	0	0	0	2
16 years old	2	0	1	1
17 years old	1	2	0	1
18 years old	0	0	0	0
Students in reliability study (n = 24)	7	5	3	9
15 years old	0	2	2	3
16 years old	3	1	1	3
17 years old	4	2	0	3
18 years old	0	0	0	0

6.2.2 Height and weight measurements

The mean age for the validity group was 16.2 years (SD 0.8); the mean height was 1.63m (SD 0.1); and the mean weight was 54.6kg (SD 7.7). The mean age for the reliability group was 16.1 years (SD 0.8); the mean height was 1.58m (SD 0.2); and the mean weight was 56.6kg (SD 11.1).

6.2.3 Validity findings

6.2.3.1 *Postural angles from the 3D-PAT and Vicon system*

Table 6.2 below summarises the mean, the SD, the maximum and the minimum values obtained for each instrument for the nine postural angles.

Table 6.2: The mean, the SD, the maximum and the minimum values for each instrument for the nine postural angles (n = 28)

		Head flexion (°)	Neck flexion (°)	Cranio-cervical angle (°)	Cervico-thoracic angle (°)	Trunk flexion (°)	Head lateral bending (°)	Neck lateral bending (°)	Head rotation (°)	Thoracic trunk rotation (°)
VICON	Mean	66.1	54.2	166.1	158.9	-7.4	4.1	0.0	-2.0	-1.2
	SD	8.3	6.8	8.7	9.6	5.2	2.6	6.9	4.5	2.0
	Max	87.2	68.8	176.0	175.4	2.5	11.8	12.1	4.3	3.6
	Min	50.1	46.3	149.1	139.3	-16.1	0.3	-15.4	-12.5	-4.7
3D-PAT	Mean	66.9	54.8	163.4	155.3	-6.6	4.1	-3.5	0.7	2.8
	SD	8.7	6.9	9.4	10.4	5.5	3.4	12.4	7.6	3.6
	Max	89.2	69.6	176.1	168.1	3.1	17.1	11.5	14.3	9.4
	Min	51.7	45.8	146.4	131.2	-15.0	0.4	-43.0	-13.3	-5.7

6.2.3.2 *Differences between two measurements from two instruments*

The agreement between the measurements from the 3D-PAT and the Vicon system for the nine postural angles was estimated and interpreted by examining the difference between the two measurements (Vicon – 3D-PAT) obtained per angle per student. Table 6.3 below presents the estimated bias (the mean difference), the variability of the scores (the SD of the differences), and the upper and lower levels of the limits of agreement within which 95% of the differences between the measurements, by the two instruments, would lie. Table 6.3 also presents the relative bias, the CV and the width of the limits of agreement. The SE of the limits of agreement is also shown in the table.

Table 6.3: The estimated bias, the variability of the scores and the limits of agreement for the nine postural angles (n = 28)

		Head flexion	Neck flexion	Cranio-cervical angle	Cervico-thoracic angle	Trunk flexion	Head lateral bending	Neck lateral bending	Head rotation	Thoracic trunk rotation
DF	*n – 1*	27	27	27	27	27	27	27	27	27
Estimated bias	*Mean difference (d)*	-0.74°	-0.64°	2.65°	3.69°	-0.83°	0.01°	3.57°	-2.70°	-3.93°
Variation	*SD of the differences (s)*	1.96	1.68	3.95	9.24	1.09	1.84	8.78	5.19	3.25
VICON	*Mean*	66.1°	54.2°	166.1°	158.9°	-7.4°	4.1°	0.0°	-2.0°	-1.2°
Relative bias	*d / Vicon mean*	-0.01	-0.01	0.02	0.02	0.11	0.00	35.70	1.35	3.28
CV	*s/d*	2.65	2.63	1.49	2.50	1.31	184.00	2.46	1.92	0.83
SE of bias	s^2/n	0.37	0.32	0.75	1.75	0.21	0.35	1.66	0.98	0.61
95% limits of agreement	*Upper limit (d+1.96s)*	3.10	2.65	10.39	21.80	1.31	3.60	20.78	7.48	2.44
	Lower limit (d-1.96s)	-4.58	-3.93	-5.10	-14.42	-2.96	-3.59	-13.64	-12.88	-10.29
Width	*UL – LL*	7.68°	6.58°	15.49°	36.22°	4.27°	7.19°	34.42°	20.36°	12.73°
SE of limits of agreement	$\sqrt{(3*s^2/n)}$	0.64	0.55	1.29	3.02	0.36	0.60	2.87	1.70	1.06

The largest biases were seen for the cervico-thoracic angle, neck lateral bending and thoracic trunk rotation. The relative bias was high for neck lateral bending and thoracic trunk rotation. The limits of agreement were the widest for the cervico-thoracic angle, neck lateral bending and head rotation.

Figures 6.6 to 6.14 are Bland-Altman plots visualising the relationship between the measurements that were obtained by means of the two instruments. In the graph, the difference between the measurements is plotted against the mean score for each student. The red line represents the *estimated bias*, with the two blue lines representing the *upper and lower 95% limits of agreement.*

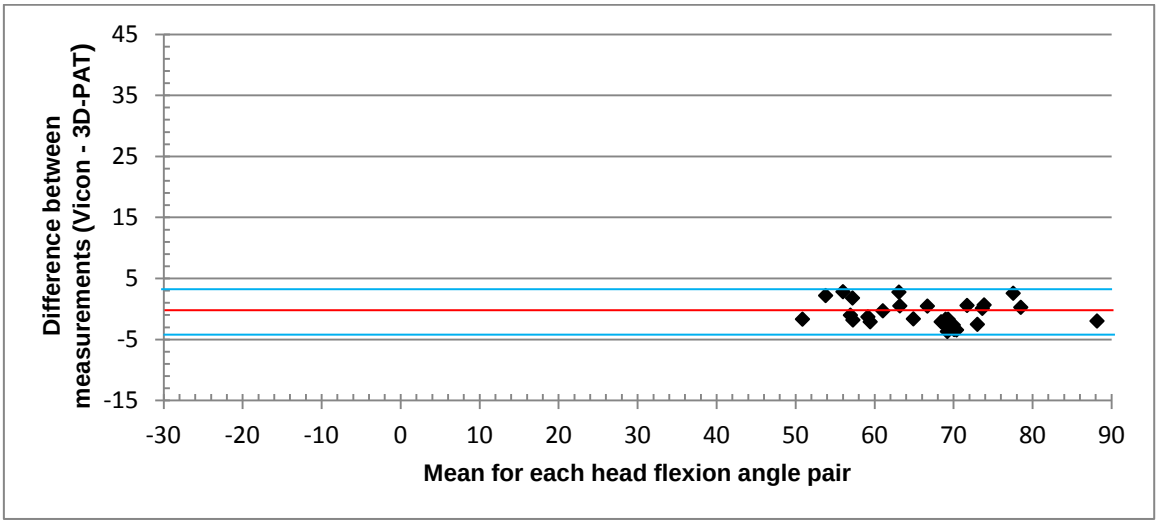


Figure 6.6: Bland-Altman plot for head flexion

The bias of -0.74° for head flexion was small, with little variation (± 1.96°). All the scores fell within the 95% limits of agreement.

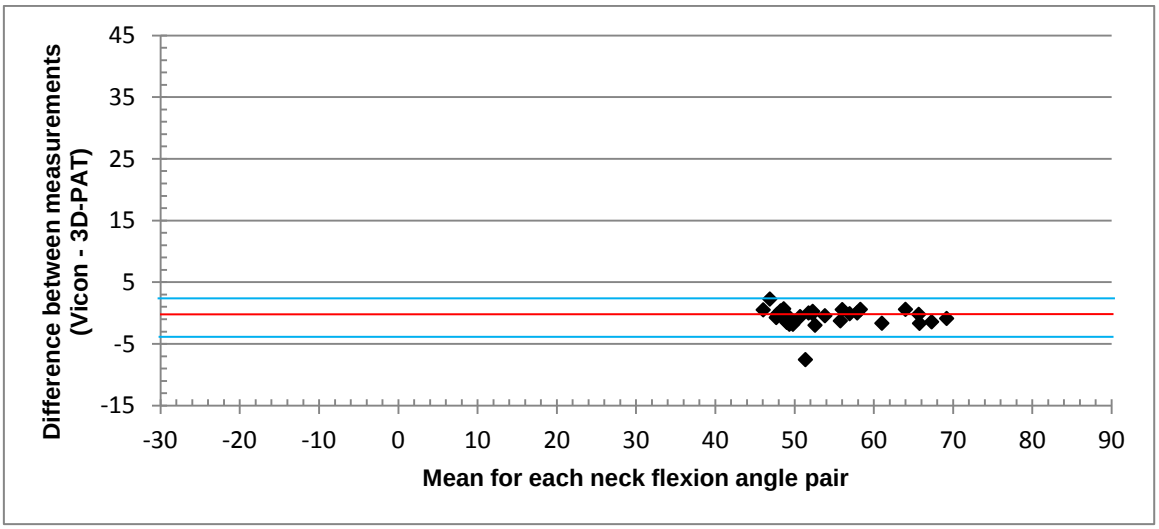


Figure 6.7: Bland-Altman plot for neck flexion

The bias of 0.64° for neck flexion was small, with little variation (± 1.68°). All but one score fell within the 95% limits of agreement.

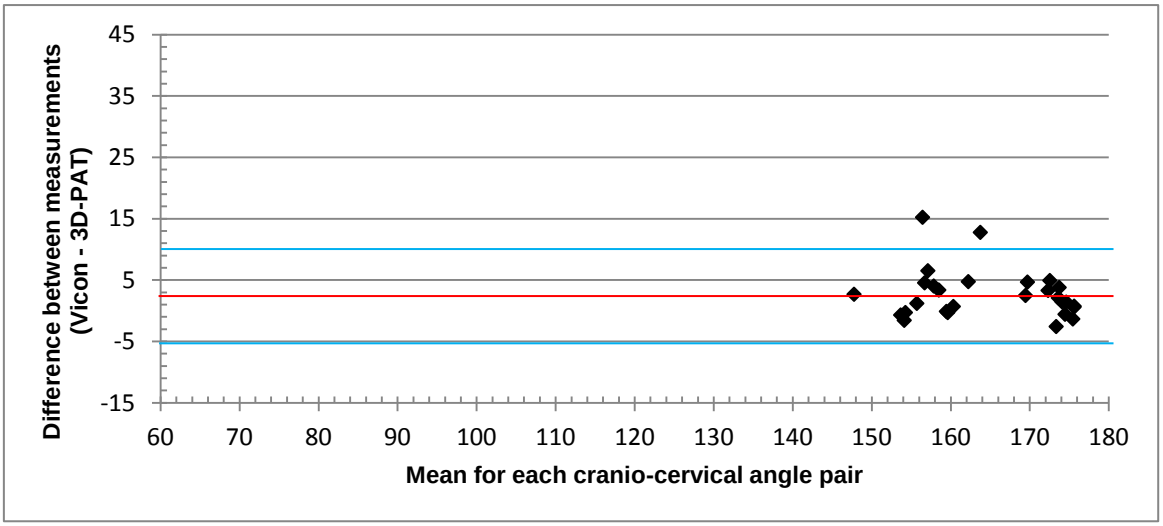


Figure 6.8: Bland-Altman plot for cranio-cervical angle

The bias of 2.65° for the cranio-cervical angle was moderate, with moderate variation (± 3.95°). Two scores fell outside the 95% limits of agreement.

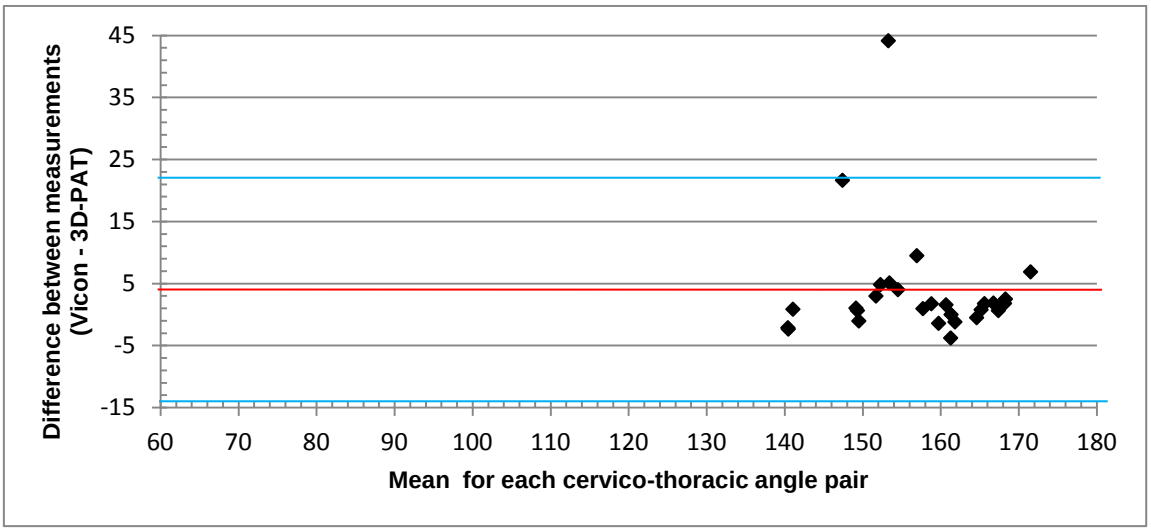


Figure 6.9: Bland-Altman plot for cervico-thoracic angle

The bias of 3.69° for the cervico-thoracic angle was large, with large variation (± 9.24°). One score fell outside the 95% limits of agreement.

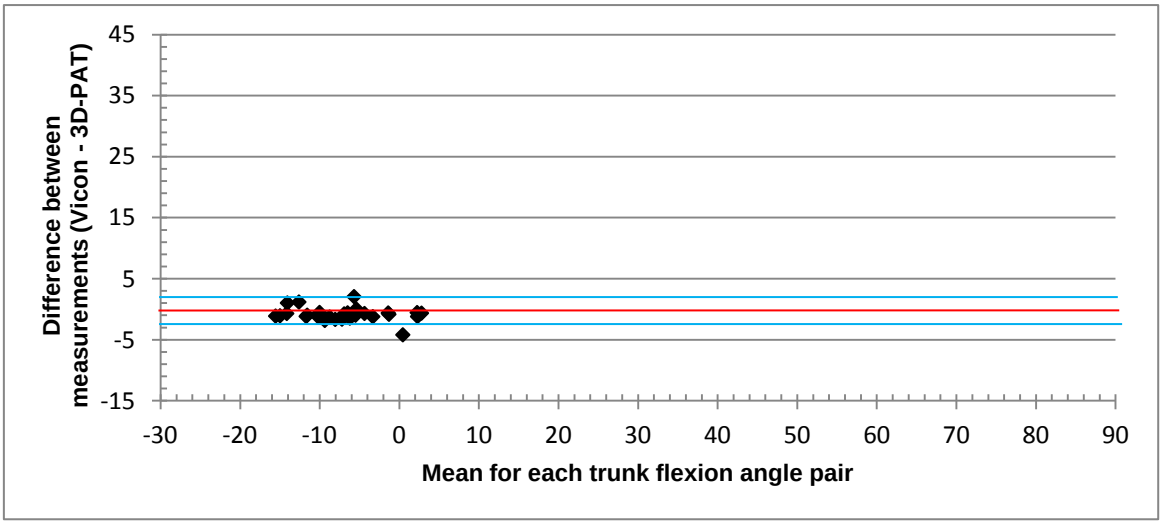


Figure 6.10: Bland-Altman plot for trunk flexion

The bias of -0.83° for trunk flexion was small, with little variation (± 1.09°). Two scores fell outside the 95% limits of agreement.

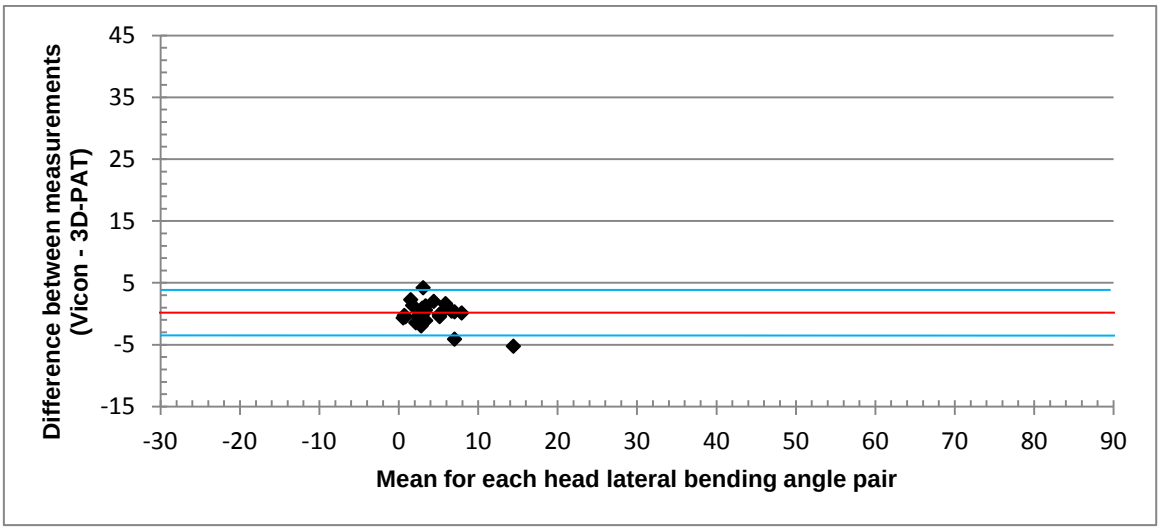


Figure 6.11: Bland-Altman plot for head lateral bending

The bias of 0.01° for head lateral bending was small, with little variation (± 1.84°). Three scores fell outside the 95% limits of agreement.

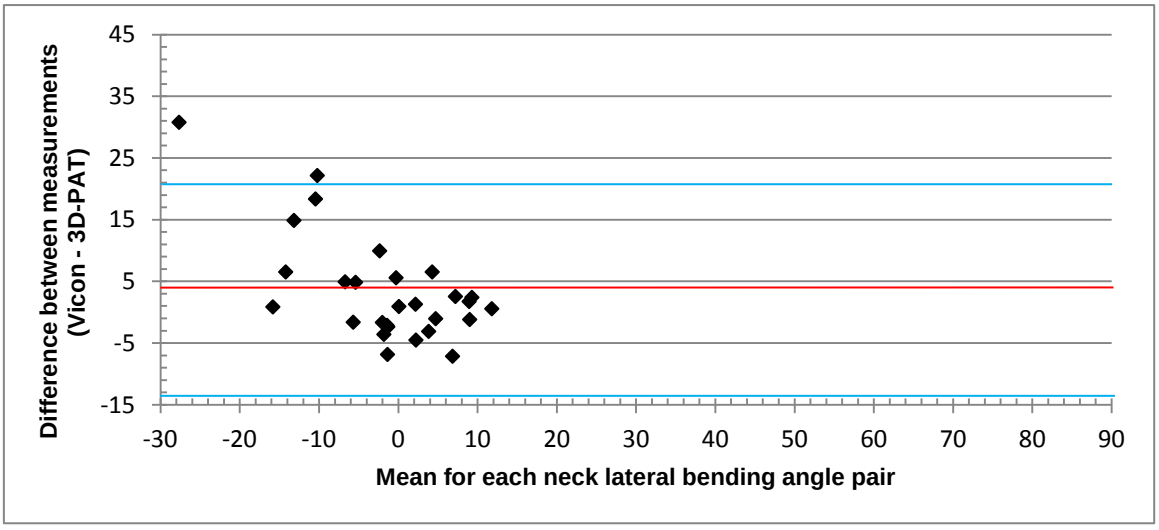


Figure 6.12: Bland-Altman plot for neck lateral bending

The bias of 3.57° for neck lateral bending was large, with large variation (± 8.78°). Two scores fell outside the 95% limits of agreement.

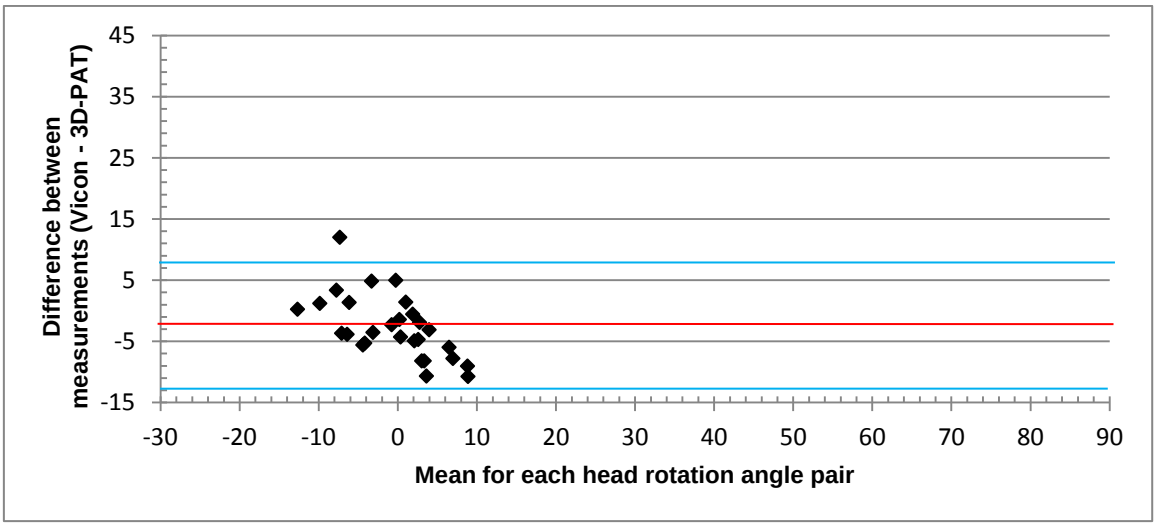


Figure 6.13: Bland-Altman plot for head rotation

The bias of -2.70° for head rotation was moderate, with moderate variation (± 5.19°). One score fell outside the 95% limits of agreement.

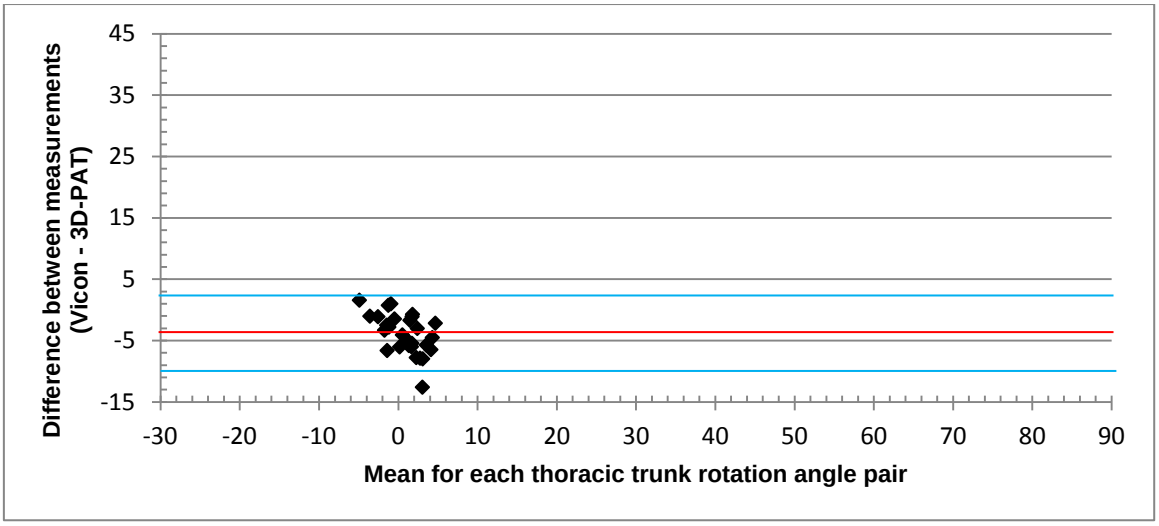


Figure 6.14: Bland-Altman plot for thoracic trunk rotation

The bias of -3.93° for thoracic trunk rotation was large, with moderate variation (± 3.25°). One score fell outside the 95% limits of agreement.

6.2.4 Reliability findings

6.2.4.1 *Postural angles from the 3D-PAT*

The mean scores for the first measurement (mean 1), and for the second (mean 2) and the third repeated measurements (mean 3), for each of the nine postural angles, are reported in Table 6.4 below.

Table 6.4: The mean and SD for the repeated measurements from the 3D-PAT (n = 23/22/21)

	Mean 1 (°) **n = 23**	**Mean 2 (°)** **n = 22**	**Mean 3 (°)** **n = 21**
Head flexion	68.9 (±7.5)	69.9 (±7.5)	66.6 (±8.1)
Neck flexion	57.0 (±6.2)	56.4(±6.46)	55.8 (± 6.3)
Cranio-cervical angle	160.8 (±8.6)	159.4 (±9.6)	158.3 (± 10.6)
Cervico-thoracic angle	150.9 (±12.8)	152.9 (±10.5)	148.8 (± 16.7)
Trunk flexion	-8.5 (±4.0)	-9.4 (±7.0)	-8.4 (± 5.3)
Head lateral bending	4.8 (±4.6)	4.9 (±5.2)	3.2 (± 2.9)
Neck lateral bending	-12.7 (±18.3)	-13.2 (±17.8)	-17.4 (± 18.6)
Head rotation	3.2 (±6.0)	1.2 (±6.8)	3.4 (± 6.2)
Thoracic trunk rotation	0.3 (±11.1)	-9.4 (±17.7)	-2.4 (± 11.4)

6.2.4.2 *Agreement between repeated measurements*

Table 6.5 below reports the calculated ICC that reflects the reproducibility of the measurements for the nine postural angles studied. The upper and lower CIs are also reported per postural angle. The results indicate very good reproducibility for head flexion and trunk flexion; good reproducibility of neck flexion, cranio-cervical angle, and head lateral bending; and poor reproducibility for cervico-thoracic angle, neck lateral bending, head rotation and thoracic trunk rotation.

Table 6.5: The ICC upper and lower CIs per postural angle (n=24)

	ICC	Lower 95% CI	Upper 95% CI
Head flexion	0.86	0.76	0.96
Neck flexion	0.69	0.51	0.87
Cranio-cervical angle	0.64	0.43	0.86
Cervico-thoracic angle	0.37	0.08	0.66
Trunk flexion	0.78	0.64	0.92
Head lateral bending	0.54	0.29	0.78
Neck lateral bending	0.45	0.18	0.72
Head rotation	0.29	0.00	0.61
Thoracic trunk rotation	0.38	0.11	0.66

6.3 SUMMARY

The current chapter described the third assessment of the degree of reliability and validity with which the 3D-PAT measures the nine postural angles of high school students. The findings illustrated very good agreement between the measurements from the 3D-PAT and the Vicon system for head flexion, neck flexion, trunk flexion and head lateral bending; good agreement for cranio-cervical angle and head rotation; but poor agreement for cervico-thoracic angle, neck lateral bending and thoracic trunk rotation. The reliability testing revealed very good reproducibility for head flexion and trunk flexion; good reproducibility of neck flexion, cranio-cervical angle and head lateral bending; and poor reproducibility for cervico-thoracic angle, neck lateral bending, head rotation and thoracic trunk rotation.

As a result, after conducting phase three of the psychometric testing procedures, the results indicated that the 3D-PAT compared very well with the reference standard and that its use was justified for measuring all the angles concerned, except for cervico-thoracic angle, neck lateral bending and thoracic trunk rotation. The following Part II of the current

dissertation presents a cohort study in Chapter 8, in which the 3D-PAT was utilised to measure the sitting postural angles of computing high school students.

PART II

ADOLESCENT UPPER QUADRANT MUSCULOSKELETAL PAIN

Preface

The dearth of literature describing the objective assessment of sitting posture and its relation to UQMP in adolescents impedes our understanding of a possible associative or causative relationship. Part I of the dissertation has shown that the psychometric properties of the 3D-PAT were satisfactorily assessed under conditions similar to the instrument's intended use in future research. The findings indicated that the 3D-PAT was an objective, cost-effective and portable posture measurement instrument that could be used in various computer classrooms to measure six, postural angles of South African adolescents between the ages of 15 to 18 years, with negligible measurement error.

Following this, Part II of the dissertation explores the search for evidence of a relationship between sitting posture and UQMP in adolescents by implementing the 3D-PAT in a clinical research setting in order to measure the 3D sitting posture of a cohort of asymptomatic computing high school students. The cohort was followed for one year, assessing seated-related UQMP prospectively (Chapter 8). The prospective study design enabled the research project to contribute to an understanding of any causative relationship between the exposure (sitting postural angles) and the outcome (seated-related UQMP) in a subgroup of adolescents (computer users). Rapport on the cohort study is preceded by a systematic review of the literature concerning the relationship between sitting and UQMP in children and adolescents, which evaluates the latest

published research for evidence as to whether sitting is related to UQMP, and, if so, to identify the elements of sitting that significantly contribute to UQMP (see Chapter 7).

The lack of understanding of the association between posture and musculoskeletal pain may be attributed to the complexity in controlling for the known and unknown confounding factors. Due to the accessibility of the cohort, such elements as depression and anxiety, and sport and music participation, were also measured at baseline and one-year follow-up, but since no association within this particular adolescent population was established during previous research (Smith et al., 2009; Brink et al., 2009a), the data obtained were not analysed as part of the dissertation and will be reported at a later stage. Thus, sitting posture (exposure) and computer use (potential confounder) are reported in the cohort study, due to the focus of the research project.

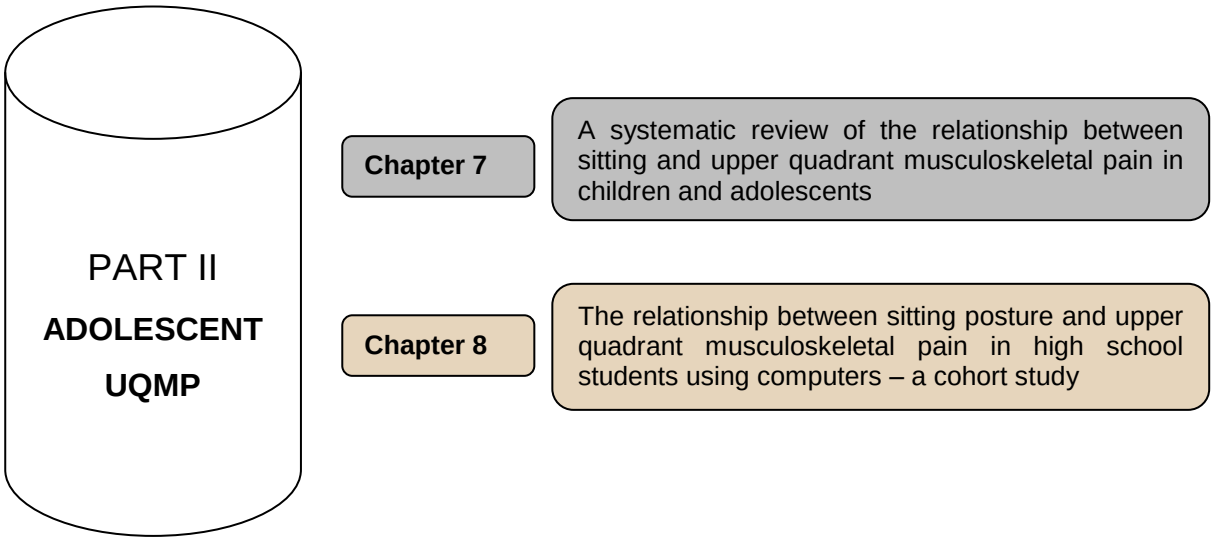


Figure Part II Preface: Graphical visualisation of the presentation of the dissertation – Part II

PART II

CHAPTER 7

A systematic review of the relationship between sitting and upper quadrant musculoskeletal pain in children and adolescents

7.1 INTRODUCTION

UQMP in children and adolescents has been widely researched in recent years. Both acute and chronic conditions have been reported and investigated (Brattberg, 2004; El-Metwally, Salminen, Auvinen, Kautiainen & Mikkelsson, 2004; Perry, Straker, O'Sullivan, Smith & Hands, 2008b; Briggs et al., 2009a; Paananen *et al*., 2010; Rees *et al*., 2011). It is evident that, as the prevalence of musculoskeletal pain increases with age (Siivola *et al*., 2004; Sjolie, 2004; Stahl *et al*., 2004; Mikkelsson *et al*., 2008), so does the impact of the health problem on the individual's social interaction, peer relationships, mental health, school absenteeism, scholastic competence and participation in physical activities (Guite, Logan, Sherry & Rose, 2007; Sunblad, Jansson, Saartok, Renström & Engström, 2008; Rees *et al*., 2011).

Research has shown that associative factors for non-specific UQMP are multifactorial in nature. A review by Prins *et al.* (2008) found evidence that such psychosocial factors as depression, mental distress and psychosomatic complaints are associated with UQMP. The review also reported prolonged sitting to be a risk factor, although, due to the limited amount of research available at the time, the finding was less evident, and the review was inconclusive as to whether sitting posture should be considered an associative factor.

The impact of sitting or sitting posture on UQMP seems to be controversial, since some research has reported no significant associations between UQMP and sitting or sitting posture among children and adolescents (Cardon *et al*., 2004; Straker *et al*., 2008a; Briggs *et al*., 2009a), whereas other research has reported positive associations between the elements concerned (Murphy *et al*., 2004; Kelly *et al*., 2009; O'Sullivan *et al*., 2011a; Hakala *et al*., 2012). As children and adolescents are increasingly exposed to sedentary lifestyles, mainly due to the growing use of screen-based activities, it was considered necessary to conduct a review to determine whether the latest published research could clarify the related controversy (Torsheim, Eriksson, Schnohr, Hansen, Bjarnason & Valimaa, 2010).

The aim of the review was to ascertain whether there was evidence for sitting as an associative or causative factor for UQMP experienced by children and adolescents. A secondary aim was to determine the different elements of sitting that are related to UQMP. The review questions can be formulated as follows:

1) Is there evidence to support the proposition that sitting is related to UQMP experienced by children and adolescents?
2) What are the different elements of sitting that are related to UQMP?

7.2 REVIEW METHOD

7.2.2 Search strategies

As the systematic review was to update a previously published review (Prins *et al*., 2008), a similar method of research was used to that which had been used in the previous study. The reviewer (YB) undertook a search of six electronic databases consisting of: BioMed Central; CINAHL; PROQUEST; PUBMED; SCIENCE DIRECT; and Scopus). As the previous review had been based on database searches that had been performed up until

April 2007, the current review sought to identify relevant papers published from January 2007 onwards. The databases were searched from January 2007 to December 2011, with the exception of the Scopus database, which was searched from 1960 to 2011, because it had not been included in the review by Prins *et al*. (2008). Combinations of the following keywords were used: pain; neck and/or shoulder pain; musculoskeletal pain; upper limb pain; upper extremity pain; posture; sitting posture; children; adolescents; learner; and student. MESH terms were used in PUBMED. Secondary searching (pearling) was performed on the reference list of retrieved articles.

One reviewer (YB) screened all the titles and excluded inappropriate papers, after which the abstracts and full-text versions of the papers that offered potential in regard to the study were read. Papers that did not adhere to the inclusion and exclusion criteria were excluded from the study. A list of all the performed searches appears in Addendum 16.

7.2.2 Inclusion criteria for selection of studies

Descriptive or analytical observational studies, with a cross-sectional or prospective time frame, were sought (Portney & Watkins, 2009). Only papers published in English and presented in full-text format were accepted. Papers published from 2007 until December 2011 were included in the review.

Papers reporting on the sitting of male and female children between the ages of 6 and 12 years and of adolescents between the ages of 13 and 18 years were eligible for inclusion in the review. Static sitting could be described by means of direct measurement of postural angles, by means of visual or observational posture analysis, or by means of self-reported analysis of sitting or seated activities via questionnaires or interviews.

Eligible studies also had to measure UQMP in terms of the onset, area, frequency, intensity or duration of pain as an outcome measure. The studies had to measure at least one of the above mentioned aspects of pain.

7.2.3 Exclusion criteria for selection of studies

Papers were excluded according to the following criteria: (1) if the only pain outcome measured was headache; (2) if musculoskeletal pain was due to a systemic condition; (3) if UQMP was not reported separately to other areas of musculoskeletal pain; and (4) if a study sample was within the age limit at baseline measures, but exceeded said age limit when follow-up measures were taken.

7.2.4 Methodological quality appraisal

One reviewer (YB) appraised the selected papers according to the Critical Appraisal Form for Quantitative Studies published by McMaster University in Canada (Law, Stewart, Pollock, Letts, Bosch & Westmoreland, 1998a, 1998b). The authors consulted the user guidelines for interpretation of the CAT (Law, Stewart, Pollock, Letts, Bosch & Westmoreland, 1998c). The CAT is given in Addendum 17, and was used in the same format as in the review by Prins *et al*. (2008) for purposes of consistency. A second reviewer (QL) randomly audited papers. Discrepancies between the scores of the two reviewers were discussed until consensus was reached. The CAT consisted of 16 questions, and had a total score of 16. All the questions scoring a 'yes' answer added to the total score assigned, except for questions 3 and 4, for which a 'no' answer added to the total score. The higher the score, the greater was the methodological quality of the paper concerned.

7.3 RESULTS

7.3.1 Search results

Ten papers were found to be eligible for the review. Nine papers were retrieved from the database searches and one paper (Auvinen *et al*., 2007) was added after pearling was performed on the reference list of an eligible paper. Due to the heterogeneity of the methodologies of the studies in terms of the set study aims, the age range of the participants, the measurement method for sitting and the definition of UQMP, a meta-analysis of the results was regarded as being inappropriate (Moher, Liberati, Tetzlaff & Altman, 2009). The current review, therefore, presents a descriptive analysis of the results obtained.

7.3.2 Critical appraisal of methodological quality

The average score obtained for the methodological quality was 11.7 (73.4%). The low-scoring papers were not excluded due to the low number of papers retrieved for the review.

All papers met criteria 1, 2, 5, 8, 9, 13, 14 and 16. Table 7.1 below provides the methodological quality scores obtained by each paper, a positive or negative scoring per criterion, and a description of the non-compliances of the reviewed papers per criterion. Sample biases (criterion 3) were found in seven papers, due either to a low response rate of less than 80% or to convenience sampling. Briggs *et al*. (2009b) reported a low response rate, although the authors stated that their sample still was representative of the original cohort. Measurement biases (criterion 4) were detected in eight papers, due either to no or limited reporting of psychometric testing of measures, or to respondent biases, due to the use of self-report questionnaires for measurement of sitting, or due to the pain recall period. Two papers did not score positively for their sample description (criterion 6),

because they either reported varying or no gender distribution. Only one study (Briggs *et al.*, 2009b) reported the results from a post-hoc analysis to justify the sample size used (criterion 7). The validity and reliability testing of the measurement instruments was poorly reported (criteria 10 and 11). The paper by Coleman, Straker and Ciccarelli (2009) did not report findings in terms of statistical significance (criterion 12). Four studies neither reported missing data nor dropouts, as was evident from the fact that there were inconsistencies in the sample sizes of the reported data (criterion 15).

Table 7.1: Detailed description of the non-compliances of the reviewed papers

Author	CAT Score (%)	Criterion 1	Criterion 2	Criterion 3	Criterion 4	Criterion 5	Criterion 6	Criterion 7	Criterion 8	Criterion 9	Criterion 10	Criterion 11	Criterion 12	Criterion 13	Criterion 14	Criterion 15	Criterion 16
Auvinen *et al*., 2007	56	+	+	- a	- c/e	+	- f	- h	+	+	- j	- k	+	+	+	- n	+
Geldhof *et al*., 2007b	81	+	+	+	- c	+	+	- h	+	+	+	- k	+	+	+	+	+
Straker *et al*., 2008a	69	+	+	- a	- c	+	+	- h	+	+	+	- l	+	+	+	- n	+
Briggs *et al*., 2009b	94	+	+	+	- d	+	+	+	+	+	+	+	+	+	+	+	+
Brink *et al*., 2009a	88	+	+	- a	+	+	+	- h	+	+	+	+	+	+	+	+	+
Brink , Hillier, Louw & Schreve, 2009b	94	+	+	+	+	+	+	- h	+	+	+	+	+	+	+	+	+
Coleman *et al*., 2009	63	+	+	- b	- c/d	+	+	- h	+	+	- j	- l	- m	+	+	+	+
Straker *et al*., 2009a	63	+	+	- a	- c	+	+	- h	+	+	- i	- l	+	+	+	- n	+
Weber Hellstenius, 2009	63	+	+	- b	- c/e	+	- g	- h	+	+	- j	- k	+	+	+	+	+
Straker *et al*., 2011	63	+	+	- a	- c	+	+	- h	+	+	- j	- k	+	+	+	- n	+

Reasons for non-compliances
Sample biases (criterion 3): (a) less than 80% response rate; (b) convenience sampling. Measurement biases (criterion 4): (c) no/limited reporting of psychometric testing of measures; (d) respondent biases, due to use of self-report questionnaires for measurement of sitting; (e) respondent bias, due to pain recall period. Sample description (criterion 6): (f) varying gender distribution; (g) no gender distribution. Sample justification (criterion 7): (h) no sample size calculation. Reliable measures (criterion 10): (i) limited reporting; (j) none reported. Valid measures (criterion 11): (k) limited reporting; (l) none reported. Statistical significance (criterion 12): (m) results not reported in terms of statistical significance. Missing data/Dropouts (criterion 15): (n) no reporting of missing data or dropouts.

7.3.3 Study aim, study design, sampling method and response rate

Two of the studies, which were reported by Straker *et al*. (2008a, 2011), had a similar study aim, whereas the other eight studies had divergent aims. However, all the reviewed studies aimed to describe a possible relation between some form of sitting and UQMP. A descriptive cross-sectional study design was implemented in eight of the ten papers. Brink *et al*. (2009a) and Brink, Hillier, Louw and Schreve (2009b) measured the outcome (UQMP) prospectively. Two papers performed convenience sampling and eight papers performed random sampling. The participants' ages ranged from 8.5 to 16.9 years, including both preadolescents and adolescents. The sample size varied from 27 to 5 993 participants and the response rate for participation ranged from 26.5% to 100%. Four papers had response rates greater than the required 80% (Liddle, Williamson & Irwig, 1996). Table 7.2 below summarises the study aim, as it is relevant to the review question, and the sample characteristics of each reviewed paper.

7.3.4 Study characteristics

A description of the measured variables, namely UQMP and sitting, is outlined in Table 7.3 below. Only the type of sitting data that was stipulated as acceptable by the inclusion criteria of the review, and thus which was regarded as suitable for interpretation in the review, is presented. The different aspects of pain measured by the questionnaires and the pain recall period for UQMP are also summarised in the same table. The pain recall period, which varied greatly between the studies, ranged between having experienced pain on the day of testing to having previously experienced pain.

Table 7.2: Study aims, sampling method, sample composition and response rates

Author	Aims	Sampling method	Age	Sample size	Response rate (%)
Auvinen et al., 2007	1) To evaluate the association between sitting time and neck/occipital and shoulder pain	Random sampling	15-16	n = 5 993 3 185-3 191girls; 2 802-2 808 boys	63.2
Geldhof et al., 2007b	1) To relate postural behaviours to self-reported neck pain	Random sampling	8.5-12.5	n = 105 54 boys; 51 girls	100
Straker et al., 2008a	1) To describe the differences between sitting postures of adolescents with and without neck/shoulder pain 2) To describe the relationship between neck/shoulder pain and sitting posture, considering gender	Random sampling	14.1	n = 1 470 713 boys; 757 girls	51.3
Briggs et al., 2009b	1) To clarify the relationship between adolescent neck/shoulder pain and physical activity	Random sampling	14.0	n = 643 292 boys; 351 girls	26.5%
Brink et al., 2009a	1) To determine whether sitting posture is a risk factor for UQMP	Random sampling	15-17	n = 104 at baseline 55 boys; 49 girls	80.7 at baseline 72.6 at 3 months 68.9 at 6 months
Brink et al., 2009b	1) To investigate the effect of time on the sitting posture of adolescents who developed neck and shoulder pain	Random sampling	15-17	n = 27 9 girls; 18 boys	100
Coleman et al., 2009	1) To describe children's beliefs about why they experience musculoskeletal discomfort in general, as well as in relation to specific activities	Convenience sampling	11.0-16.9	n = 88 44 boys; 44 girls	88.9
Straker et al., 2009a	1) To evaluate the relationship between spinal sitting postures and adolescent prolonged neck/shoulder pain, considering gender	Random sampling	14.1	n = 1 593 814 boys; 779 girls	55.5
Weber Hellstenius, 2009	1) To investigate whether preadolescents with recurrent neck pain and/ or headaches have different head postures to those of asymptomatic preadolescents	Convenience sampling	10-13	n = 110 (no gender distribution)	84
Straker et al., 2011	1) To examine the relationship between, habitual posture and NSP, and the influence of gender on the relationship	Random sampling	14.1	n = 1 483 759 boys; 724 girls	61.20

Table 7.3: Type of sitting data and musculoskeletal pain

Author	Type of sitting data	Pain definition	Recall period
Auvinen et al., 2007	• Duration of sitting watching TV, categorised into four groups; duration of sitting reading or working on computer, categorised into three groups; sum of duration of activities, categorised into three groups	1) Area of pain (neck/occipital/shoulder) 2) Intensity of pain in three categories: a) no pain; b) reporting pain but not seeking medical help; c) reporting pain and seeking consultation	Six-monthly
Geldhof et al., 2007b	• Duration and frequency of trunk flexion / trunk rotation / neck rotation > 45°; neck flexion > 20°, sitting with or without arm or back support • Duration and frequency of static / dynamic sitting; writing; reading; standing; walking; being active; lying on floor	1) Area of pain (neck/back) 2) Intensity of pain on 2 - point scale (pain or no pain) 3) Frequency of pain on 4 - point scale (once to continuous)	Weekly
Straker et al., 2008a	• Angles reported in degrees: head flexion; neck flexion; craniocervical angle; cervicothoracic angle; trunk angle; lumbar angle; pelvic tilt • Three postures recorded: sitting looking straight ahead; looking down at lap; slump sitting	1) Area of pain (neck/shoulder) 2) Frequency of pain (life, month and point prevalence)	Monthly; ever before; on day of testing
Briggs et al., 2009b	• Activity level, i.e. sedentary • Posture during activity, i.e. sitting • Type of sedentary activity: watching TV; using computer; reading • Duration: number of hours spent on activity per week	1) Area of pain (neck/shoulder) 2) Frequency of pain (life and month prevalence) 3) Duration of pain (pain lasting more than three months)	Monthly; ever before
Brink et al., 2009a	• Angles reported in degrees: head tilt; cervical angle; shoulder pro- and retraction angle; thoracic angle	1) Onset of pain 2) Area of pain (upper quadrant) 3) Intensity of pain	Monthly
Brink et al., 2009b	• Angles reported in degrees: head tilt; cervical angle; craniocervical angle; shoulder pro- and retraction angle; thoracic angle	1) Onset of pain 2) Area of pain (upper quadrant) 3) Intensity of pain	Monthly
Coleman et al., 2009	• Open-ended questions: participants asked what they thought caused the discomfort	1) Area of pain (whole body) 2) Frequency of pain (once per month; once per week; twice to three times per week; daily) 3) Intensity of pain on 10-point scale (0 = no soreness to 10 = extreme soreness)	Monthly

Table 7.3: Type of sitting data and musculoskeletal pain (cont)

Author	Type of sitting data	Pain definition	Recall period
Straker et al., 2009a	• Angles reported in degrees: head flexion; neck flexion; craniocervical angle; cervicothoracic angle; thoracic flexion; trunk angle; lumbar angle; pelvic tilt • Three postures recorded: sitting looking straight ahead; looking down at lap; slump sitting	1) Area of pain (neck/shoulder) 2) Duration of pain (prolonged pain: pain for longer than three months ever in the past and pain during the preceding month = Yes/No)	Monthly
Weber Hellstenius, 2009	• FHP (the external auditory meatus anterior to the plumb line)	1) Area of pain (neck/shoulder) 2) Duration of pain 3) Frequency of pain 4) Intensity of pain on 11-point scale (0 = no pain to 11 = intolerable pain)	None reported
Straker et al., 2011	• Angles reported in degrees: head flexion; neck flexion; craniocervical angle; cervicothoracic angle; thoracic flexion; trunk angle; lumbar angle; pelvic tilt • Postures recorded: sitting looking straight ahead	1) Area of pain (posterior neck and upper trapezius) 2) Frequency of pain (month prevalence)	Monthly

Table 7.4 below summarises the various measurement instruments used to measure UQMP and to describe sitting, and gives an indication of the measurement instruments' psychometric testing.

Table 7.4: Summary of the measurement tools for UQMP and sitting

Author	Measurement tool for pain	Psychometric properties	Type of analysis	Measurement tool for sitting	Psychometric properties
Auvinen et al., 2007	Self-designed questionnaire	None	Self-reported analysis	Self - developed questionnaire	None
Geldhof et al., 2007b	Self-designed questionnaire	Reference for reliability	Visual or observational posture analysis	Portable ergonomic observation method	Acceptable validity and high intra- and inter-observer reliability with references
Straker et al., 2008a	Self-designed questionnaire	Reliability of one aspect of the questionnaire	Two-dimensional direct measurement of postural angles	PEAK motion analysis system	Reference for reliability
Briggs et al., 2009b	Nordic Musculoskeletal Questionnaire	Reference for validity and reliability	Self-reported analysis	Multimedia Activity Recall for Children and Adolescents questionnaire	Reference for concurrent validity and test re-test reliability
Brink et al., 2009a	Computer Use Questionnaire	Reference for validity and reliability	Two-dimensional direct measurement of postural angles	Photographic Posture Analysis Method	Reference for validity and reliability
Brink et al., 2009b	Computer Use Questionnaire	Reference for validity and reliability	Two-dimensional direct measurement of postural angles	Photographic Posture Analysis Method	Reference for validity and reliability
Coleman et al., 2009	Young people's activity questionnaire	None	Self-reported analysis	Young people's activity questionnaire	None
Straker et al., 2009a	Self-designed questionnaire	None	Two-dimensional direct measurement of postural angles	Peak Motus motion analysis system	Fair to good inter-rater reliability
Weber Hellstenius, 2009	Self-designed questionnaire	Pilot study testing comprehension of questionnaire	Visual or observational posture analysis	Plumb line test	None
Straker et al., 2011	Nordic Musculoskeletal Questionnaire	Reference for validity and reliability	Two-dimensional direct measurement of postural angles	Peak Motus motion analysis system	None

Three papers used self-reported analysis by way of questionnaires to describe sitting. The structure of the questions was either open-ended (Coleman *et al*., 2009) or multiple-choice categorisation of the data (Auvinen *et al*., 2007; Briggs *et al*., 2009b). Two papers described sitting using visual or observational posture analysis. Five papers measured sitting by means of 2D direct measurement of postural angles via lateral photographs. Three studies (Geldhof *et al*., 2007b; Brink *et al*., 2009a, 2009b) reported on the sitting posture of the participants in the school classroom. Straker *et al*. (2008a, 2009a, 2011) assessed sitting posture in a laboratory set-up. Weber Hellstenius, (2009) measured sitting posture at school, but not in a classroom set-up.

7.3.5 Statistical analysis

All the reviewed papers used logistic regression models to describe the relationship between sitting and UQMP, apart from those of Geldhof *et al*. (2007b), Brink *et al.* (2009b), Coleman *et al*. (2009) and Straker *et al*. (2009a), which used one-way ANOVA, repeated measures ANOVA, frequency distributions and independent t-tests respectively.

7.3.6 Study outcomes

Four papers (Briggs *et al*., 2009b; Brink *et al*., 2009a; Straker *et al.,* 2009a, 2011) reported significant associations between sitting and UQMP in children and adolescents. Brink *et al*. (2009a) and Straker *et al*. (2009a, 2011) reported associations between postural angles and UQMP, whereas Briggs *et al*. (2009b) reported that the duration of sitting was associated with UQMP for boys. The significant results obtained are summarised in Table 7.5, along with the findings that were insignificant associations but which add to the body of knowledge concerning the relationship between sitting and UQMP. The significant findings are highlighted in grey and marked with an asterisk.

Five elements of sitting were identified as relating to UQMP: the *sitting duration* (Auvinen *et al*., 2007; Briggs *et al*., 2009a); *activities while sitting* (Coleman *et al*., 2009); *activities while sitting and sitting duration* (Auvinen *et al*., 2007; Briggs *et al*., 2009b; Weber Hellstenius, 2009); *dynamism* (Geldhof *et al*., 2007b; Brink *et al*., 2009b) and *postural angles* (Straker *et al*., 2008a; Brink *et al*., 2009a; Straker *et al.,* 2009a, 2011).

Table 7.5: The aspects of sitting associated with UQMP

The aspects of sitting associated with UQMP

Postural angles	**Activities and duration**
• extreme Fl/Ext cervical angles (UQMP)[5*]	• watching television ≥ 2 h p/d for girls (severe NP)[1]
• combination of extreme cervical and thoracic angles (UQMP)[5*]	• watching television 1-2 h p/d for girls (mild/severe NP)[1]
• looking ahead: ↑ cervicothoracic flexion; ↑ trunk extension; ↑ lordotic lumbar angle; ↑ anterior pelvic tilt (PNSP)[8*]	• watching television ≥ 4 h p/d for girls (mild SP)[1]
• looking down: ↑ lordotic lumbar angle; ↑ anterior pelvic tilt (PNSP)[8*]	• reading ≥ 2 h p/d for girls (mild/severe NP)[1]
• looking ahead and down: ↑ lordotic lumbar angle; ↑ anterior pelvic tilt for females (PNSP)[8*]	• computer work ≥ 2 h p/d for boys (mild/severe NP)[1]
• cervicothoracic angle; trunk angle; thoracic flexion and pelvic tilt (NSP)[10*]	• > 12 h p/w watching television and using computer (NSP)[4]
• ↓ trunk angle (NSP)[3]	• other sedentary activities ≥ 2 h p/d for girls (mild NP)[1]
• extreme thoracic angles (UQMP)[5]	• other sedentary activities ≥ 2 h p/d for boys (mild/severe NP)[1]
• combination of extreme cervical and thoracic angles for boys (UQMP)[5]	• other sedentary activities ≥2 h p/d for girls (mild SP)[1]
• looking down: ↑ cervicothoracic flexion; ↑ trunk extension (PNSP)[8]	• other sedentary activities ≥ 1 h p/d for boys (mild/severe SP)[1]
• head flexion; neck flexion; craniocervical angle; lumbar angle (NSP)[10]	
Sitting duration	**Activities**
• sitting 60-70 h p/w, compared to 50-60 hrs p/w for males (NSP ever)[4*]	• school computer use (MBP)[7]
• sitting ≥ 8 h p/d for girls and boys (severe NP)[1]	• writing (right elbow/hand pain)[7]
• sitting ≥ 4 h p/d for girls (mild NP)[1]	• pain during watching television; reading; writing and computer use due to "bad posture"[7]
• sitting ≥ 4 h p/d for boys (mild/severe NP)[1]	• pain during school computer use and writing due to "doing it too much"[7]
• sitting ≥ 8 h p/d for girls (mild/severe SP)[1]	**Dynamism**
• sitting 60-65 h p/w, compared to < 60 h and > 65 h p/w (NSP)[4]	• ↑ static sitting (NP)[2] / little change in posture over time (NSP)[6]
• sitting ≤ 40 h p/w, compared to 50-60 h p/w for females (NSP)[4]	• ↓ duration of trunk flexion > 45° and ↑ duration of neck rotation > 45° (NP)[2]
• sitting 40-50 h p/w, compared to 50-60 h p/w for males (NSP)[4]	

[1]Auvinen et al., 2007; [2]Geldhof et al., 2007b; [3]Straker et al., 2008a; [4]Briggs et al., 2009b; [5]Brink et al., 2009a; [6]Brink et al., 2009b; [7]Coleman et al., 2009; [8]Straker et al., 2009a; [9]Weber Hellstenius, 2009; [10]Straker et al., 2011; NSP = neck/shoulder pain; NP = neck pain; SP = shoulder pain; PNSP = prolonged neck and shoulder pain; UBP = upper back pain; MBP = mid-back pain; p/w = per week; p/d = per day.

The Cohen's ***d*** statistic was calculated to report the effect size of the significant findings reported by Straker *et al*. (2009a). The relative size of Cohen's ***d*** is categorised as follows: negligible effect (> = -0.15 and < 0.15); small effect (> = 0.15 and < 0.40); medium effect (> = 0.40 and < 0.75); large effect (> = 0.75 and < 1.10); very large effect (> = 1.10 and < 1.45) and huge effect (> = 1.45) (Thalheimer & Cook, 2002). All the significant findings reported by Straker *et al*. (2009a), had small effect sizes, with the Cohen's ***d*** ranging from 0.23 to 0.37.

The significant findings reported with odds ratios (OR) are presented in Table 7.6 below. Briggs *et al.* (2009b) and Brink *et al.* (2009a) reported adjusted OR, whereas Straker *et al*. (2011) reported crude OR. Once Straker *et al*. (2011) adjusted for gender, no significant associations remained.

Table 7.6: Crude and adjusted ORs for significant findings

Author	Exposures	OR (95% CI) Group	OR (95% CI) Boys
Straker et al., 2011	Cervicothoracic angle	0.83* (0.72-0.95)	
Straker et al., 2011	Trunk angle	0.87* (0.79-0.95)	
Straker et al., 2011	Thoracic flexion	0.85* (0.76-0.96)	
Straker et al., 2011	Pelvic tilt	1.08* (1.00-1.17)	
Brink et al., 2009a	Extreme cervical flexion angle	2.8** (1.1-7.3)	
Brink et al., 2009a	Extreme cervical flexion and thoracic flexion angles	2.2** (1.1-5.6)	
Briggs et al., 2009b	Sitting 60-70 h per week, compared to sitting 50-60 h per week		2.07** (2.11-3.84)

*crude OR
**adjusted OR

7.4 SUMMARY

The review identified five elements of sitting that were related to UQMP in children and adolescents, which were categorised into: 'sitting duration'; 'activities while sitting'; 'activities while sitting and sitting duration; 'dynamism' (amount of movement while seated); and 'postural angles' (spinal angles while seated). As the design of 80% of the eligible studies was cross-sectional, the level of evidence for causation of UQMP was compromised, since cross-sectional studies do not provide insight into cause and effect (Portney & Watkins, 2009).

The review indicated that objectively measured postural angles are more likely to produce significant associations with UQMP. The direct measurement of postural angles (Straker *et al.*, 2008a; Brink *et al.,* 2009a, 2009b; Straker *et al*., 2009a, 2011) provides an objective account of sitting posture and is a superior method of postural examination compared to subjective or self-report measures. Objective assessment of posture can provide information about the biomechanical alignment of the bony structures at any specific

moment in time. Thus, if sitting posture is fairly static and prolonged, certain anatomical structures tend to be adversely affected by undue, prolonged strain, with the structures concerned consequently possibly being the cause of musculoskeletal pain (Beach, Parkinson, Stothart & Callaghan, 2005; Edmondston, Bjornsdottir, Palsson, Solgard, Ussing & Allison, 2011). Although visual or observational analysis of sitting posture (Geldhof *et al.,* 2007b; Weber Hellstenius, 2009) is also an objective analysis of posture, it can introduce bias, since the reliability of the data can be influenced by the rater's competence level and experience. The lack of significant findings could be due to the misclassification of posture and not necessarily due to a lack of an association between sitting and UQMP. One significant finding was reported from a study that used a questionnaire to describe sitting. The use of self-reported analysis to describe sitting allows for a subjective interpretation of the child's or adolescent's sitting, and does not correlate with objective measures (Murphy, Buckle & Stubbs, 2002). As the results from the self-reported analysis of sitting provide no insight into the postural alignment while sitting, the physiology or biomechanics cannot be explained when such measurement methods are used.

Contradictory findings between studies may be due to the differences in methodological quality, the limitations of the study designs or the differences between the questionnaires for both sitting and pain measurement. Despite the studies by Straker *et al.* (2008a, 2009a, 2011) being very similar in terms of the methodology of the studies, they did not all report significant associations between sitting and UQMP, possibly because of the varying pain recall periods used.

Gender played an important role in the findings. Brink *et al*. (2009a) found that upper quadrant spinal angles were more associated with pain in males, whereas Straker *et al*.

(2009a) found that lumbopelvic angles were more associated with pain in females. The relationship between the different anatomical spinal angles and UQMP could either be linked to gender differences in spinal alignment during sitting (Poussa, Heliovaara, Seitsamo, Kononen, Hurmerinta & Nissinen, 2005; O'Sullivan *et al*., 2011b), in the endurance of the deep neck flexor muscles (DNF) (Domenech, Sizer, Dedrick, McGillaird & Brismee, 2011), or in the level of trunk muscle activity during sitting (O'Sullivan, Dankaerts, Burnett, Straker, Bargon, Moloney, Perry & Tsang, 2006).

The current review therefore concludes that there is unequivocal evidence that sitting and UQMP are related in children and adolescents, due to the inconsistency in the results from the reviewed studies. Therefore, sitting or sitting posture, as either a risk factor or predictor of UQMP, remains unclear and further exploration of the different elements of sitting is warranted. Objective posture measurement instruments, which have been thoroughly tested for their psychometric properties, should be advanced and applied in future research to gain a better understanding of possible associative or causative pathways between posture and pain and to enable a deepening of insight into the underlying mechanisms that could be the cause of pain.

The following chapter presents a cohort study, in which the 3D-PAT was used to measure the upper quadrant spinal postural angles in computing high school students to investigate whether postural angles are predictive of adolescent UQMP.

PART II

CHAPTER 8

The relationship between sitting posture and upper quadrant musculoskeletal pain in high school students using computers – a cohort study

The current chapter presents primary research that continues the search for evidence of a causal pathway between UQMP in adolescents and sitting posture. The chapter reports a cohort study that addressed those shortcomings highlighted in the systematic review of the previous chapter by 1) using an objective posture measurement instrument, the 3D-PAT; 2) measuring sitting spinal postural angles; 3) using a standardised method for assessing adolescent UQMP prospectively; and 4) focusing on a subgroup of UQMP namely seated-related UQMP in computing adolescents. The objectives of the study were: 1) to use the 3D-PAT to describe the sitting posture of Grade 10 high school students while they worked on desk-top computers in the school's computer room; 2) to determine the onset, intensity and area of UQMP by means of the CUQ; and 3) to determine whether sitting posture is predictive of UQMP in computing high school students.

8.1 METHODOLOGY

8.1.1 Study design

A cohort study with a prospective period of one year was conducted.

8.1.2 Study population

The study population consisted of Grade ten high school students in the metropolitan region of the Western Cape Province. The students were aged between 15 and 17 years and commenced with Computer Application Technology as part of their curriculum at the beginning of the 2010 academic school year.

8.1.3 Study time period

The participating students at baseline were monitored for one year (Feldman, Shrier, Rossignol & Abenhaim, 2002). Said period was chosen due to the time frame in which the project had to be completed.

8.1.4 Sampling method

8.1.4.1 *Sample size*

A sample size calculation was performed, with the minimum sample size for the cohort study being 240 students at one-year follow-up, the level of significance α, and power (1-β) = 95% (Carlin & Doyle, 2003; Schulz & Grimes, 2005). A 10% loss-to-follow-up for the sample size was incorporated in the power calculation. In order to obtain 240 students at one-year follow-up, it was necessary to screen 821 students for participation in the study. The 821 included the 10% drop-out rate, non-consent, no return of consent and those symptomatic students. The result was the inclusion of 20 schools, with five from each EMDC. From 20 high schools, there should have been approximately 264 students who were eligible to participate in the study, after the inclusion and exclusion criteria had been applied. The figure in question stemmed from a previous study conducted among the same study population (Brink *et al*., 2009a).

8.1.4.2 *Sampling of schools*

The study was conducted in the four EMDCs of the Cape metropolitan region, due to their easy accessibility. Eligibility for inclusion in the study depended on the high schools in question 1) having fully functional computer rooms; 2) offering Computer Application Technology for curriculum delivery; 3) having similar computer laboratory set-up (chair/desk height, etc.); and 4) forming part of the Khanya project (refer to footnote, p 45). After a list of the schools was pooled, computer-generated randomisation was performed. Excluded from the list were all of the high schools that 1) did not offer Computer Application Technology as a subject; 2) had less than 20 pupils in the 2009 Computer Application Technology class; and 3) were unisex. Making such exclusions was necessary, as 1) only students with Computer Application Technology as a subject could participate in the study; 2) the existence of fewer than 20 students per class would minimise the chance of obtaining an adequate number of participants; and 3) the cohort study was aimed at equal gender distribution. The four EMDCs had 111 schools that were eligible to participate.

During October and November 2009, the principals of the first five schools on the list, per EMDC, were invited, telephonically or via e-mail, to have their schools participate in the study. Those principals, who verbally consented to allow their school to participate, received an emailed summary of the proposed study, which clearly explained its purpose, aims, objectives and procedures. The principal was given an approximate time frame within which data collection would take place at the school. The selected schools, which represented the high school population of the Cape metropolitan region, spanned the geographical spectrum of said region. Figure 8.1 below outlines the procedure involved.

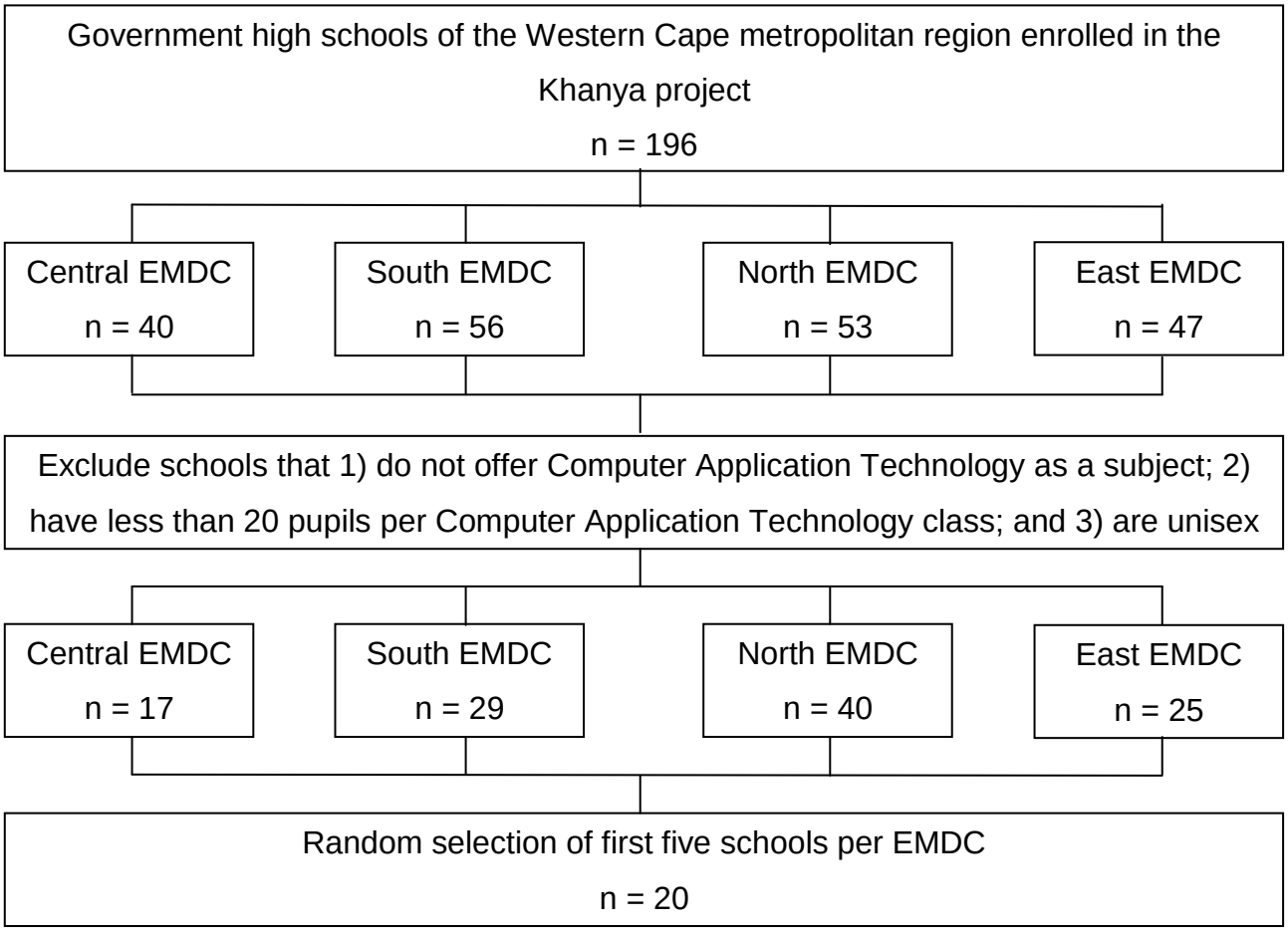


Figure 8.1 A flow chart to demonstrate the recruitment of high schools

8.1.4.3 *Sampling of students*

The Grade 10 high school students who chose to take Computer Application Technology as a subject at the beginning of the academic year (January 2010) were eligible to participate in the study. The students concerned received curriculum delivery via computers for the first time during that year. The researcher contacted the various representative teachers of each high school in January 2010, and decided on a suitable time during the month of February 2010 in which to present the proposed study to the eligible Grade 10 students during school hours. On the same day, the students were screened for UQMP by means of being asked to complete the CUQ that was earlier described in subsection 4.1.3.3 of the current dissertation. Students were excluded according to the inclusion and exclusion criteria, as have been presented in subsections

8.1.4.4 and 8.1.4.5. The asymptomatic students identified were invited to participate in the study.

8.1.4.4 *Inclusion criteria*

The inclusion criteria for the study were the following:

- male and female Grade 10 students aged 15 to 17 years old who commenced with Computer Application Technology as a subject at the beginning of the 2010 academic year;
- students who had no history of musculoskeletal pain or discomfort in the month prior to data collection; and
- students from whom parental / legal guardian consent had been obtained.

8.1.4.5 *Exclusion criteria*

The exclusion criteria for the study were the following:

- students diagnosed with movement disorders and severe fixed skeletal abnormalities, as investigations into disease and severe postural abnormalities did not conform with the aims of the study;
- students, who had failed Computer Application Technology in or before 2009 and who were repeating the subject, since they had already been exposed to curriculum delivery via the computer; and
- students who were absent on the day of testing.

8.1.4.6 *Ethical considerations*

Written permission was obtained from the WCED for the 2010 data collection (Addendum 18) and telephonic approval for the 2011 data collection. Written informed consent was obtained from the student and his/her parents / legal guardians prior to the student's

participation in the project. The informed consent letters were available in English, Afrikaans and isiXhosa (Addenda 19, 20 and 21). If the parents asked any questions, then an intermediate person, who was fluent in isiXhosa and who was knowledgeable concerning the study, would be asked to assist the researcher in answering them. However, no questions arose after the informed consent letters were distributed.

Figure 8.2 below demonstrates the sample recruitment procedure that was followed in respect of the students

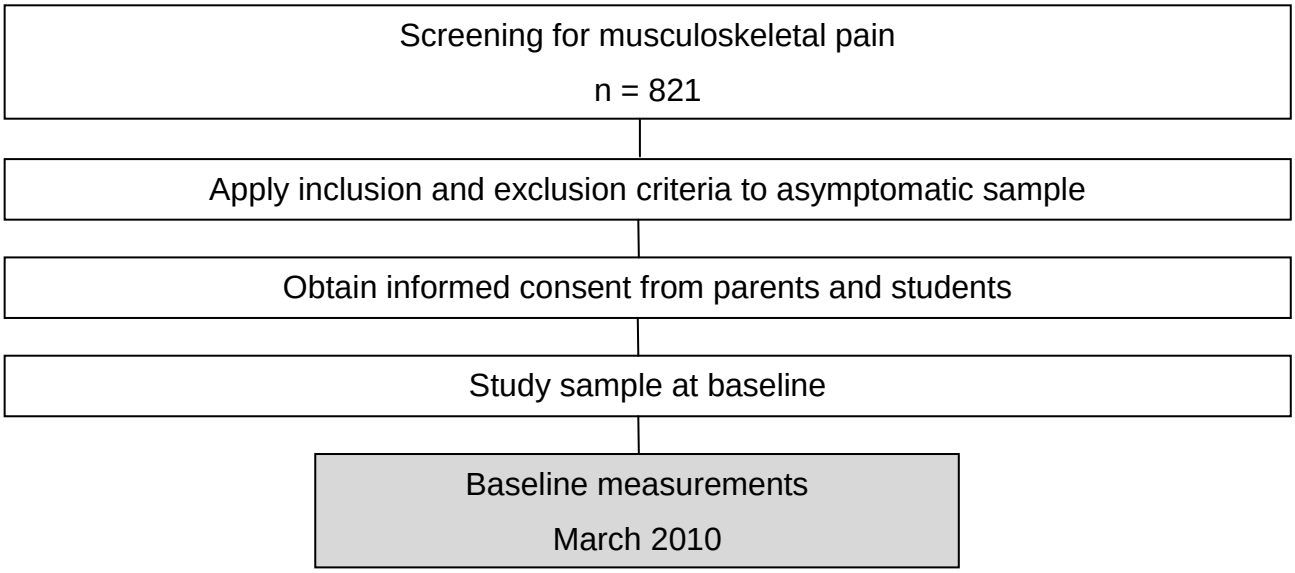


Figure 8.2: A flow chart to demonstrate the sample recruitment of student participants

8.1.5 Measurement instruments

8.1.5.1 *Measurement instrument for sitting posture*

The 3D-PAT was used at the baseline and one-year follow-up to measure the sitting posture of high school students as they worked on desk-top computers. (For a description of the measurement instrument, see Chapter 3.) The nine postural angles used for the validity and reliability testing of the measurement instrument, as described in subsection 4.1.4.1 of the current dissertation, were measured. The subsection also defines the

postural angles studied. All nine postural angles were measured, including the angles with poor validity and reliability as described in Chapter 6, subsection 6.3, because the cohort study commenced prior to the phases two and three of the psychometric testing of the 3D-PAT reported in Chapters 5 and 6.

8.1.5.2 *Measurement instrument for UQMP*

The musculoskeletal pain response was measured at six-month and one-year follow-ups (Feldman *et al*., 2002). The students, who were asked to complete the musculoskeletal pain section of the CUQ, had to recall any musculoskeletal pain during the preceding month (Diepenmaat *et al*., 2006; Murphy *et al.,* 2007; Adamson *et al.,* 2007). The area of pain was indicated on a body chart, with its intensity being measured on a 2-point scale. This questionnaire is included in Addenda 6 and 7, with the questions concerned being numbered from 1 to 11 and 35 to 41. Their validity and reliability have been discussed in subsection 4.1.3.3.

8.1.5.3 *Measurement instrument for computer use*

The CUQ was administered at baseline and one-year follow-up in order to determine computer use at school and elsewhere (Smith, 2007). Exposure to computer use was described in terms of the duration per session, the frequency of weekly usage, and the total number of hours per week. Said component of the CUQ forms Addenda 6 and 7, with the questions concerned being 1 to 11 and from 12 to 27. Their validity and reliability have been discussed in subsection 4.1.3.3.

8.1.6 Study procedure

8.1.6.1 *Measurements at baseline*

(a) Preparation of the classroom for sitting postural evaluation

The researcher arranged with the teachers from each high school a month in advance, with the dates for the baseline data collection being set in March 2010. For the postural evaluation, the computer classroom of the school had to be available to the researcher. Refer to subsection 4.1.5.1 of the current dissertation for a detailed description of the set-up of, and the calibration procedures for, the 3D-PAT. The researcher performed the set-up of the 3D-PAT as shown in Figure 8.3 below.

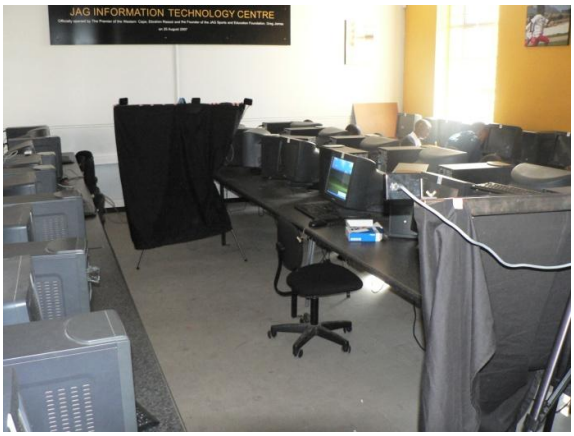


Figure 8.3: The set-up of the 3D-PAT in the classroom

The corner calibration object, as was described in subsection 3.2.2, was used when the first two schools were assessed at baseline. From the third school onwards, the pyramid calibration object, as described in subsection 3.2.2, was used. Each student in turn was required to sit on the same chair and use the computer monitor setting as provided in the computer classroom during a normal class period as the 3D-PAT set-up was fixed at one computer workstation per school.

(b) Preparation of the students for sitting postural evaluation

The researcher explained the study procedure to the students in the school computer room. The students were asked to wear a black t-shirt and grey pants (provided by the researcher) in order for the reflective markers to be clearly visible on the digital photographs taken. Height and weight were measured by a research assistant, as previously described (refer to subsection 4.1.5.2), prior to the postural evaluation.

Reflective markers were placed on the nine anatomical landmarks of the students by the researcher, as was described in subsection 4.1.5.2, in order to allow for the nine postural angles to be measured by means of the 3D-PAT (Straker *et al.,* 2008c). Figures 8.4 and 8.5 below demonstrate the placement of the reflective markers on the students.

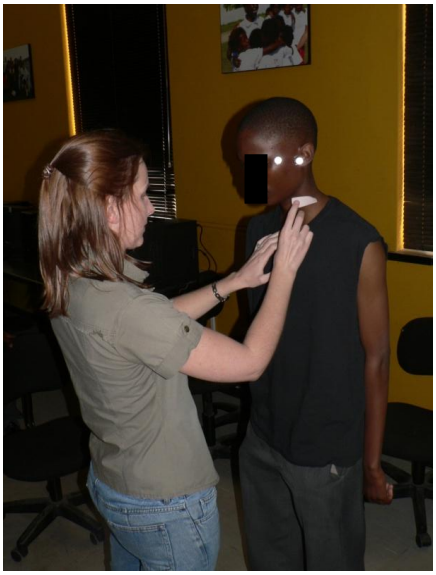


Figure 8.4: Researcher placing reflective markers on a student

Figure 8.5: The positioning of the reflective markers on a student

(c) Sitting postural evaluation

The sitting posture of a single student was measured per capture. Each student in turn was instructed to sit in front of the computer, as they would usually do when performing a curriculum activity on the computer during class. The student was given a short paragraph (Addendum 22) to type repeatedly until the 3D-PAT had finished the data capturing. The student was allowed to type for five minutes before the 3D-PAT captured his or her postural alignment (Szeto, Straker & Raine, 2002; Briggs *et al*., 2004). The amount of time allocated to the task in question was sufficient to allow for the student to assume a relaxed posture and in order to minimise disruption of the academic programme of the school. A research assistant operated the 3D-PAT. Figure 8.6 below is a photograph of a student that was taken while she was typing during the data capturing.

Figure 8.6 Data capture being performed

Once the student completed the postural measurements, the researcher removed the reflective markers and prepared them for the next student. The postural measurements took approximately 10 minutes per student to complete.

(d) Computer use

The CUQ (Addenda 6 and 7, questions 1 to 41) was administered to the students, with a research assistant being available to answer any questions that arose. The questionnaire took approximately 10 minutes to complete.

(e) Time period for data collection per school

According to the number of eligible students at one school, the researcher established a time frame within which the data collection would take place at all the other schools. Baseline measurements were performed in the morning during school hours at each high school. Each student took approximately 40 minutes to complete the full assessment at baseline. Said period included the time it took to assess the other variables (anxiety, depression, sport, and music participation) which are not reported in the current dissertation, as was explained in the preface.

8.1.6.2 *Measurements at six months post baseline*

(a) Onset, intensity and area of UQMP

The researcher collected follow-up data at six months post baseline (September 2010) and administered the pain-related section of the CUQ to the participating students (Addenda 6 and 7, questions 1 to 11, and 35 to 36). The questionnaire took 10 minutes to complete.

8.1.6.3 *Measurements at one-year follow-up*

In January 2011, the researcher consulted with the computer teachers at each school to set dates for data collection in March 2011. The same procedure was followed as had been followed for the baseline measurements and six months post baseline measurements. Repeat measures of sitting posture, computer use and onset, intensity and area of UQMP were performed on the same study sample. The CUQ administered at one-year follow-up is given in Addenda 6 and 7, with the questions concerned numbering from 1 to 41. Figure 8.7 below summarises the study procedure followed.

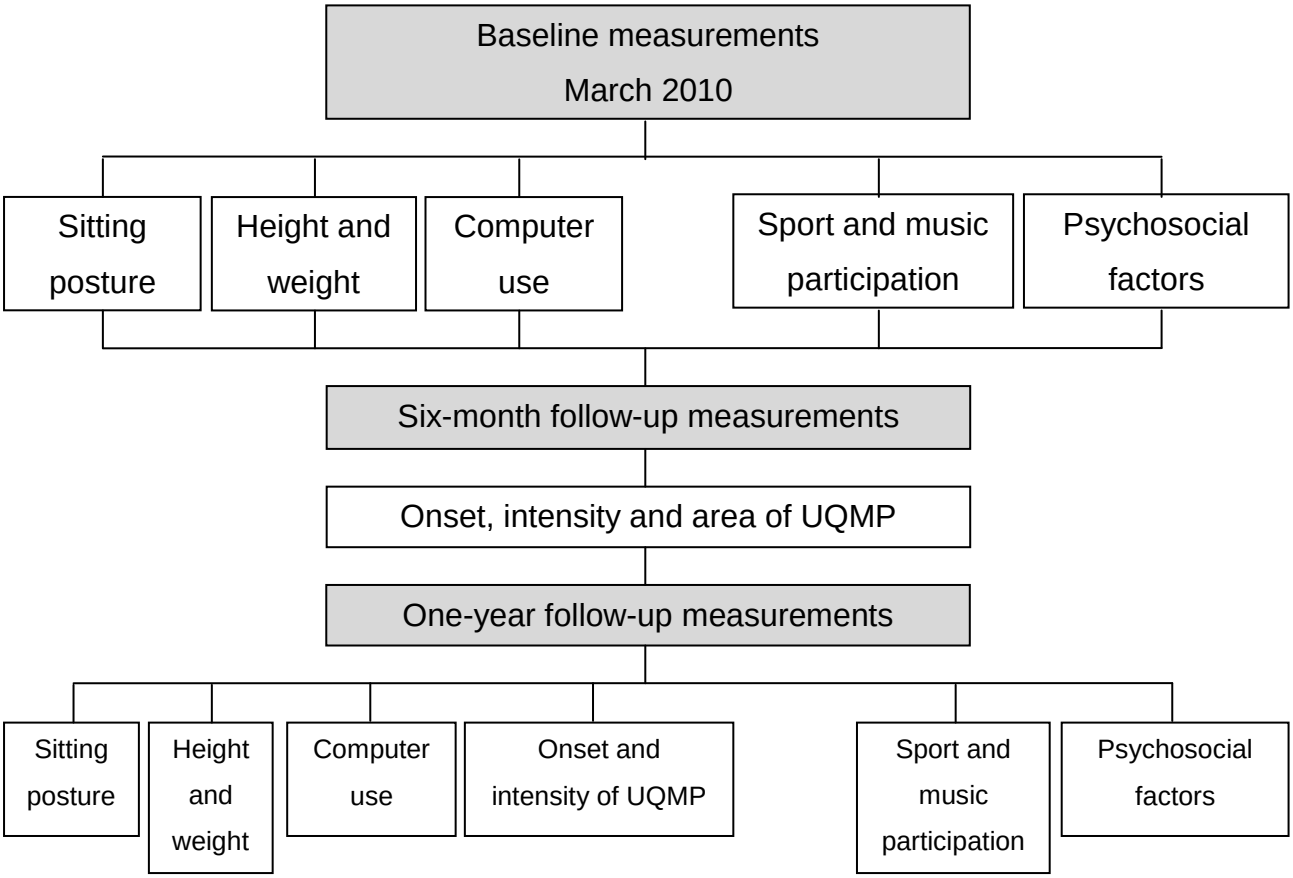


Figure 8.7: A flow chart to demonstrate the measurements taken at various time intervals during the study

8.1.7 Data processing

8.1.7.1 *Sitting posture*

The corner calibration object was used for the first two schools during baseline measurements, thus the data from these two schools (consisting of 15 sets of angular data) were not included in the data analysis, as the postural angles could not be trusted. As explained in Chapter 3, subsection 3.3.1, the corner calibration object was replaced with the pyramid object as a means to improve the accuracy of postural angle measurement. The researcher selected the frame closest to the 50th frame (Straker *et al*., 2002), in which the student's eyes were focused on the computer screen, per camera to form a set of five photographs. A research assistant performed the marker selection of the reflective markers. The researcher performed the marker selection of the calibration object

and the reconstruction of the X-, Y- and Z-coordinates, thus calculating the nine postural angles. The marker selection and reconstruction procedures were similar to those described in subsection 4.1.6.1. Wherever there appeared to be unjustifiable angles, the researcher performed the marker selection of the reflective markers on the students and recalculated the angles concerned. For the baseline postural evaluation, 13 sets of angles were recalculated, of which six sets yielded different results. The recalculated angles that yielded different results were used in the analysis. Two sets of angular data (from two students) from the baseline measurements were considered corrupt, due to a technical problem with the 3D-PAT. Only the baseline postural evaluation was used for statistical analysis in the study, although the one-year follow-up data were processed and reported.

8.1.7.2 *Computer use*

The data from the questionnaire were entered into MS Excel by a research assistant. The number of hours per week of computer use at school and elsewhere was calculated separately. By adding the weekly school and elsewhere computer use, a total amount of computer use per week was calculated. Only the baseline computer use data were used in the statistical analysis of the study, although the one-year follow-up data were processed and reported.

8.1.7.3 *Onset, intensity and area of UQMP*

The data from the questionnaire were entered into MS Excel by a research assistant. Each student who recalled having experienced UQMP during the preceding month, at six-month and one-year follow-up, was given a pain score on a continuous scale. Since the current study only measured UQMP, any lower limb pain areas indicated on the body chart, were ignored. The researcher, however, incorporated lower back pain into the pain score, although it bore less weight than did the UQMP areas because the study only incorporated

seated-related pain and LBP has been associated with sitting. The pain areas indicated on the body chart (Question 35; Addendum 6/7) and the areas indicated on the intensity-of-pain table (Question 36; Addendum 6/7) were matched in order to allow for the maximum number of pain areas to be accounted for in the pain score. Each upper quadrant area with slight pain was assigned one point, with each upper quadrant area with severe pain being assigned two points. The point system was subjectively decided upon. Slight lower back pain and severe lower back pain were allocated 0.5 and one point respectively. The points were tallied to give a total pain score per student. For example, if the student indicated having experienced severe headache (2), slight neck pain (1), severe mid-back pain (2), slight right shoulder pain (1), and slight lower back pain (0.5), the student would score 6.5 for a pain score.

Although each student had a pain score at six-month and one-year follow-up, only one score per student was used in the statistical analysis of the study. If the student experienced pain at both intervals, only the pain score at one year was used. If the student experienced pain at six months but no pain at one year, they were allocated a 0 score. If the student experienced pain at six months, but there were no pain data for one year, due to absenteeism or discontinuing with the study, the student was allocated the pain score received at six months.

The student was only allocated a pain score if the pain was related to seated activities as documented in the CUQ. If the student had UQMP due to sport-related injuries or for other reasons not related to seated activities, the student received a 0 pain score. Thus, the pain score took both the number of pain areas and each area's pain intensity into consideration.

8.1.8 Statistical analysis

Summary statistics for the nine postural angles were used to describe the distribution in terms of means, SD, minimum and maximum values. Pearson correlation coefficients and scatterplots were employed to describe the linear associations between the nine postural angles studied. Computer use was described in frequency tables for the individual components and the composite measure was described in terms of means and SD. Pearson correlation coefficients indicated the strength of the linear associations between the school use and elsewhere computer use.

Treating pain as a binary outcome, logistic regression analysis was undertaken to assess whether postural angles predicted pain at one year. The associations of postural angles with pain at one year were also considered as treating pain as a continuous outcome variable. Due to the zero-inflated distribution for pain at one year (65.8% of children did not have pain at one year), quantile regression analysis was performed. Quantile regression models the relationship between the predictors (posture angles) and the specific percentiles of the response variable (pain score). Various percentiles were used ranging from the 60^{th} to the 90^{th} percentile. The regression of the n^{th} percentile of pain score on the posture angles specified the changes in the n^{th} percentile pain score as a function of the predictors. Univariate and multiple regressions included age, gender, weight, height and computer use as potential confounders.

To investigate the impact of a combination of angles (a specific posture) on pain, a factor analysis was first performed on the posture angles obtained in order to determine the latent constructs measured by the nine postural angles. For ease of interpretation, a varimax rotation was used to provide orthogonal factors. The significant factors were then entered into the quantile regression as predictors. Scatterplots of the results aided in

interpreting the results of the above analysis. Figure 8.8 below demonstrates which data sets were processed and analysed for the current study and which data sets were only processed.

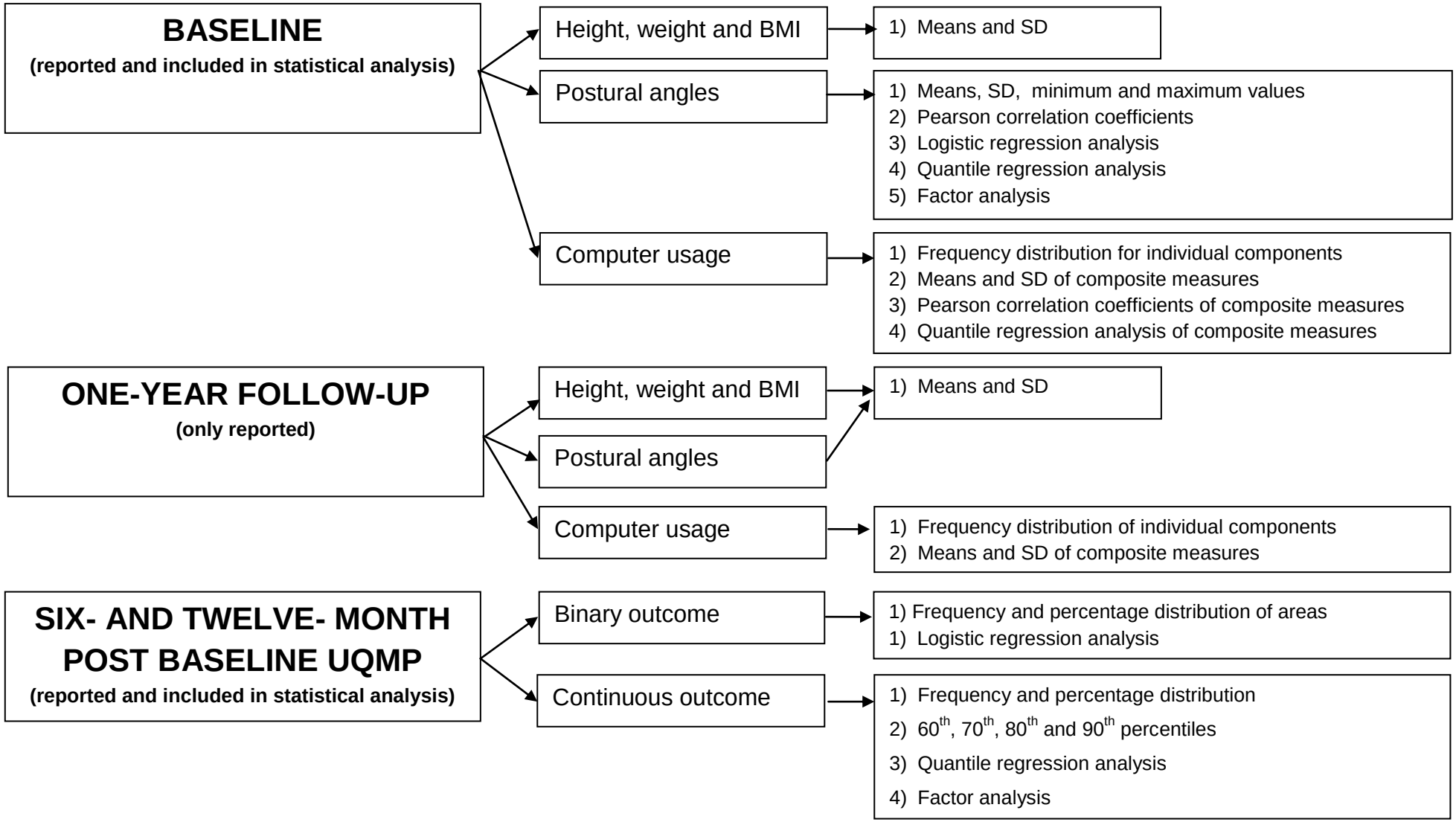


Figure 8.8: Consort diagram indicating which data were used for statistical analysis and which data have only been reported

8.2 RESULTS

8.2.1 Sample composition at baseline

Two of the 20 selected high schools withdrew from the study prior to the baseline data collection, therefore only 18 high schools ultimately participated in the study. From said number of high schools, 994 Grade 10 high school students were screened for musculoskeletal pain. Asymptomatic students numbered 471 and, after the inclusion and exclusion criteria were applied, 353 students were invited to participate in the study and received informed consent letters. Written informed consent was obtained from 235 students. The baseline sitting posture data of two schools had to be rejected because the corner calibration object was in use when the first two schools were assessed and the angular data from another two students were considered corrupt, due to a technical problem with the 3D-PAT, and were therefore also rejected. Thus, even though 211 students participated at baseline, with a response of 59.8%, the data from 194 students are reported in the current chapter.

Table 8.1 below illustrates the number of students screened, of those excluded per inclusion and exclusion criteria, from whom written informed consent from the parents and students were obtained at baseline, and those excluded due to corrupt sitting postural data.

Table 8.1: Screened, excluded and participating students, per EMDC

	Central EMDC	South EMDC	North EMDC	East EMDC	Total
Number of schools	5	4	5	4	**18**
Screened for musculoskeletal pain	266	299	255	174	**994**
Excluded due to musculoskeletal pain	192	100	138	93	**523**
Excluded due to age	7	81	6	3	**99**
Excluded due to repeating the subject	3	7	6	2	**18**
Excluded due to language barrier	1	0	0	0	**1**
Received consent from parents / legal guardians	42	65	79	49	**235**
Absent on day of baseline measurements	4	8	8	4	**24**
Participating students at baseline	38	57	71	45	**211**
Students excluded, due to corrupt sitting postural data	15	0	0	2	**17**
Analysed data	23	57	71	43	**194**

Figure 8.9 below illustrates the sample selection procedure that lead to the sample composition for the baseline measurements and which shows the gender distribution.

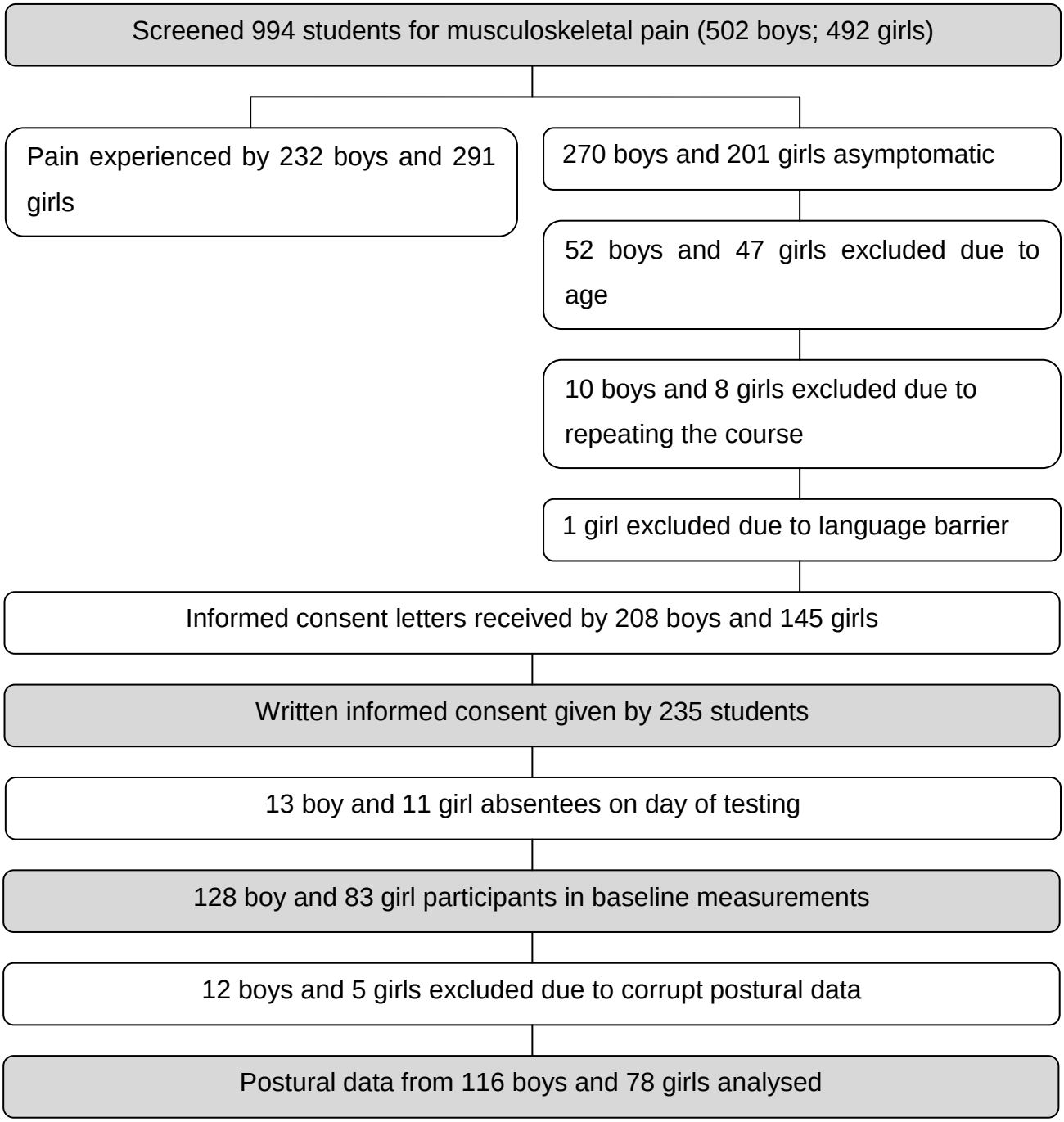


Figure 8.9: Sample selection procedure for baseline measurements with gender distribution

Table 8.2 below shows the age and gender distribution of the students (n = 194) who participated in the study.

Table 8.2: Age and gender distribution of the participating students (n = 194)

	15 years old	16 years old	17 years old	Total
Boys	2	81	33	116
Girls	1	55	22	78
Total	3	136	55	194

Table 8.3 below shows those students (n = 135) who were excluded from the study because they did not return written informed consent letters or returned declining letters, or from whom the postural data were not analysed, as was previously explained.

Table 8.3: Students from whom consent was not obtained and the data were not analysed (n = 135)

	15 years old	16 years old	17 years old	Total
Boys	2	49	28	79
Girls	2	41	13	56
Total	4	90	41	135

The mean age of the participating students was 16.3 years (SD 0.5). The age and gender distribution of said students did not differ from those who were excluded from the study.

8.2.2 Measurements at baseline

8.2.2.1 *Height and weight measurements*

The mean height, weight and BMI of the participants were 1.66 m (SD 0.1), 59.35 kg (SD 13.1) and 21.34 (SD 3.9), respectively.

8.2.2.2 *Sitting posture*

(a) The postural data

The postural data from 194 students were included for the analysis, as was explained in subsection 8.2.1 above. Table 8.4 below summarises the mean, SD, maximum and minimum values obtained from the 3D-PAT for the nine postural angles studied.

Table 8.4: The mean, SD, maximum and minimum values for the nine postural angles studied (n = 194)

	Mean	**SD**	**Maximum**	**Minimum**
Head flexion (°)	78.70	8.4	97.49	53.62
Neck flexion (°)	61.93	8.7	92.64	31.87
Cranio-cervical angle (°)	161.62	7.7	178.81	141.67
Cervico-thoracic angle (°)	150.32	6.8	179.75	125.50
Trunk flexion (°)	-9.54	9.6	18.84	-37.54
Head lateral bending (°)	-0.65	5.1	12.67	-15.26
Neck lateral bending (°)	2.10	17.9	98.23	-48.74
Head rotation (°)	0.69	8.5	29.28	-18.11
Thoracic trunk rotation (°)	-3.01	6.7	34.61	-20.73

The angles greater than 90° for head flexion were obtained when the canthus of the eyes was lower than was the trachus of the ears, as is indicated with the red line in Figure 8.10 below.

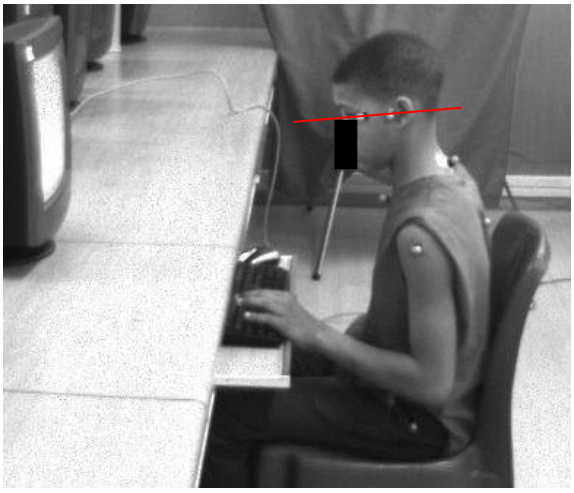


Figure 8.10: A student with a head flexion angle greater than 90°

A neck flexion angle greater than 90° indicates that the trachus of the ears is lower than the level of the C_7 SP, as indicated with the red line in Figure 8.11 below.

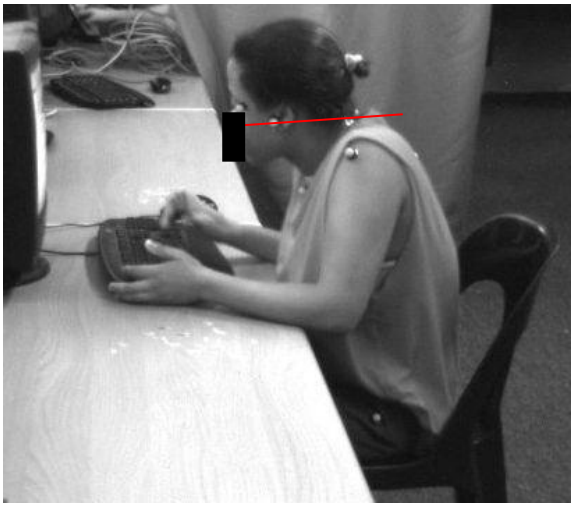
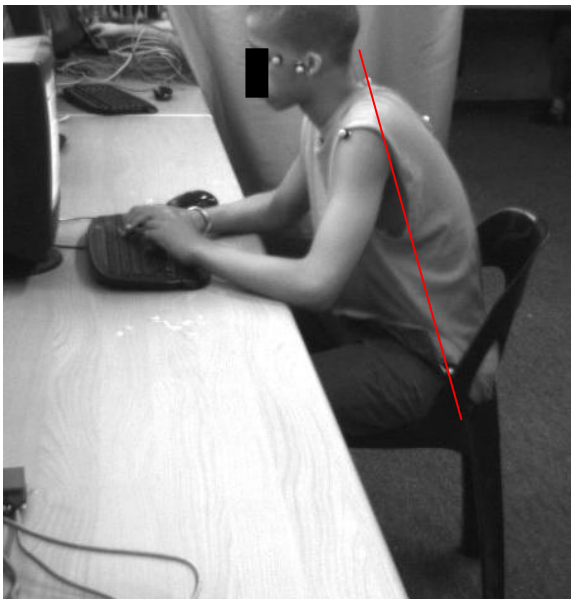
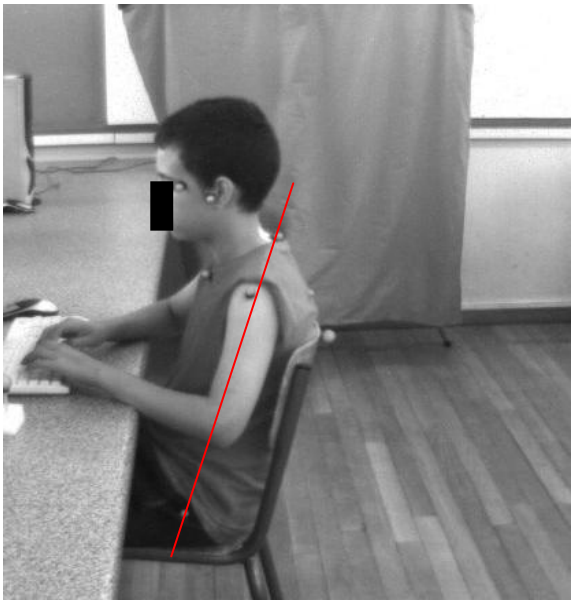


Figure 8.11: A student with a neck flexion angle greater than 90°

If the trunk flexion angle was positive, the C_7 SP was positioned anterior to the greater trochanters, and the student had adopted a more flexed posture, as indicated with the red line in Figure 8.12a below. If the trunk flexion angle was negative, the C_7 SP was positioned posterior to the greater trochanters, and the student had adopted a more extended posture, as indicated with the red line in Figure 8.12b below.



(a) Student with more flexed posture



(b) Student with more extended posture

Figure 8.12: Students in more trunk-flexed and more trunk-extended position

A negative value for head lateral bend, neck lateral bend, head rotation and thoracic trunk rotation indicated that the head or neck was bent in the frontal plane or rotated in the transverse plane to the left and vice versa.

(b) The correlation between the postural angles

Table 8.5 below presents the correlation matrix of the nine postural angles, with associations being reported as Pearson correlation coefficients (***r***). The significant correlations ($\rho<0.0001$) are indicated with an asterisk.

Table 8.5: Pearson correlation coefficients (***r***) demonstrating correlation between postural angles

	Head flexion	**Neck flexion**	**Cranio-cervical angle**	**Cervico-thoracic angle**	**Trunk flexion**	**Head lateral bending**	**Neck lateral bending**	**Head rotation**	**Thoracic trunk rotation**
Head flexion	1	0.504*	-0.480*	-0.148	0.326*	0.083	0.213	0.179	-0.137
Neck flexion		1	0.399*	0.013	0.593*	0.186	0.110	0.232	-0.159
Cranio-cervical angle			1	0.11061	0.224	0.043	-0.013	0.032	-0.057
Cervico-thoracic angle				1	0.361*	0.055	-0.060	-0.044	0.040
Trunk flexion					1	0.010	0.195	0.292*	-0.253
Head lateral bending						1	-0.158	-0.199	0.084
Neck lateral bending							1	0.581*	-0.005
Head rotation								1	-0.040
Thoracic trunk rotation									1

*Significant Pearson correlation coefficients ρ<0.0001.

Figures 8.13 to 8.20 are scatterplot graphs of the significant correlations reported in Table 8.5 above.

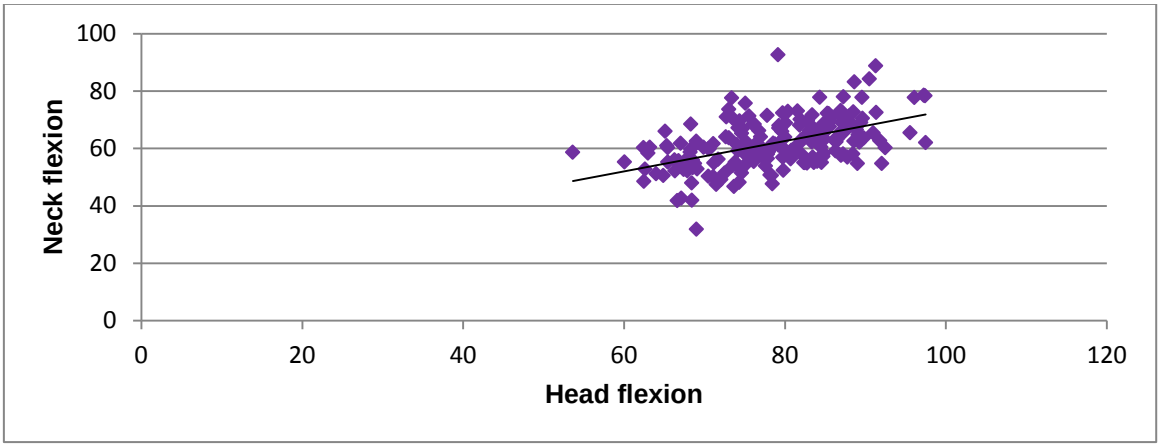


Figure 8.13: The positive correlation between head and neck flexion (r = 0.50)

Figure 8.13 above shows that the students with greater head flexion angles presented with greater neck flexion angles, thus some students were found to have erect and others to have more flexed head and neck segments.

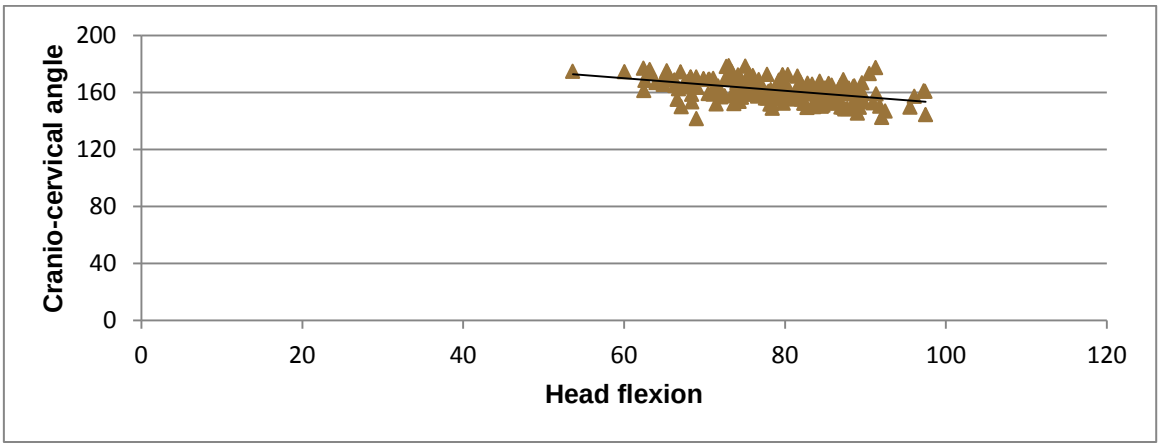


Figure 8.14: The negative correlation between head flexion and cranio-cervical angle (r = -0.48)

Students with increased head flexion angles also presented with less cranio-cervical angles, as is shown in Figure 8.14 above. The cranio-cervical angle is an intersegmental

angle that could be derived from the segmental angles, head and neck flexion, hence the significant correlation.

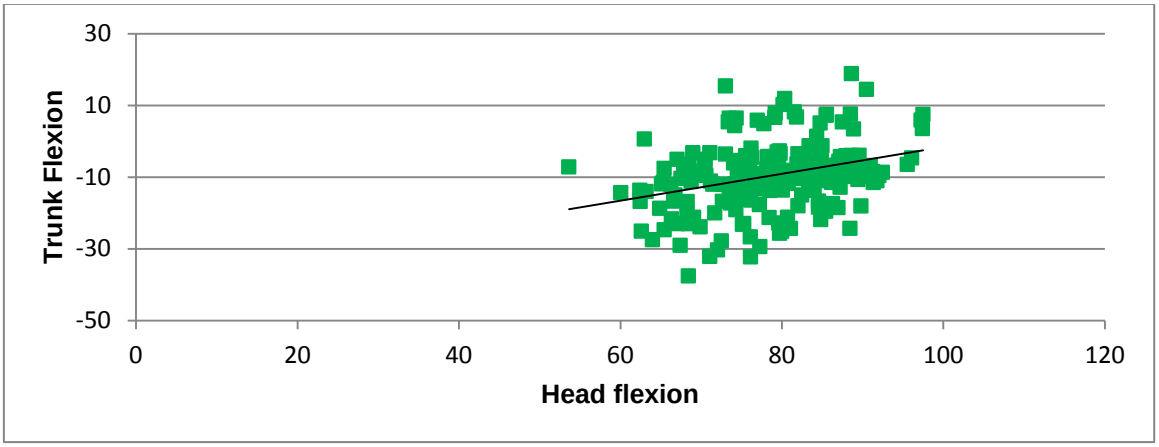


Figure 8.15: The positive correlation between head and trunk flexion (r = 0.33)

Figure 8.15 above shows that students with greater head flexion angles also assumed increased trunk flexion postures, creating a more forward flexed posture.

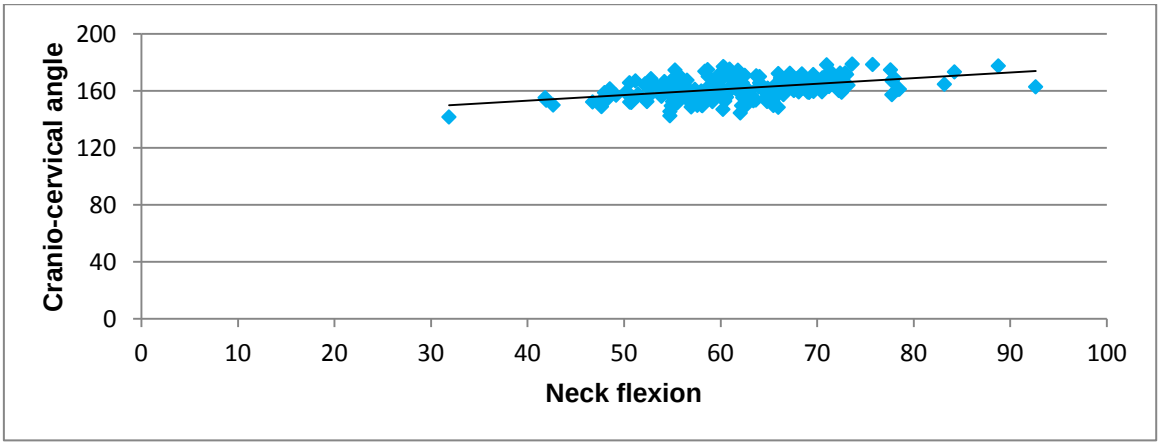


Figure 8.16: The positive correlation between neck flexion and cranio-cervical angle (r = 0.40)

Students with increased neck flexion angles presented with greater cranio-cervical angles, thus creating a more FHP, as is shown in Figure 8.16 above. Once again, the cranio-

cervical angle is an intersegmental angle which depends upon the segmental angles, head and neck flexion, hence the significant correlation.

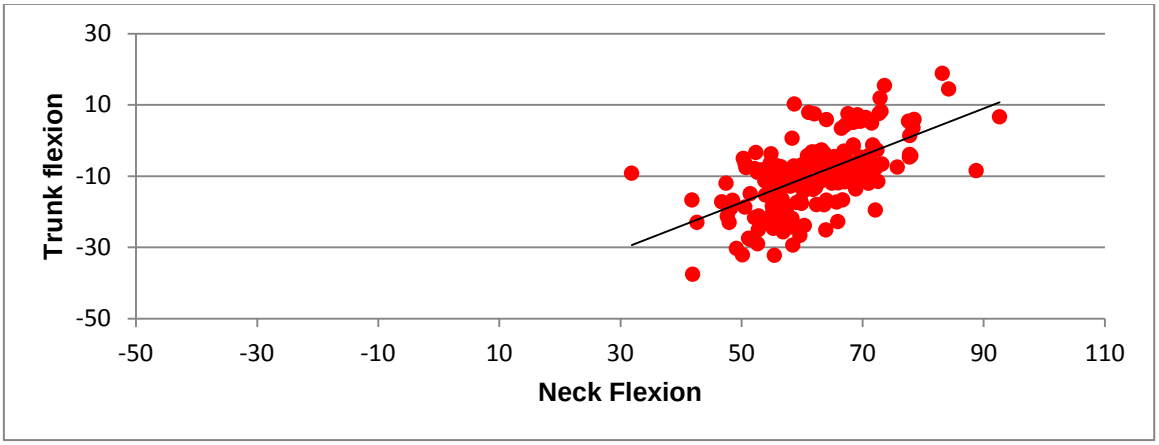


Figure 8.17: The positive correlation between neck and trunk flexion (r = 0.59)

Figure 8.17above shows that students with greater neck flexion angles also assumed increased trunk flexion postures, creating a more forward flexed posture.

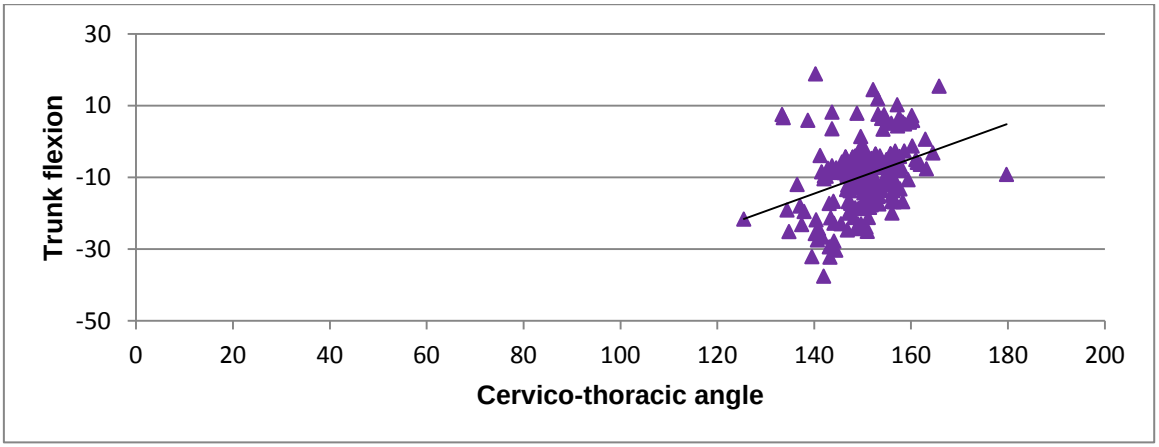


Figure 8.18: The positive correlation between cervico-thoracic angle and trunk flexion (r = 0.36)

Figure 8.18 above demonstrates that students with lesser cervico-thoracic angles adopted more extended or reclined trunk postures, creating more flexed lower cervical and upper thoracic spinal postures to accommodate the trunk's extended position and vice versa.

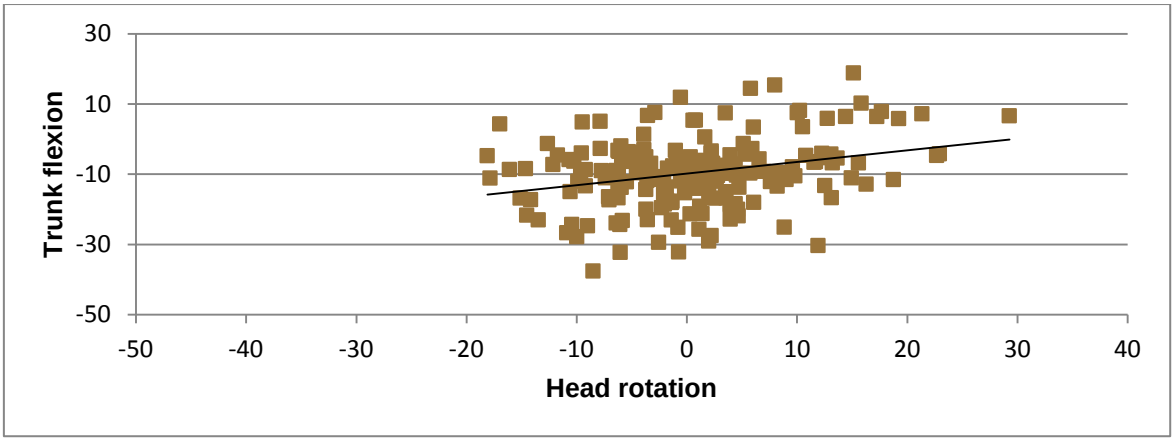


Figure 8.19: The positive correlation between head rotation and trunk flexion (r = 0.29)

Students with increased head rotation angles to the right had more trunk flexion angles and students with more head rotation angles to the left assumed more extended trunk positions, as is shown in Figure 8.19 above.

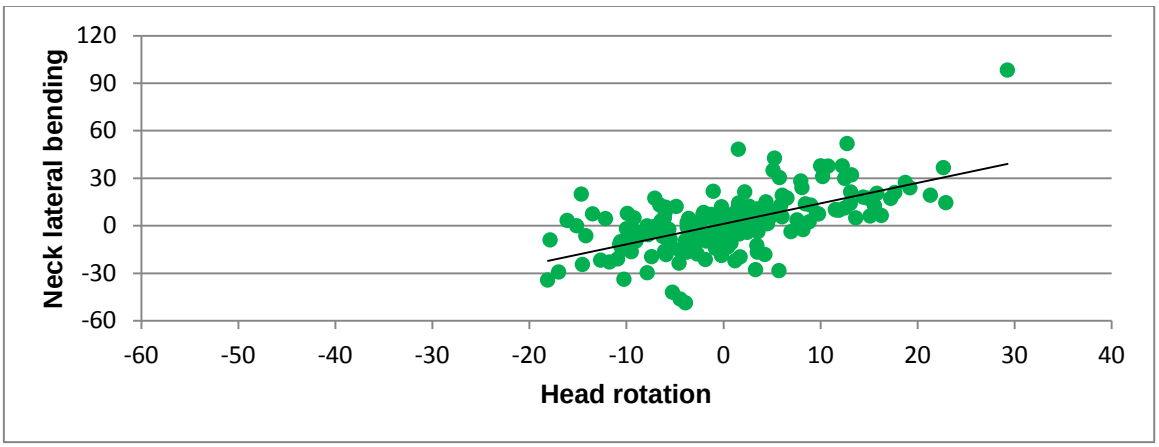


Figure 8.20: The positive correlation between head rotation and neck lateral bending (r = 0.58)

Students with greater head rotation angles to the right, presented with neck lateral bending to the right and students with greater head rotation angles to the left presented with more neutral neck lateral bending angles.

Since negative angles indicate direction and not magnitude, all negative angles were also squared before calculating the ***r*** coefficient. The only significant association was for neck

lateral bending (squared) and neck flexion. Figure 8.21 below is a scatterplot graph that demonstrates that students with greater neck lateral bending to either side also had increased neck flexion angles.

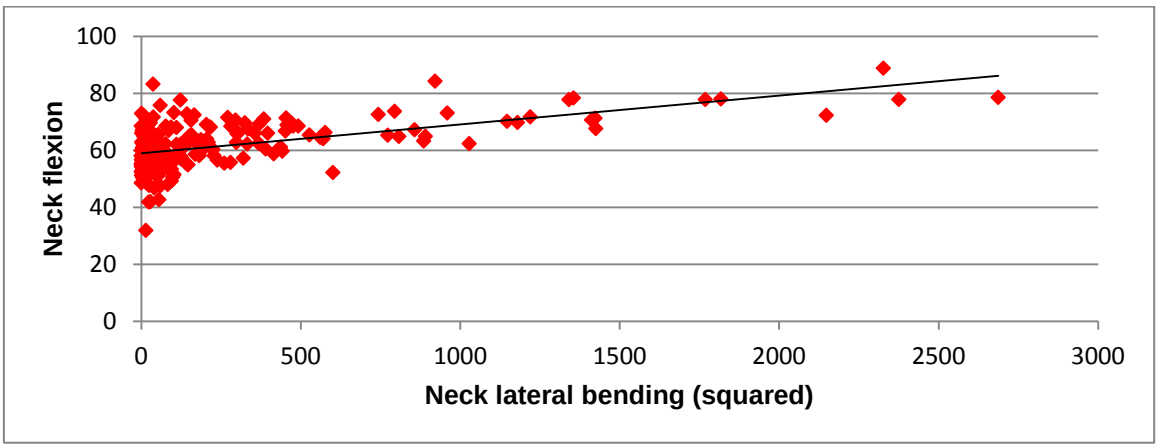


Figure 8.21: Positive correlation between neck lateral bending squared and neck flexion (r = 0.56)

8.2.2.3 *Computer use*

The baseline measurements of the years of exposure to computer use, the duration of a computer session and the frequency of computer use per week at school and elsewhere, are reported in Table 8.6 below.

More than 50% of the students had less than a year's exposure to computer use at school. Of the students, 80% reported that computer class sessions did not exceed an hour and most (65.5%) students reported daily computer use at school. Computer exposure elsewhere, for example at home, indicated more years of computer experience and longer duration per session, but less frequency in computer use per week than was reported for at school computer use.

Table 8.6: Years of exposure, duration per session and frequency per week of computer use at school and elsewhere at baseline (n = 194)

At school			Elsewhere		
Years of exposure					
	Frequency (n)	**Percentage (%)**		**Frequency (n)**	**Percentage (%)**
< 1 yr	109	56.2	**< 1 yr**	53	27.5
2 yrs	30	15.5	**2-3 yrs**	50	25.9
3 yrs	25	12.9	**4 yrs**	25	13.0
> = 4 yrs	30	15.5	**> = 5 yrs**	65	33.7
Duration per session					
	Frequency (n)	**Percentage (%)**		**Frequency (n)**	**Percentage (%)**
<30 min	7	3.6	**<30 min**	51	26.4
45 min	157	80.9	**1 h**	80	41.5
1 h	25	12.9	**2-3 h**	51	26.4
1 ½ h	4	2.1	**> = 4 h**	11	5.7
2/+ h	1	0.5			
Frequency per week					
	Frequency (n)	**Percentage (%)**		**Frequency (n)**	**Percentage (%)**
Once or less	3	1.6	**Once or less**	21	10.9
Twice	2	1.0	**Twice**	42	21.9
Three times	19	9.8	**Three times**	34	17.7
Four times	43	22.2	**Four times**	16	8.3
Five times	127	65.5	**Five times**	79	41.2

Table 8.7 below presents the computer use per week at school and elsewhere. The weekly computer use elsewhere (mean = 5.4; SD = 4.9) was greater than the use at school (mean = 3.5; SD = 0.9). The computer use at school was not highly correlated with the total weekly computer use (r = 0.21), whereas the computer use elsewhere was highly correlated with the total weekly computer use (r = 98). The latter high correlation implies

that the majority of the total weekly computer use was used elsewhere. The school computer use was also not highly correlated with the computer use elsewhere (r = 0.03).

Table 8.7: The mean, the SD, the maximum and the minimum values for computer use per week at baseline (n = 194)

	Computer usage at school per week (h)	**Computer usage elsewhere per week (h)**	**Total computer usage per week (h)**
Mean	3.55	5.36	8.91
SD	0.9	4.9	5.1
Minimum	0.75	0	2.0
Maximum	10.0	20.0	23.75

8.2.3 Sample composition at six months post baseline

Four (three boys; one girl) of the 194 students from baseline were absent on the day of the six-month follow-up measurements. Thus, 190 students participated in the six-month pain measurement.

8.2.4 Measurements at six months post baseline

8.2.4.1 *Upper quadrant musculoskeletal pain (UQMP)*

Of the 190 students, 82 experienced pain at six months. Of the latter, 74 students complained of UQMP (which might also have included pain from other areas besides the upper quadrant), 2 students only had LBP and 6 students only had pain in the lower extremities, such as knee pain. Of such students, 15, 5 and 1 had UQMP, lower extremity pain or LBP, respectively either due to sports injuries or other reasons unrelated to seated activities, or did not complete the relevant questions. Therefore, only 60 (31.6%) students

had UQMP (+ one LBP) due to seated activities. Refer to subsection 8.1.7.3 above for a detailed description of the manner in which the pain score was calculated.

8.2.4.2 *Areas of UQMP*

Table 8.8 below reports 10 areas of the upper quadrant, and the frequency of students who indicated experiencing pain in that area. The number of those who experienced pain in the lower back is also shown.

Table 8.8: Symptomatic areas (n = 275) of the upper quadrant and lower back, indicated by the 76 students at six-month follow-up

Area	Frequency (n)	Percentage (%)
Head	49	17.8
Neck	29	10.5
Upper back	23	8.4
Mid-back	24	8.7
Lower back	26	9.5
Right shoulder	30	10.9
Left shoulder	24	8.7
Right elbow	18	6.5
Left elbow	17	6.2
Right wrist and hand	18	6.5
Left wrist and hand	17	6.2

8.2.5 Sample composition at one-year follow-up

In total, 19 students (12 boys; 7 girls) had left the schools concerned; 16 students (12 boys; 4 girls) were absent on the day of testing; and 6 students (4 boys; 2 girls) did not want to continue with the project. Therefore, 153 of the 194 students participated in the one-year follow-up data collection. Table 8.9 below shows the age and gender distribution of the students (n = 41) who did not participate at one-year follow-up. Table 8.10 below shows the age and gender distribution of the participating students at one-year follow-up.

Table 8.9: Students who did not participate at one-year follow-up (n = 41).

	15 years old	16 years old	17 years old	Total
Boys	1	18	9	28
Girls	1	7	5	13
Total	2	25	14	41

Table 8.10: Students participating in the one-year measurements (n = 153)

	15 years old	16 years old	17 years old	Total
Boys	1	63	24	88
Girls	0	48	17	65
Total	1	111	41	153

8.2.6 Measurements at one-year follow-up

8.2.6.1 *Height and weight measurements*

The mean height, weight and BMI of the participants were 1.68 m (SD 0.1), 61.33 kg (SD 14.0) and 21.73 (SD 4.1), respectively.

8.2.6.2 *Sitting posture and computer use*

The postural data for the 153 students is reported in Addendum 23, as it is not included in the statistical analysis of the current study, as was explained in Figure 8.8 above. The number of years of exposure to computer use, the duration of a computer session, and the frequency of computer use per week at school and elsewhere for the one-year follow-up measurements are reported in Addendum 24, as it is also not included in the statistical analysis of the present study, as was also explained previously in Figure 8.8, subsection 8.1.8.

Table 8.11 below presents the one-year follow-up measurements for computer use at school and elsewhere per week. A similar trend was observed as for the baseline

computer use (refer to subsection 8.2.2.3). The weekly computer use elsewhere (mean = 7.0; SD = 5.9) was greater than was the use at school (mean = 3.5; SD = 1.2). The computer use at school was not highly correlated with the total weekly computer use (r = 0.30), whereas the computer use elsewhere was highly correlated with the total weekly computer use (r = 98). The school computer use was also not highly correlated with the computer use elsewhere (r = 0.11).

Table 8.11: Computer usage at one-year follow-up (n = 153)

	Computer usage at school per week (h)	**Computer usage elsewhere per week (h)**	**Total computer usage per week (h)**
Mean	3.49	7.0	10.4
SD	1.2	5.9	6.1
Minimum	0.75	0.5	2.5
Maximum	10.0	20.0	25.0

8.2.6.3 *Upper quadrant musculoskeletal pain (UQMP)*

At one-year follow-up, of the 153 students who participated in the study, 71 stated that they had experienced pain. Complaints of UQMP (possibly including pain from other areas besides the upper quadrant) were received from 67 students, whereas 2 students only reported having suffered lower back pain and two students only had pain in their lower extremities. Of the students, 19 and 2 had UQMP and lower extremity pain respectively, either due to sports injuries or other reasons unrelated to seated activities, or did not complete the relevant questions. Therefore, only 50 (26.3%) students were found to have experienced UQMP (+ two LBP) due to seated activities. (Refer to subsection 8.1.7.3 for a detailed description of the pain score calculation.)

8.2.6.4 *Areas of UQMP*

Table 8.12 below reports on 10 areas of the upper quadrant and on the frequency of students who experienced pain in the area concerned. The number of those who experienced pain in the lower back is also shown.

Table 8.12: Symptomatic areas (n = 263) of the upper quadrant and lower back, indicated by the 69 students at one-year follow-up

Area	Frequency (n)	Percentage (%)
Head	44	16.7
Neck	31	11.8
Upper back	25	9.5
Mid-back	21	8.0
Lower back	34	12.9
Right shoulder	34	12.9
Left shoulder	20	7.6
Right elbow	12	4.6
Left elbow	11	4.2
Right wrist and hand	18	6.8
Left wrist and hand	13	4.9

8.2.7 Predictive factors associated with the development of UQMP

8.2.7.1 *UQMP during the one-year period*

A total pain score was allocated to each student whose baseline postural data were analysed, according to subsection 8.1.7.3. Of the 194 students, 4 had missing data due to absenteeism. For the period under review, 125 students received a 0 pain score. The remaining 65 students had pain scores ranging from 0.5 to 14.5. Table 8.13 below shows the frequency of each pain score obtained by the 190 students. For said students, the mean pain score was 1.39 (SD = 3.0; lower quartile = 0; median = 0; upper quartile = 1). For the 65 children with pain, the mean pain score was 4.1 (SD = 3.9; lower quartile = 1; median = 2.5; upper quartile = 5.5).

Table 8.13: Pain score, frequency distribution, percentage and cumulative percent (n = 190)

Pain score	Frequency	Percentage	Cumulative percent		Pain score	Frequency	Percentage	Cumulative percent
0	125	65.79	65.79		6	1	0.53	92.63
0.5	1	0.53	66.32		6.5	2	1.05	93.68
1	19	10.00	76.32		7	1	0.53	94.21
1.5	5	2.63	78.95		7.5	1	0.53	94.74
2	7	3.68	82.63		9	1	0.53	95.26
2.5	2	1.05	83.68		9.5	1	0.53	95.79
3	4	2.11	85.79		10.5	1	0.53	96.32
3.5	1	0.53	86.32		11	1	0.53	96.84
4	4	2.11	88.42		13	4	2.11	98.95
4.5	4	2.11	90.53		13.5	1	0.53	99.47
5	1	0.53	91.05		14.5	1	0.53	100.00
5.5	2	1.05	92.11					

8.2.7.2 *Sitting posture of the pain subgroups*

Due to the zero-inflated distribution for pain (with 65.8% of the students not having experienced pain after one year), the posture angles for the pain groups above and below the 90th percentile (4.5) for pain were compared. The score for 22 students was **≥** 4.5. Table 8.14 below presents the means and SD's of the 'pain' and 'no pain' groups and the two groups for the 90th pain percentile.

Table 8.14: The mean and SD of the postural angles for the pain (n = 65), the no pain (n = 125) and the 90th percentile pain groups

	Pain group (n = 65)		No pain group (n = 125)		90th percentile			
					Pain score ≥ 4.5 (n = 22)		Pain score < 4.5 (n = 168)	
	Mean	**SD**	**Mean**	**SD**	**Mean**	**SD**	**Mean**	**SD**
Head flexion (°)	80.0	8.3	78.3	8.3	82.28	8.4	78.42	8.3
Neck flexion (°)	62.5	9.2	61.7	8.5	64.94	10.2	61.60	8.5
Cranio-cervical angle (°)	161.1	8.0	161.7	7.6	161.34	8.8	161.52	7.6
Cervico-thoracic angle (°)	150.7	7.0	150.3	6.4	147.74	5.5	150.78	6.7
Trunk flexion (°)	-9.6	8.6	-9.3	10.2	-11.10	9.1	-9.18	9.8
Head lateral bending (°)	-1.2	4.5	-0.4	5.4	-1.13	5.3	-0.61	5.1
Neck lateral bending (°)	3.4	17.5	1.8	18.3	8.00	19.0	1.60	17.8
Head rotation (°)	0.1	7.9	1.1	8.8	1.43	8.1	0.68	8.6
Thoracic trunk rotation (°)	-3.3	7.7	-3.0	6.1	-4.06	7.4	-3.00	6.5

8.2.7.3 *Individual postural angles*

A quantile regression analysis for the nine postural angles at the 60th, 70th, 80th and 90th percentile for pain indicated that only head flexion at the 90th percentile, was a significant predictor of UQMP (ρ = 0.0001). None of the other posture angles were significant predictors of pain at any percentile. Table 8.15 below reports the association between the individual angles and UQMP, adjusted for confounders. Age, gender weight, height and computer use were included as confounders in the quantile regression analysis for the individual angles. None of the potential confounders was significant confounders in the current study. Analysis for the 60th, 70th and 80th percentiles are not shown for other predictors, as none showed any significant results.

Table 8.15: Individual postural angles at the 90th percentile for pain adjusted for age, gender, weight, height and computer use

Postural angles	Estimate	SE	t-value	P-value
Head flexion 60th	0.01	0.01	0.40	0.689
Head flexion 70th	0.02	0.03	0.64	0.522
Head flexion 80th	0.08	0.06	1.35	0.180
Head flexion 90th	0.24	0.06	3.92	0.0001*
Neck flexion	-0.04	0.09	-0.45	0.657
Cranio-cervical angle	-0.06	0.12	-0.44	0.661
Cervico-thoracic angle	-0.17	0.17	-1.02	0.310
Trunk flexion	-0.02	0.10	-0.24	0.812
Head lateral bending	-0.02	0.167	-0.12	0.905
Neck lateral bending	0.07	0.05	1.46	0.147
Head rotation	0.02	0.11	0.18	0.861
Thoracic trunk rotation	-0.199	0.14	-1.45	0.15
Neck lateral bend squared	0.003	0.001	1.91	0.057

*Significant association (ρ = 0.0001).

Since the study focussed on seated-related UQMP, the two students with seated-related LBP was excluded from the pain group. A sensitivity analysis was performed to determine

whether excluding the two students from the pain group affected the significant predictor shown in Table 8.15. For students complaining only of seated-related UQMP (n=63), the only significant predictor for UQMP remained head flexion at the 90th percentile for pain (ρ = 0.0002) as reported in Table 8.16 below.

Table 8.16: Head flexion angles at the 60th, 70th, 80th and 90th percentiles for pain adjusted for age, gender, weight, height and computer use

Postural angles	Estimate	SE	t-value	P-value
Head flexion 60th	0.01	0.02	0.39	0.695
Head flexion 70th	0.02	0.03	0.70	0.483
Head flexion 80th	0.08	0.06	1.34	0.183
Head flexion 90th	0.24	0.06	3.84	0.0002*

*Significant association (ρ = 0.0002).

For head flexion below and above a cut-off of 80^{0}, the 90th percentile for pain was 4.5 and 5.5 respectively, which was significantly different (the means were 1.3 and 1.5 respectively). Of the students, 86 had head flexion angles greater than 80^{0,} of whom 11 had pain scores ≥ 5.5. Figure 8.22 below demonstrates the relationship between head flexion and pain at the 90th percentile. The figure shows that the greater the head flexion angle, the higher the 90th percentile for the pain score. As was indicated in Table 8.15 above, the relationship concerned was found to be significant.

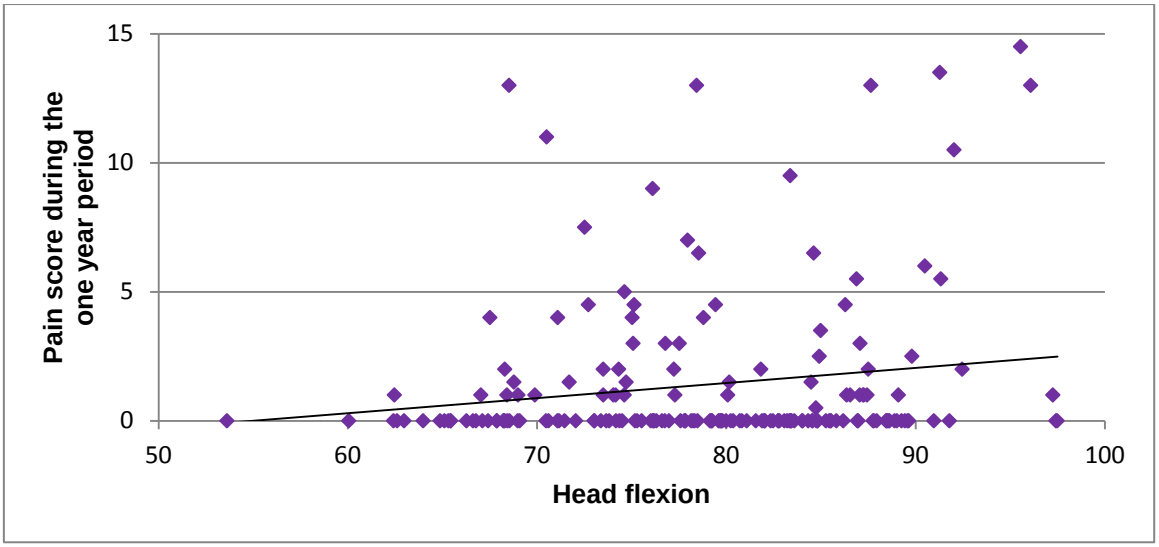


Figure 8.22: Scatterplot graph for head flexion versus pain at the 90th percentile (ρ = 0.0001)

8.2.7.4 *Combinations of postural angles*

The combinations of postural angles were investigated to determine whether a specific posture, could predict UQMP. A factor analysis, including the nine angles, identified two important factors. The first factor was a linear combination with high loadings (>40) for head flexion, neck flexion and trunk flexion, which combination explained 44% of the variability. The second factor was a linear combination with high loadings (>40) for head flexion and cranio-cervical angle, with smaller loadings (between 20 and 30) for neck flexion, cervical-thoracic angle and trunk flexion. Factor two explained 77% of the variability in the nine angles. Table 8.17 below reports the rotated factor pattern of factors one and two. The rotated factor pattern is a rotation of the original factors, which in said case, makes the two factors uncorrelated and also gives a simpler interpretation of the factors.

Table 8.17: The rotated factor pattern for factors one and two

Postural angles	Factor one	Factor two
Head flexion	67*	-69*
Neck flexion	91*	21
Cranio-cervical angle	14	93*
Cervico-thoracic angle	11	26
Trunk flexion	64*	23
Head lateral bending	21	0
Neck lateral bending	4	-5
Head rotation	13	4
Thoracic trunk rotation	-20	-2

*Contributing to the composition of a factor.

The above-mentioned two factors were included in a quantile regression analysis as predictors, adjusting for the other covariates (age, gender, weight, height and computer use) (Table 8.18). The second factor was a significant predictor for pain at the 90th percentile ($\rho = 0.007$).

Table 8.18: Factor one and two at the 90th percentile for pain adjusted for age, gender, weight, height and computer use

Postural angles	Estimate	SE	t-value	ρ-value
Factor one	-0.11	0.77	-0.14	0.888
Factor two	-1.27	0.47	-2.71	0.007*

*Significant association ($\rho = 0.007$).

To aid in the interpretation of factor two, the values for head flexion and cranio-cervical angle were plotted for three categories of the factor: <-1; -1 to +1; and >1. The categories, as plotted, are shown in Figure 8.23 below. The choice of cut-points (-1 and +1) was subjective, but illustrates the bottom and top end of the scale for the factor concerned. The graph in Figure 8.23 shows that a large head flexion and small cranio-cervical angle gave a value for factor two of below -1, while a small head flexion with a large cranio-cervical

angle resulted in a larger value for the factor. From the regression, we know that the estimated coefficient for factor two was negative (-1.27), implying that values above the 90th percentile for pain score were related to lower levels of factor two. In turn, lower levels for factor two were related to larger head flexion angles and smaller cranio-cervical angles.

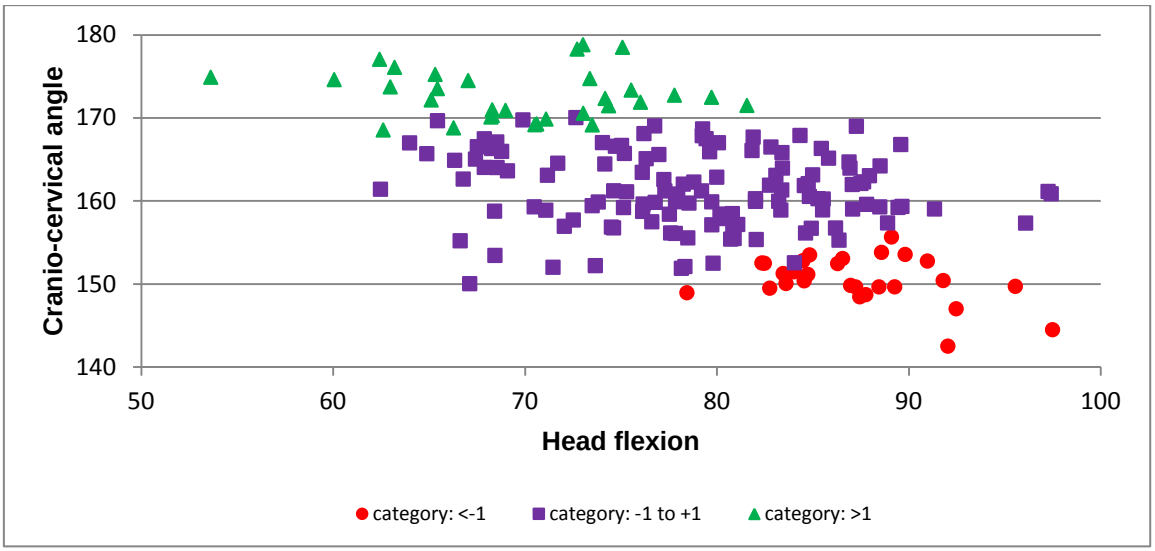


Figure 8.23: Scatterplot graph of head flexion and cranio-cervical angle plotted for three categories of factor 2: <-1; -1 to +1; >1

8.2.7.5 *Computer use*

A quantile regression analysis for the total hours of computer use per week (school and elsewhere) at the 90th percentile for pain indicated no significant relationship between weekly computer use and UQMP (ρ = 0.232). The same also held true for computer use during school hours (ρ = 0.536) and elsewhere (ρ = 0.3338). Figure 8.24 below demonstrates the relationship between weekly computer use and pain at the 90th percentile.

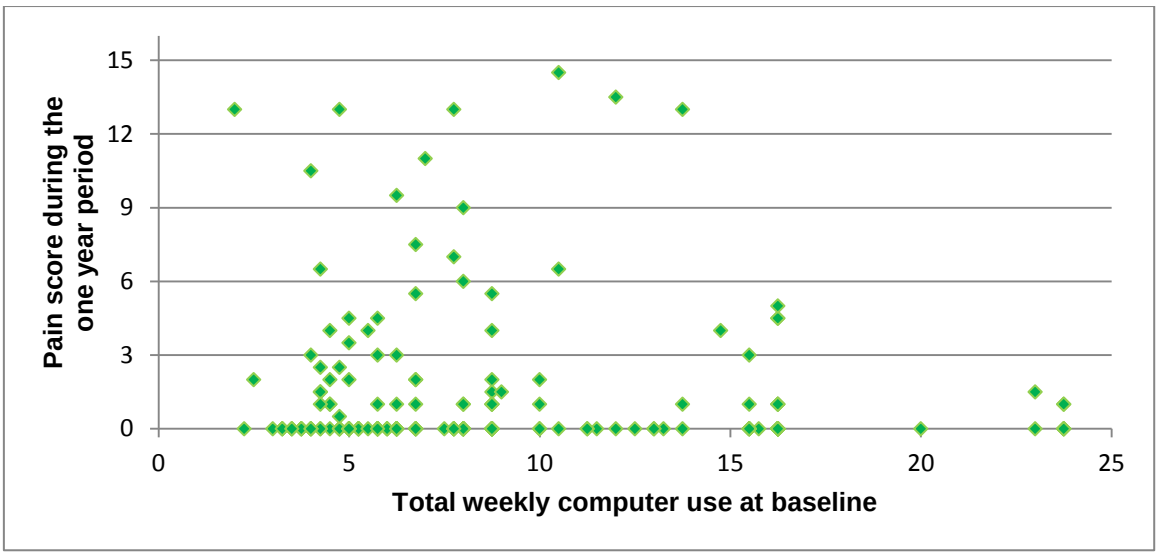


Figure 8.24: Scatterplot graph for weekly computer use in relation to pain at the 90th percentile (ρ = 0.232)

The total amount of computer use per week for baseline and one-year follow-up was not highly correlated (r = 0.42). On average, an increase in computer use during the year was experienced. Figure 8.25 below demonstrates the correlation between total weekly computer use at baseline and at one-year follow-up.

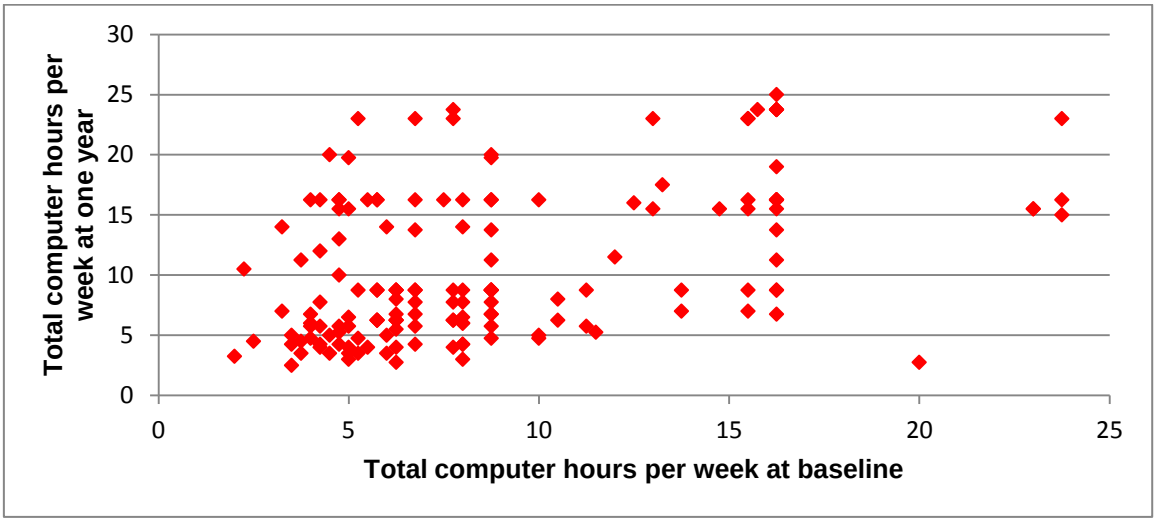


Figure 8.25: Scatterplot graph of the total number of hours per week at baseline and at one-year follow-up (r = 0.42)

8.3 SUMMARY

The current chapter described the findings of the cohort study, with a prospective follow-up period of one year. A 59.8% response rate was achieved at baseline, of which 98.1% participation took place at six months and 79.6% at one-year follow-up. Of students studied, 33.5% complained of seated-related UQMP during the follow-up period. Exposure to increased head flexion and the combination of increased head flexion and decreased cranio-cervical angles were significant predictors of seated-related UQMP for those computing high school students complaining of pain greater than the 90th percentile. Computer use was not a confounder for the associations between sitting postural angles and seated-related UQMP in computing high school students between the ages of 15 and 18 years.

CHAPTER 9

DISCUSSION

The aim of the current research project was to determine the reliability and validity of the 3D-PAT and to establish whether sitting postural angles, measured in a real-life setting, were predictive of UQMP in computing South African high school students. The systematic reviews presented in the present dissertation highlighted the limitations in the literature that hinder our gaining a full understanding of the causation of adolescent UQMP (refer to the summary sections in Chapter 2 and 7). Some of the shortcomings identified have been addressed by means of a series of primary research studies presented in the dissertation. In the process, an attempt was made to bridge the gap in knowledge that exists concerning the association between sitting posture, in terms of postural angles, and adolescent UQMP.

9.1 DEVELOPMENT AND PSYCHOMETRIC TESTING OF THE 3D-PAT

Since no cost-effective, portable, reliable and valid 3D posture measurement instrument was identified in the systematic review (Brink *et al*., 2011) presented in Chapter 2, a new instrument was developed in order to assess sitting postural angles of computing high school students. The psychometric testing results were obtained within the context of the 3D-PAT's intended use. The reliability and validity findings reflected that the 3D-PAT has a very good ability to measure six sitting postural angles (head flexion, neck flexion, cranio-cervical angle, trunk flexion, head lateral bending and head rotation) of computing high school students in the school computer classroom. The psychometric property-testing procedures (phases one, two and three) addressed the methodological shortcomings

(rater qualification, reference standard, rater blinding and statistical methods) reported in the systematic review (Brink *et al*., 2011), where the quality of evidence of reliability and validity of other 3D posture measurement instruments were reviewed.

The rater's qualification should be considered when interpreting study findings, and should be extrapolated for applicability and generalisability to other clinical and research settings (Bossuyt et al., 2003). The rater's qualification to operate the 3D-PAT was appropriate for the level of psychometric testing that the 3D-PAT was undergoing at the time of the study, since the three phases of psychometric testing were the first testing that the instrument had undergone. The 3D-PAT was only operated either by the mechanical engineer who developed the instrument or by the researcher, who received training prior to the commencement of the research project. The researcher was the only person who was allowed to place the reflective markers on the students and mannequin, and, since the researcher was a trained physiotherapist who had been in clinical practice for 10 years, she was qualified to identify anatomical landmarks and to perform the marker placement. As the 3D-PAT had also not been used previously in any clinical or research setting, there was no danger of misinterpretation of the results, due to the competence of the raters to operate the 3D-PAT. No comparison could therefore, be made to other psychometric testing results that had already been obtained with the 3D-PAT.

The validity studies reviewed in Chapter 2, which used humans, also employed stereoradiography as the reference standard, as, until this day, radiography remains the most accurate assessment for posture, even though there is a possible health risk associated with repeated X-ray exposure to healthy spines and organs (Wagner, Bowing, Deimling, Rascher & Rupprecht, 2001). The most suitable non-invasive 3D reference standard for postural measurements has not, so far, been unanimously determined in said

field of research. The reference standard (Vicon system) used in the project, which was suitable for measuring, and the best available instrument to measure sitting postural angles, was described in detail.

As a variety of statistical measures were reported in the review (Chapter 2) as measuring the same constructs, another method for improving the quality reporting could involve authors justifying why they chose a particular statisical test, relevant to the purpose of the testing. Such justification would provide the reader with better insight into the results, and would perhaps guide future authors in choice, and interpretation of more appropriate statisical analysis. The Bland-Altman method for validity testing of the 3D-PAT was justified and considered to be the most appropriate method for interpretation of the results, given that no published reports of similar validity testing procedures could be found in the literature concerned. The concordance correlation coefficient and ICC for the test-retest reliability of the 3D-PAT are the most frequently used methods for determining reliability testing of an objective posture measurement instrument (Brink *et al.*, 2011). Blinding of the rater was inappropriate, as rater reliability was not examined in the project.

9.2 UQMP REPORTING

The primary finding of the current research project was that increased head flexion, to a degree greater than 80°, is a predictor of seated-related UQMP developing within six to 12 months for those computing high school students with a pain score equal to, or greater than, 4.5 (the 90th percentile for pain) on the pain scale. The finding indicates that the head flexion angle is more predictive of pain for those high school students complaining of severe and/or multiple areas of UQMP. Physical factors and intensity of musculoskeletal pain and/or multiple areas of musculoskeletal pain in adolescents are associated (Auvinen *et al*., 2007; Paananen *et al*., 2010). Thus, the number of pain areas and the intensity of

pain were scored on a continuous scale to enhance insight into the complexity of musculoskeletal pain. A continuous pain scale was advantageous, since the skew distribution of the pain data (zero-inflated pain scores) compromised the use of the pain data in binary form (refer to Table 8.13). The sample of symptomatic students was also too small to allow for pain subgroups according to the intensity of pain or the area of pain.

Pain is an abstract concept and subjective experience best described by self-reported measures, and psychosocial or environmental factors can influence an adolescent's experience or perception of musculoskeletal pain, thus increasing the complexity of pain reporting (Guite *et al*., 2007; Von Bayer & Spagrud, 2007). A study by Coleman *et al*. (2009) indicated that 43% of children were unsure of the cause of their pain, and that pain that was caused by one thing could cause discomfort when they were doing something else. Hakala *et al*. (2012), in contrast, questioned adolescents on their experience of computer-related musculoskeletal pain that was based on their perception of whether computer use caused the discomfort concerned. Therefore, a standardised questionnaire, which was reliable and valid for assessing risk factors associated with musculoskeletal pain in high school students of the same population, was used in the current research project to ensure that only seated-related UQMP was included in the pain group, based on questions 38, 39 and 40 from the CUQ (Addendum 6/7).

Pain was assessed at six months post baseline to accommodate those students lost to follow-up at the one-year measurements. Accordingly, one pain score was allocated per student that represented pain experienced during the course of a year (refer to subsection 8.1.7.3 for a detailed description of which students were allocated a positive pain score). More students reported pain at six months (31.6%) than at one year (26.3%), possibly due to the time of year at which the measurements were taken. Only two follow-up

measurements of the outcome were plausible within a one-year time frame, due to the exigencies of the academic school programme. The March and September time frames were considered best for data collection, since no research projects are allowed during the last quarter of the year, during which students are preparing for their final school examination. At six months post baseline (September), most schools have just completed school tests, so that the students involved in the study were exposed to longer periods of sitting than usual in preparation for the school tests, which could have exacerbated their UQMP symptoms. The one-year follow-up measurements were conducted near the beginning of the academic school year during the first quarter of the year, after the school holidays, so that the students were more rested and not as exposed to prolonged sitting periods, which could have lessened the impact of sitting posture on UQMP. Feldman *et al*. (2002) reported that school-attending adolescents who also had additional white-collar (entailing office work) jobs were more at risk of neck and upper extremity pain than were those adolescents with additional blue-collar (entailing physical work) jobs. The authors also reported a higher incidence of UQMP after the first six months, because the time period covered also included the bulk of the school year, similarly to the cohort study. Furthermore, 21% of the 194 students were lost to follow-up at the one-year measurements, with 63% having no pain at six months post baseline, resulting in the allocation of a zero pain score for the one-year period. Some of the 63% of students might have developed UQMP later than six months post baseline, but could not be accounted for at the one-year follow-up, as other research (Siiviola *et al.,* 2004; Paananen *et al.,* 2010) has shown that the prevalence of adolescent musculoskeletal pain increases with age.

9.3 SITTING POSTURE FOR HIGH SCHOOL COMPUTER USERS

The increased head flexion reported for students experiencing severe or multiple areas of UQMP was not considered a typical posture to accommodate for the height of the

computer monitor. Burgess-Limerick, Mon-Williams and Coppard (2000) found that trunk extension or a reclined position was correlated with increased neck and head flexion in order to accommodate for the height of the computer monitor. However, in the cohort study a reclined position of the trunk was correlated with less neck and head flexion. The implication was that the students either sat with a more forward flexed or a more reclined and extended posture irrespective of the workstation design, which illustrates that the students assumed postures due to intrinsic mechanisms and not in order to account for the height of the computer monitor concerned (Szeto *et al*., 2002). Height was also not a confounder that affected the relationship between seated-related UQMP and head flexion (refer to subsection 8.2.7.3). The computer height and chair placement were kept according to the student's preference and represented the student's habitual classroom posture.

9.4 CRITERIA OF CAUSATION

Since the aim of the cohort study was to determine whether sitting postural angles are predictors of seated-related UQMP in high school students, the research project addressed the following three criteria of causation: temporality, biological gradient and plausibility (Hill, 1965).

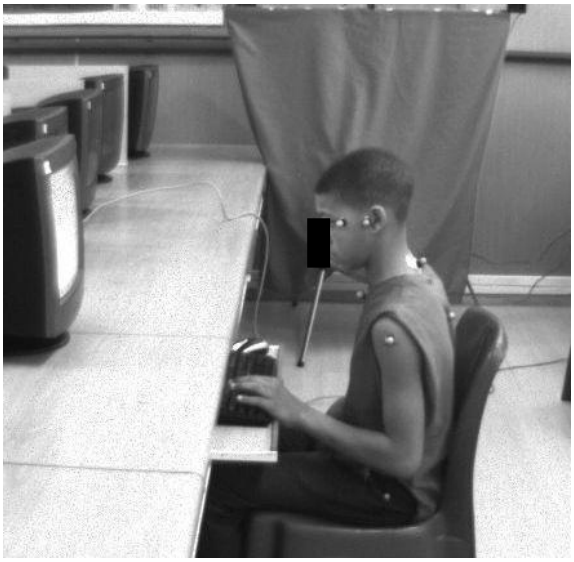
Temporality implies that the exposure preceded the outcome of interest (Marcus, Gerr, Monteilh, Oritz, Gentry, Cohen, Edwards, Ensor & Kleinbaum., 2002). In this cohort study the asymptomatic (disease-free) high school students were defined as students without pain one month prior to baseline data collection. Thus the exposure (sitting postural angles) were present prior to a new onset of seated-related UQMP, as those asymptomatic adolescents at inception of the cohort study might have had a previous episode of seated-related UQMP dated prior to the one month pain recall period. The pain

screening questionnaire's psychometric properties indicated that the questionnaire was reliable with respect to a one month pain recall period for this adolescent population (Smith, 2007). If lifetime prevalence or recalling pain ever before would have been used then more students might have been excluded, however there is a possibility that a longer pain recall period might introduce unreliable pain data as a result of memory decay which relates to the gradual loss of recalling events over time, thus complicating the interpretations of the associations between the exposure and pain. The only approach will be to conduct a longitudinal study over years but that would not have been feasible within the resources and scope of this project. Therefore the temporality criterion of causation must be interpreted within the framework of the one month retrospective pain prevalence of this cohort study.

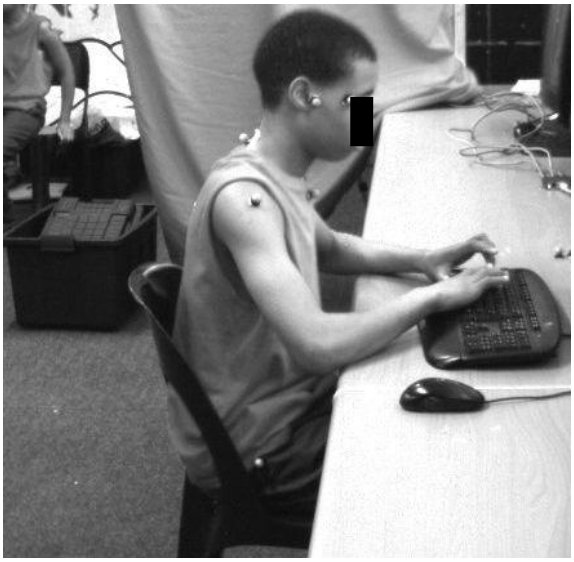
The **biological gradient or dose response** criterion was sufficiently addressed in the study by the fact that, as the exposure to head flexion angle increased beyond 80°, the 90th percentile for pain also increased (refer to Figure 8.22). There has, as yet, been no other research to support the dose (increased head flexion) response (adolescent UQMP) criterion, as the only other prospective study measuring sitting postural angles and adolescent UQMP found that increased exposure to extreme neck flexion angles (less than the 25th or greater than the 75th percentile for neck flexion) was predictive of UQMP in high school students (Brink *et al.,* 2009a). The researchers in question (2009a) found no significant association between head flexion and adolescent UQMP.

The **plausibility** criterion could be satisfactorily met by considering the biomechanical alignment of increased head flexion greater than 80°. Head flexion, which is a segmental angle, represents the head-on-neck alignment, and gives information about the effect of gravity around the atlanto-occipital joint (AOJ) (Straker *et al.,* 2008c). The centre of mass

of the head lies anterior to the neck, requiring posterior extensor muscle activity to maintain an upright head-on-neck posture. As head flexion increases, flexion around the AOJ increases, thus leading to an increased distance of the centre of mass of the head away from the joint axis. The posture concerned requires increased extensor torque from the posterior suboccipital muscles and, to a lesser extent, the semispinalis capitis and cervicus muscles in order to counterbalance the increasing extensor moment around the AOJ, as well as in order to maintain static equilibrium (Burgess-Limerick, Plooy, Fraser & Ankrum, 1999; Briggs *et al.,* 2004). The increased sustained muscle activity may predispose said muscles to early fatigue, resulting in UQMP (Briggs *et al.,* 2004). As the posterior extensor muscles are maintained in a lengthened position, they may add sarcomeres (lengthening of the muscle), thus changing the length-tension relationship of the muscles (Norkin & Levangie 1992), resulting in the muscles' inability to assist with segmental stability of the cervical spine (Burgess-Limerick *et al*., 2000; Boyd-Clark, Briggs & Galea, 2002). A muscle's force-generating capability is highly dependent on its length-tension relationship and, if a muscle is kept at an insufficient length-tension relationship, it also predisposes the muscle to fatigue (Szeto *et al*., 2002). Figures 9.1(a-d) are photographs of students with head flexion angles greater than 80°, and with a pain score greater than the 90th percentile for pain.

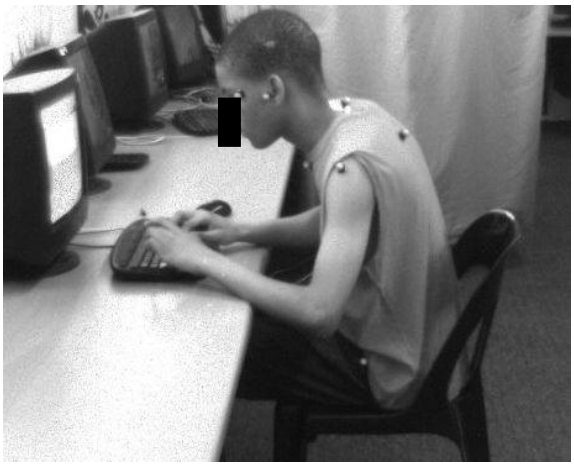


(a) Students no. 1



(b) Student no. 2

(c) Students no. 3



(d) Student no. 4

Figure 9.1(a-d) Students with increased head flexion and a pain score greater than the 90th percentile for pain

Head flexion is restrained by increased tension in the posterior extensor muscles, in the ligamentum flavum, in capsules of the zygapophyseal joints and in the interspinous ligaments. As the head flexes, the AOJ is also more exposed to compression load. Towards increased head flexion ranges, beyond 80°, less support is provided by the active structures (muscles). The passive ligamentous structures of the upper cervical spine then

takes the majority of the load, due to the complexity of the AOJ (C_0/C_1) and the atlanto-axial joint (C_1/C_2) and the absence of intervertebral (IV) disks between C_0/C_1 and C_1/C_2. (Bogduk & Mercer, 2000; Brolin & Halldin, 2004). The process is also demonstrated in the lumbar spine, where slump sitting is maintained by the passive structures, as the postural muscle activity decreases (Beach *et al*., 2005; O'Sullivan *et al*., 2002). The passive structures are highly innervated with nociceptive fibres, and pathological changes to the passive structures in response to undue strain could lead to UQMP (Briggs *et al*., 2004).

At both six-month and one-year follow-up, the students mostly complained of seated-related headaches, neck and shoulder pain, as well as, to a lesser extent other anatomical areas that constitute the upper quadrant. A nociceptive stimulus, due to pathological changes to, or injury of, structures innervated by the first three cervical nerves, can lead to headache and neck pain (Alix &Bates, 1999; Aprill, Axinn & Bogduk, 2002). Some of the structures concerned include the AOJ, posterior extensor muscles, the dura mater of the upper cervical spinal cord, the C2/3 IV disk, the DNFs and the C_2-C_4 zygapophyseal joints. The posterior extensor muscles (rectus capitus posterior minor) and the AOJ are attached to the dura mater of the upper cervical spinal cord, thus increasing tension on the posterior muscles or undue strain to the AOJ, which could, potentially, influence the spinal dura, leading to headaches and neck pain (Alix & Bates, 1999; Harrison, Calliet, Harrison, Troyanovich & Harrison. 1999).

The cohort study reported a significant predictive relationship between the combination of increased head flexion and decreased cranio-cervical angle and seated-related UQMP for high school students experiencing pain greater than the 90th percentile. The cranio-cervical angle is an intersegmental angle and provides information about stresses related to both head and neck flexion joint ranges (Straker *et al*., 2008c). The reduced cranio-cervical

angle was more a result of increased head flexion than of decreased neck flexion (refer to Figure 8.23). Straker, Pollock, Burgess-Limerick, Skoss & Coleman, (2008d) also reported lesser cranio-cervical angles, due to increased head flexion angles, which was accompanied by increased muscle activity of the superficial cervical erector spinae muscles, due to the greater extensor moment around the C_7 SP for young adults (mean age = 20.6 years). A greater extensor moment around C_7 SP is produced when the neck flexion angle increases and the centre of the mass of the head moves further away from the joint axis. The cohort study reported a mean neck flexion of 62°, which is approximately 10° greater than what was reported by previous cross-sectional studies in which no musculoskeletal pain was measured (Briggs *et al*., 2004; Straker *et al*., 2007, 2008b, 2009b). The cohort study's neck flexion angle was more comparable to the mean neck flexion angle of 56.5° reported by O'Sullivan *et al*. (2011a) for a group of adolescents experiencing musculoskeletal pain. Therefore, since decreased neck flexion did not contribute to the decreased cranio-cervical angle, increased neck flexion was significantly correlated with increased head flexion (refer to Table 8.5) and a greater mean neck flexion angle was reported in the current cohort study, it is possible that increased neck flexion might have been a predictor of adolescent UQMP, although, due to inadequate statistical power, it was not reported as such. Thus, the accompanying increased neck flexion as the head flexion increases could result in pathological changes to active and passive structures innervated by cervical nerves lower than C_3 and could follow a similar pathway in predisposing other areas of the upper quadrant (excluding the head and neck) to musculoskeletal pain.

The DNF are responsible for upper cervical flexion and the flattening of the cervical lordosis (cranio-cervical flexion). Weakness and endurance deficits of the DNF muscles are correlated with an inability to maintain cranio-cervical flexion in the inner-range position

(Domenech et al., 2011). In the current cohort study those students with increased head flexion angles (> 80°) maintained such an inner-range head position for prolonged periods. Consequently, the researcher postulates that the DNF were unable to assist the posterior neck stabilizers in maintaining cervical stability, due to probable muscle weakness and endurance deficits. Cervical instability occurs when the neutral zone[7] increases and the active and passive structures cannot compensate for the increased neutral zone, leading to poor quality of spinal motion within the neutral zone. Undue strain to active and passive structures results, which could lead to the development of UQMP (Olsen & Joder, 2001).

The consistency criteria of causation could not be met. O'Sullivan *et al*.'s (2011a) study was the only one to report similar results to the current study. However, in the study mentioned, head flexion was measured two-dimensionally, the pain was defined as chronic non-specific musculoskeletal pain and both children and adolescents were included. The authors reported a non-significant difference between head flexion for the pain group of 85.5° (±12.8), compared to the no pain group of 77.6° (±8.4). Szeto *et al.* (2005) also reported an increased mean head flexion angle of 8° for adult office workers with UQMP. Although head flexion was measured three-dimensionally, the angle was not defined similarly to that in the cohort study. The strength of association criteria could not be addressed, due to the lack of research investigating the association between upper quadrant sitting postural angles and adolescent UQMP. The dearth of relevant literature in aforementioned respect was emphasised in the systematic review presented in Chapter 7, where only five of the ten studies reported on upper quadrant sitting postural angles and adolescent UQMP. Over and above the lack of research, there was no consistency in the definitions of postural angles or the measurement of UQMP in terms of area, intensity,

[7] 'The range of physiological IV motion measured from the neutral position within which spinal motion is produced with minimal internal resistance' (Panjabi, 1992: 391)

frequency, duration and the pain recall period. As a result, it was almost impossible to draw meaningful conclusions across studies.

9.5 CLINICAL IMPLICATION

Since the predictor for adolescent UQMP was increased head flexion portrayed by high school students in the school computer classroom, it would be best fitting to address potential factors contributing to the posture while the students are using computers in said classroom. Accordingly, postural educational strategies should implement the training of non-increased head flexion postures while students interact with desk-top computers. It might also be appropriate to evaluate the school computer workstation set-up to verify that the increased head flexion posture is not a consequence of poor workstation design.

9.6 INFLUENCE OF CONFOUNDERS

The potential confounders considered for the association between sitting postural angles and UQMP in the given adolescent population were age, gender, height, weight and computer use. Psychosocial factors were not considered, since previous research had found no association between such factors and UQMP for the particular South African adolescent population in question (Smith *et al*., 2009; Brink *et al*., 2009a).

More than 50% of the students who were involved in the current study had less than a year's exposure to school computer use at baseline. The poor correlation between total computer use per week for baseline and the one-year follow-up measurements (r = 0.42) implies that students were exposed to increased amounts of computer use during the one-year period. The computer use at baseline was not a true reflection of the exposure during the course of the year, which could have affected the impact of computer use on the association between sitting postural angles and UQMP. However, it was not feasible to

arrange more repeated measurements of exposures in a school setting, due to the busy academic programmes of the schools involved.

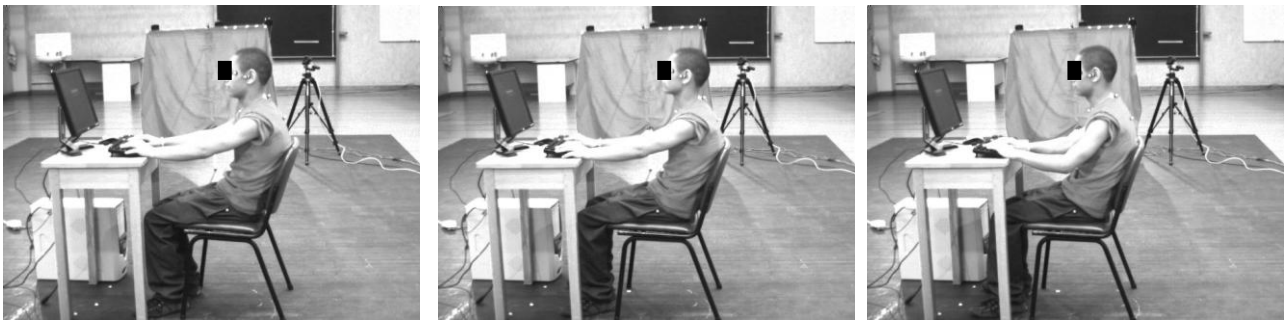
9.7 COMLEXITY OF POSTURE MEASUREMENT

The cohort study reported that all angles that produce movement in the sagittal plane (head flexion, neck flexion, cranio-cervical angle, cervico-thoracic angle and trunk flexion) had the potential to contribute to the composite sitting posture associated with seated-related UQMP, as described by the factor analysis (refer subsection 8.2.7.4). However, the angles that produce movement in the transverse (head rotation and thoracic trunk rotation) and frontal planes (head lateral bending and neck lateral bending) did not contribute to a pain-related composite sitting posture, possibly because the four angles concerned were less reproducible than were the angles producing movement in the sagittal plane (refer to Table 6.5). Rodacki Fowler, Rodacki and Birch (2001) acknowledge that the head has more degrees of freedom than does the rest of the spine, which results in greater variability of the head and neck segment. Thus, the mobility of the head/neck segment could have caused greater variability in the transverse and frontal planes than in the sagittal plane. It could be assumed that, due to the increased variability of said four angles, the students were not exposed to specific ranges of the angles for prolonged periods of time, and that, therefore, the angles demonstrated less importance related to UQMP.

Very little literature is available on the reproducibility of sitting posture of adolescents, especially where the measurement error pertains to the variability of the subject's positioning and not to the marker placement, different raters, testing procedure or the instrument concerned. To the researcher's knowledge, only Perry *et al*. (2008a) and Van Niekerk, Louw, Vaughan, Grimmer-Somers and Schreve (2008) describe the reliability of sitting postures in adolescents. Perry *et al*. (2008a) report moderate to good reliability for

all angles, except head flexion (ICC = 0.37) and the cranio-cervical angle (ICC = 0.40), whereas Van Niekerk *et al.* (2008) report very good reliability for head, cervical and thoracic angles (ICC = 1.96-1.98). The only study found that measured 3D sitting posture reported moderate ICCs for reliability of seated thoracic curvature (ICC = 0.69) and lumbar curvature (ICC = 0.52) of children, and not adolescents (Geldhof *et al*., 2007b).

McEvoy and Grimmer (2005) suggest that children and adolescents have less ability to resume a required posture, due to anthropometric and motor control immaturity. The three photographs in Figure 9.2(a-c) below show a typical example of the variability of sitting posture for the population of high school students included in the current study. The re-positioning of the chair during the phase three reliability testing could have influenced the reproducibility of the angles, as can be seen in Figure 9.2(c), where the chair is shown positioned closer to the desk than in either of the other two photographs. Consequently, specific instructions should be given to students concerning the placement of the chair and the positioning of the head/neck segment when reliability is tested.



(a) First capture (b) Second capture (c) Third capture

Figure 9.2(a-c) A set of three consecutive photographs, demonstrating the variability in sitting posture during the phase three reliability testing

The difference in the capture rate of the Vicon system, in comparison with that of the 3D-PAT, also exaggerated the problem of sitting posture variability, as there was an increased chance that the two instruments failed to capture the exact same sitting posture. However the angular data from the 3D-PAT were matched with a frame from the Vicon system with the best-fitting angular data to compensate for the measurement problem concerned.

The phase two reliability and validity study revealed that the values from the x-axis had the largest bias, compared to the values from the y- and z-axes (refer to Table 5.2), with poor marker reconstruction of the T_5 SP being observed in all the studies using humans. A prominent factor that influences the accuracy of marker coordinate calculation when using cameras is the angle between the line of sight from two cameras to the marker (Trobina, 1995). The line of sight is from the optical centre of the camera, which is fixed, to the centre of the spherical reflective marker. The line can vary, depending on the accuracy with which the centre of the spherical reflective marker is located. If the angle between the line of sight from two cameras is small (closer to 0° for calculation of the x-coordinate data, where the two cameras are positioned on one steel cross-bar) or large (closer to 180° for the T_5 SP digitisation, where the two cameras are positioned on either side of the student), a small deviation in the orientation of the line of sight produces a large error in calculating the depth (the distance from the camera) of the coordinates studied. In the current study, often only half of the T5 marker was visible, thus compromising the accuracy in depicting the centre of the marker, which also influenced the orientation of the line of sight. The longer axis of the ellipse in Figure 9.3 below demonstrates the greater error in depth.

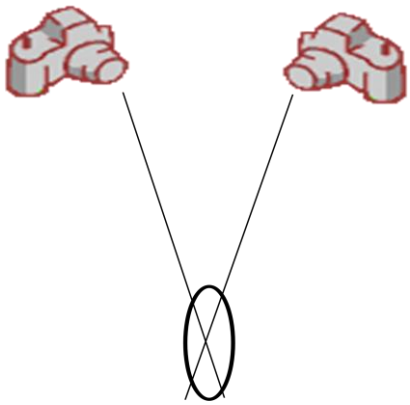


Figure 9.3 The measurement error due to the small angle between the line of sight from two cameras positioned on one cross-bar

The cohort study reported comparable mean sitting postural angles for high school students compared to previous cross-sectional studies for head flexion (66° to 80°), cranio-cervical angle (151° to 160°), cervico-thoracic angle (149° to 152°), trunk flexion (-13° to -22°), neck lateral bending (0.4° to 0.9°) and head rotation (-0.4° to 1.7°), where the angles were defined as they had been for the research project (Briggs *et al*., 2004; Straker *et al*., 2007, 2008b, 2009b; O'Sullivan *et al*., 2011a). No other study reported head lateral bending or thoracic trunk rotation as defined in the current research project, thus no comparison could be made to the previous research. However, the variation, as demonstrated by the SD, of neck lateral bending (±12.4°; ±17.9°) and head rotation (±7.6°; ±8.5°), was greater in the present research project than it was in comparison to a previous study with SD of ±0.9° for both the angles concerned (Straker *et al*., 2009b). From the cohort data obtained, it is evident that, as neck flexion and head flexion angles increased, neck lateral bending also increased, which could indicate that a projection fault occurred when the neck lateral bending was calculated in the frontal plane, thus explaining the greater variability in neck lateral bending. There are two ways in which neck lateral bending, represented by the θ angle in Figure 9.4 below, could be measured. In the first case, the OC1 moved only in the frontal plane and θ was measured in the frontal plane.

Thus, the angle was a true reflection of neck lateral bending. In the second case, the same magnitude of OC1 movement laterally was also accompanied by neck flexion in the sagittal plane, so that the OC1' was no longer within the frontal plane. However, the θ angle was still measured in the frontal plane once the OC1' was projected onto the frontal plane, which was represented by $OC1'_a$. The θ angle was measured between the vertical line and $OC1'_a$ which was not a true reflection of neck lateral bending in the frontal plane. It is suggested that neck lateral bending be defined as the smallest angle between a line from the OC1 to the C_7 SP in the sagittal plane. The head rotation angle was consequently also influenced by neck lateral bending.

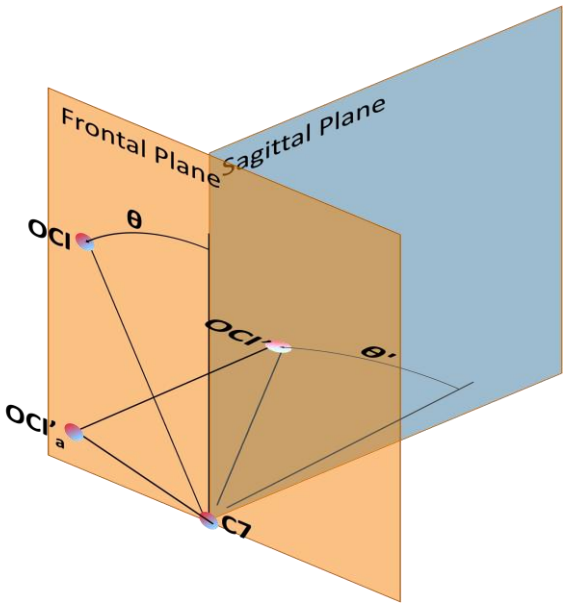


Figure 9.4 The projection fault occurring when neck lateral bending was calculated in the frontal plane

The students wore comfortable clothes during the postural evaluation in order to ensure that they displayed their habitual classroom sitting posture. However, the school pants did not fit tightly, so that the creases around the pants' pockets could have influenced the greater trochanter's marker stability during the postural evaluation, since they either allowed for the marker concerned to move away from the body, or obscured its visibility.

The portable 3D-PAT proved to be efficient in measuring six of the nine sitting postural angles in 3D satisfactorily in a research setting. Considering the 3D-PAT's low cost, the instrument compared well with an expensive, state-of-the-art reference standard.

CHAPTER 10

LIMITATIONS

10.1 LIMITATIONS PERTAINING TO THE MEASUREMENT INSTRUMENTS

The limitations pertaining to the measurement instruments were as follows:

- The JPEG decompression process used for the digitisation process of the photographic images, caused data degradation of the image, and could have influenced the accuracy of marker selection (Van der Westhuizen, 2011).
- One of the 3D-PAT cameras showed a high pixel error, resulting in poor performance during camera-pair triangulation (Van der Westhuizen, 2011).
- The 3D-PAT had five cameras for capturing the lefthand and righthand side of the subject. Since the lateral side-on views were unbalanced, it could be that fewer camera pairs existed to capture a marker that was only visible from either the left or right side, thus decreasing the accuracy of marker reconstruction.
- The exclusion of trial one from the phase two study was possibly due to a poor capture of the first trial by the Vicon system, as the y-coordinate values of the four head markers were outliers and significantly different to the values obtained by the Vicon system for trials eight and nine (refer to subsection 5.2.1). The result was that 14 fewer reflective markers could be used for the analysis.
- Ten capture trials from both the phase three and cohort studies had to be excluded after the 3D-PAT's marker reconstruction process revealed an incorrect 3D placement of the head markers used.

10.2 LIMITATIONS PERTAINING TO THE METHODOLOGICAL PROCEDURES

The limitations pertaining to the methodological procedures were as follows:

- The mannequin's positioning in relation to the 3D-PAT cameras was not always optimal for reflective marker visibility, since different positions were captured as a means to test and to confirm the best positioning of a future subject within the capture volume of the 3D-PAT (refer to subsection 5.2.1 above). In addition to the mannequin's positioning, the mannequin's head was fixed in a forward flexion and rotation position, which resulted in poor visibility of certain reflective markers in certain mannequin positions. For instance, for mannequin position seven (refer to subsection 5.2.2.2), the mannequin was tilted forward towards the left, and combined with the mannequin's fixed head alignment, the x- coordinates of the left canthus and left trachus were observed as outliers, possibly because poor visibility had caused poor digitisation.
- The low response rate (59.8%) at baseline resulted in a lower sample size than what was statistically required. Even though a sufficient number of students were screened at baseline, an unexpected number of students had to be excluded, according to the inclusion and exclusion criteria applied. Improvements were made to the 3D-PAT, after which the phases two and three studies were implemented parallel to the implementation of the cohort study, resulting in the improved instrument not being available for the postural evaluation of the first two schools at baseline. The postural data from the two schools in question had to be excluded from the cohort data analysis, as the angles obtained could not be trusted. The exclusion also contributed to reducing the sample size by 15. Of the students, 41 (21%) were lost to follow-up during the one year. However, the number of students who participated in the follow-up was 17% and 6% more than were reported by Feldman *et al*. (2002) and Grimmer *et al*. (2006), respectively. The low response rate, excluding the loss of certain

postural data and follow-up, led to the inadequate statistical power of the study and could possibly have influenced the magnitude and the number of observed associations between sitting posture and UQMP.

- The two occasions (six-month and one-year follow-up), when the outcome, adolescent UQMP was measured, might have been too little to allow for full comprehension of the development of adolescent UQMP, since the one-month pain recall period omitted any consideration of pain during the five months prior to the month in question. However, no prospective studies that measured pain more often among adolescents could be found during the literature survey.

CHAPTER 11

RECOMMENDATIONS

The following recommendations are made, based on the findings of the current research:

- More psychometric testing for validity and reliability of the 3D-PAT, with sufficient sample sizes, needs to be undertaken.
- Instructions should be given to students concerning the placement of the chair and the positioning of the head/neck segment when reliability is tested.
- An additional 3D-PAT camera should be positioned on the tripod, in order to balance the lateral side-on views of the subject, so as to allow for an increase in the number of camera pairs for triangulation, thus increasing the accuracy of marker reconstruction.
- Different clothing for postural evaluation could be introduced, especially in respect of the clothing covering the greater trochanters and the T_5 SP, in order to optimise the stability and visibility of the markers in sitting.
- Larger sample sizes that meet the statistical power of longitudinal studies as regards assessing sitting postural angles of high school students in a classroom setting should be undertaken. The increased statistical power would enhance the ability of the studies, by means of inferential statistical tests, to determine a causal relationship between the exposure and the outcome, if such exists, and to observe an additional number of associations of modest magnitude.
- Increased frequency of the measurement of the outcome, adolescent UQMP, during the duration of the cohort studies would be recommended to aid with the

interpretation of the relationship between sitting postural angles and adolescent UQMP.

- Further research should determine which is the most appropriate, reliable adolescent pain recall period for cohort studies in which the outcome is a recurring event such as musculoskeletal pain.

CHAPTER 12

CONCLUSION

The project implemented an objective 3D posture measurement instrument that provided six reliable and valid sitting postural angles in high school students. The validity findings revealed good to very good agreement for head flexion, neck flexion, cranio-cervical angle, trunk flexion, head lateral bending, and head rotation. The reliability findings revealed good to very good test-retest reliability for head flexion, neck flexion, cranio-cervical angle, trunk flexion and head lateral bending. Thus, the instrument concerned can be regarded as being highly suitable for the assessment of computer-related classroom postures in South African high schools.

The research project described in the current dissertation was a novel approach to understanding the causal pathway between sitting postural angles of the upper quadrant and seated-related UQMP in computing high school students. The primary finding of the research project was that increased head flexion, greater than 80°, is a predictor of seated-related UQMP developing within six to 12 months for those computing high school students with a pain score equal or greater than the 90th percentile for pain. Thus, postural alignment could be the source of UQMP, due to the causal relationship between increased head flexion and seated-related UQMP in computing high school students. Therefore, postural educational training should encourage non-increased head flexion postures while students are interacting with desk top computers.

The findings of future cohort studies may provide further insight into the causal relationship between sitting postural angles and adolescent UQMP. Such additional insight would enable health professionals to formulate evidence-based preventative strategies to address the rising prevalence of adolescent UQMP effectively.

REFERENCES

Adamson, G., Murphy, S., Shelvin, M. & Buckle, P.S. 2007. Profiling schoolchildren in pain and associated demographic and behavioural factors: A latent class approach. *Pain,* 129(3):295-303.

Alix, M.E. & Bates, D.K. 1999. A proposed etiology of cervicogenic headache: The neurophysiologic basis of antomic relationship between the dura mater and the Rectus posterior minor muscle. *Journal of Manipulative and Physiological Therapeutics,* 22(8):534-539.

Aprill, C., Axinn, M.J. & Bogduk, N. 2002. Occipital headaches stemming from the lateral atlanto-axial (C1-2) joint. *Cephalalgia,* 22(1):15-22.

Astfalck, R.G., O'Sullivan, P., Straker, L.M., Smith, A.J., Burnett, A. & Caneiro, J.P. 2010. Sitting postures and trunk muscle activity in adolescent with and without nonspecific chronic low back pain. *Spine*, 35(14):1387-1395.

Auvinen, B.M., Tammelin, T., Taimela, S., Zitting, P. & Karppinen, J. 2007. Neck and shoulder pains in relation to physical activity and sedentary activities in adolescence. *Spine*, 32(9):1038-1044.

Bannigan, K. & Watson, R. 2009. Reliability and validity in a nutshell. *Journal of Clinical Nursing*, 18(23):3237-3243.

Barrero, M. & Hedge, A. 2002. Computer environment for children: A review of design issues. *Work*, 18(3):227-237.

Beach, T.A.C., Parkinson, R.J., Stothart, J.P. & Callaghan, J.P. 2005. Effects of prolonged sitting on the passive flexion stiffness of the in vivo lumbar spine. *The Spine Journal,* 5(2):145-154.

Black, K.M., McClure, P. & Polansky, M. 1996. The influence of different sitting positions on cervical and lumbar posture. *Spine*, 21(1):65-70.

Bland, J.M. & Altman, D.G. 1990. A note on the use of the intra-class correlation coefficient in the evaluation of agreement between two methods of measurement. *Computers in Biology and Medicine,* 20(5):337-340.

Bland, J.M. & Altman, D.G. 1999. Measuring agreement in method comparison studies. *Statistical Methods in Medical Research,* 8(2):135-160.

Bogduk, B. & Mercer, S. 2000. Biomechanics of the cervical spine. I: Normal kinematics. *Clinical Biomechanics,* 15(9):633-648.

Bossuyt, P.M., Reitsma, J.B., Bruns, D.E., Gatsonis, C.A., Glasziou, P.P., Irwig, L.M., Moher, D., Rennie, D., De Vet, H.C.W. & Lijmer, J.G. 2003. The STARD Statement for

reporting studies of diagnostic accuracy: Explanation and elaboration. *Clinical Chemistry,* 49(1):7-18.

Boyd-Clark, L.C., Briggs, C.A. & Galea, M.P. 2002. Muscle spindle distribution, morphology and density in longus colli and multifidus muscles of the cervical spine. *Spine,* 27(7):694-701.

Brattberg, G. 2004. Do pain problems in young school children persist into early adulthood? A 13-year follow-up. *European Journal of Pain*, 8(3):187-199.

Briggs, A., Straker, L. & Grieg, A. 2004. Upper quadrant postural changes of school children in response to interaction with different information technologies. *Ergonomics,* 47(7):790-819.

Briggs, A.M., Smith, A.J., Straker, L.M. & Bragge, P. 2009a. Thoracic spine pain in the general population: Prevalence, incidence and associated factors in children, adolescents and adults. A systematic review. *BMC Musculoskeletal Disorders,* 10:77.

Briggs, A.M., Straker, L.M., Bear, N.L. & Smith, A.J. 2009b. Neck/shoulder pain in adolescents is not related to the level or nature of self-reported physical activity or type of sedentary activity in an Australian pregnancy cohort. *BMC Musculoskeletal Disorders*, 10:87.

Brink, H. 2006. Fundamentals of research methodology for health care professionals. *Cape Town: Juta*.

Brink, Y., Crous, L.C., Louw, Q.A., Grimmer-Somers, K. & Schreve, K. 2009a. The association between postural alignment and psychosocial factors to upper quadrant pain in high school students: A prospective study. *Manual Therapy*, 14(6):647-653.

Brink, Y., Hillier, S., Louw, Q. & Schreve, K. 2009b. The influence of computer use on the sitting posture of high school students who developed neck and shoulder pain. *South African Journal of Physiotherapy*, 65(2):21-26.

Brink, Y., Louw, Q. & Grimmer-Somers, K. 2011. The quality of evidence of psychometric properties of three-dimensional spine posture-measuring instruments, *BMC Musculoskeletal Disorders*, 12:93.

Brink, Y., Louw, Q. 2012. Clinical Instruments: Reliability and validity critical appraisal, *Journal of Evaluation in Clinical Practice*, 18(6):1126-1132.

Brolin, K. & Halldin, P. 2004. Development of a finite element model of the upper cervical spine and a parameter study of ligament characteristics. *Spine,* 29(4):376-385.

Bullock-Saxton, J. 1993. Postural alignment in standing: A repeatability study. *Australian Physiotherapy,* 39(1):25-29.

Burgess-Limerick, R., Plooy, A., Fraser, K. & Ankrum, D.R. 1999. The influence of computer height on head and neck posture. *International Journal of Industrial Ergonomics,* 23(3):171-179.

Burgess-Limerick, R., Mon-Williams, M. & Coppard, V.L. 2000. Visual display height. *Human factors,* 41(1):140-150.

Caneiro, J.P., O'Sullivan, P., Burnett, A., Barach, A., O'Neil, D., Tveit, O. & Olafsdottir, K. 2010. The influence of different sitting postures on head/neck posture and muscle activity. *Manual Therapy,* 15(1):54-60.

Cardon, G., De Clercq, D., De Bourdeaudhuij, I. & Breithecker, D. 2004. Sitting habits in elementary schoolchildren: A traditional versus a 'Moving school'. *Patient Education and Counseling*, 54(2):133-142.

Cargill, S.C., Pearcy, M. & Darrell B.M. 2007. Three-dimensional lumbar spine postures measured by magnetic resonance imaging reconstruction. *Spine*, 32(11):1242-1248.

Carlin, J.B. & Doyle, L.W. 2003. Statistics for clinicians, 7: Sample size. *Journal of Paediatric and Child Health*, 38(3):300-304.

Cho, C.Y. 2008. Survey of faulty postures and associated factors among Chinese adolescents. *Journal of Manipulative Physiological Therapeutics*, 31(3):224-229.

Claus, A.P., Hides, J.A., Moseley, G.L. & Hodges, P. 2009. Is 'ideal' sitting posture real?: Measurement of spinal curves in four sitting postures. *Manual Therapy,* 14(4):404-408.

Coleman, J., Straker, L. & Ciccarelli, M. 2009. Why do children think they get discomfort related to daily activities? *Work*, 32(3):267-274.

Curriculum development: WCED. 2012. [Online] Available: http://curriculum-dev.wcape.school.za [2012, July 13]

Drerup, B. & Hierholzer, E. 1994. Back shape measurement using video rasterstereography and three-dimensional reconstruction of spinal shape. *Clinical Biomechanics*, 9(1):28-36.

Drerup, B. & Hierholzer, E. 1996. Assessment of scoliotic deformity from back shape asymmetry using an improved mathematical model. Clinical Biomechanics, 11(7):376-383.

Domenech, M.A., Sizer, P.T., Dedrick, G.S., McGilliard, M.K. & Brismee, J. 2011. The deep neck flexor endurance test: normative data scores in healthy adults. *Physical Medicine and Rehabilitation*, 3(4):105-110.

D'Osualdo, F., Schierano, S., Soldano, M. & Isola, M. 2002. New tridimensional approach to the evaluation of the spine through surface measurement: the BACES system. *Journal of Medical Engineering & Technology*, 26(3):95-105.

Diepenmaat, A.C.M., Van der Wal, M.F.V. & De Vet, H.C.W. 2006. Neck/shoulder, low back, and arm pain in relation to computer use, physical activity, stress, and depression among Dutch adolescents. *Pediatrics,* 117(2):412-416.

Duong, L., Mac-Thiong, J. & Labelle, H. 2009. Real time non-invasive assessment of external trunk geometry during surgical correction of adolescent idiopathic scoliosis. *Scoliosis*, 4(5):5-15.

Edmondston, S., Bjornsdottir, G., Palsson, T., Solgard, H., Ussing, K. & Allison, G. 2011. Endurance and fatigue characteristics of the neck flexor and extensor muscles during isometric tests in patients with postural neck pain. *Manual Therapy*, 16(4):332-338.

Ehara, Y., Fujimoto, H., Miyazaki, S., Mochimaru, M., Tanaka, S. & Yamamoto, S. 1997. Comparison of the performance of 3D camera systems II*. Gait and Posture*, 5(3):251-255.

El-Metwally, A., Salminen, J.J., Auvinen, A., Kautiainen, H. & Mikkelsson, M. 2004. Prognosis of non-specific musculoskeletal pain in preadolescents: A prospective 4-year follow up study till adolescence. *Pain*, 110(3):550-559.

Falla, D., Jull, G., Russell, T., Vincenzino, B. & Hodges, P. 2007. Effect of neck exercises on sitting posture in patients with chronic neck pain. *Physical Therapy*, 87(4):408-417.

Feldman, D.E., Shrier, I., Rossignol, M. & Abenhaim, L. 2002. Risk factors for the development of neck and upper limb pain in adolescents. *Spine*, 27(5):523-528.

Fitzpatrick, J., West, J.B. & Maurer, J.R. 1998. Predicting error in rigid-body point-based registration, *IEEE Transactions on Medical Imaging,* 17(5):694–702.

Franklin, M.E., Chenier, T.C., Brauninger, L., Cook, H. & Harris, S. 1995. Effect of positive heel inclination on posture. *Journal of Orthopaedic Sports and Physical Therapy*, 21(2):94-99.

Geldhof, E., De Clercq, D., De Bourdeaudhuij, I. & Cardon, G. 2007a. Classroom postures of 8-12 year old children. *Ergonomics*, 50(10):1571-1581.

Geldhof, E., Cardon, G., De Bourdeaudhuij, I., Daneels, L., Coorevits, P., Vanderstraeten, G. & De Clerq, D. 2007b. Effects of back posture education on elementary schoolchildren's back function. *European Spine Journal*, 16(6):829-839.

Geldhof, E., Cardon, G., De Bourdeaudhuij, I. & De Clerq, D. 2007c. Back posture education in elementary schoolchildren: A 2-year follow-up study. *European Spine Journal*, 16(6):841-850.

Gram, M. & Hasan, Z. 1999. The spinal curve in standing and sitting posture in children with idiopathic scoliosis. *Spine*, 24(2):169-177.

Griegel-Morris, P., Larson, K., Meuller-Klaus, K. & Oatis, C.A. 1992. Incidence of common postural abnormalities in the cervical, shoulder, and thoracic regions and their association with pain in two age groups of healthy subjects. *Physical Therapy,* 72(6):425-431.

Grimmer, K., Nyland, l. & Milanese, S. 2006. Longitudinal investigation of low back pain in Australian adolescents: A five year study. *Physiotherapy Research International,* 11(3):161-172.

Grip, H., Sundelin, G., Gerdle, B. & Karlsson, J.S. 2007. Variations in the axis of motion during head repositioning – A comparison of subjects with whiplash-associated disorders or non-specific neck pain and healthy controls. *Clinical Biomechanics*, 22(8):865-873.

Guite, J.W., Logan, D.E., Sherry, D.D. & Rose, J.B. 2007. Adolescent self-perception: Associations with chronic musculoskeletal pain and functional disability*. The Journal of Pain,* 8(5):379-386.

Hackenberg, L., Hierholzer, E., Potzl, W., Gotze, C. & Liljenqvist, U. 2003a. Rasterstereographic back shape analysis in idiopathic scoliosis after anterior correction and fusion. *Clinical Biomechanics,* 18(1):1-8.

Hackenberg, L., Hierholzer, E., Potzl, W., Gotze, C. & Liljenqvist, U. 2003b. Rasterstereographic back shape analysis in idiopathic scoliosis after posterior correction and fusion. *Clinical Biomechanics*, 18(10):883-889.

Hakala, P.T., Saarni, L.A., Ketola, R.L., Rahkola, E.T., Salminen, J.J., & Rimpela, A.H. 2010. Computer-associated health complaints and sources of ergonomics instructions in computer-related issues among Finnish adolescents: A cross-sectional study. *BMC Public Health*, 10:41.

Hakala, P.T., Saarni, L.A., Punamaki, R.L., Wallenius, M.A., Nygard, C.H. & Rimpela, A.H. 2012. Musculoskeletal symptoms and computer use among Finnish adolescents – pain intensity and inconvenience to everyday life: A cross-sectional study. *BMC Musculoskeletal Disorders*, 13:41.

Harris, C. & Straker, L. 2000. Survey of physical ergonomics issues associated with school children's use of laptop computers*. International journal of Industrial Ergonomics*, 26(3):337-346.

Harrison, D.E., Cailliet, E., Harrison, D.D., Troyanovich, S.J. & Harrison, S.O. 1999. A review of biomechanics of the central nervous system – Part II: Spinal cord strains from postural loads. *Journal of Manipulative and Physiological Therapeutics,* 22(5):322-332

Harrison, D.E., Janik, T.J., Calliet, R., Harrison, D.D., Normand, M.C. & Perron, D.L. & Ferrantelli, J.R. 2007. Validation of a computer analysis to determine 3-D rotations and translations of the rib cage in upright posture from three 3-D digital images. *European Spine Journal*, 16(2):213-218.

Hay, O., Hershkovitz, I. &, Rivlin, E. 2009. Spine curve modelling for quantitative analysis of spinal curvature, in *31st Annual International Conference of the IEEE EMBS, Minneapolis, Minnesota, USA, September*. 6356-6359.

Hill, A.B. 1965. The environment and disease: Association or causation. *Proceedings of the Royal Society of Medicine,* 58:295-300

Howell, F.R., Mahood, J.K. &Dickson, R.A. 1992. Growth beyond skeletal maturity. *Spine*, 17(4):437-440.

Jang, R., Karwowski, W., Quesadas, P.M., Rodrick, D., Sherehiy, B., Cronin, S.N. & Layer, J.K. 2007. Biomechanical evaluation of nursing tasks in a hospital setting. *Ergonomics*, 50(11):1835-1855.

Janik, T.J., Harrison, D.E., Calliet, R., Harrison, D.D., Normand, M.C. & Perron, D.L. 2007. Validity of a computer postural analysis to estimate 3-dimensional rotations and translations of the head from three 2-dimensional digital images. *Journal of Manipulative and Physiological Therapeutics*, 30(2):124-129.

Karanicolas, P.J., Bhandari, M., Kreder, H., Moroni, A., Richardson, M., Walter, S.D., Norman, G.R., & Guyatt, G.H. 2009. Evaluating agreement: Conducting a reliability study. *The Journal of Bone & Joint Surgery,* 91(supplement 3):99-106.

Kelly, G., Dockrell, S. & Galvin, R. 2009. Computer use in school: Its effect on posture and discomfort in schoolchildren. *Work*, 32(3):321-328.

Kendall, F.P., McCreary, E.K. & Provance P.G. 1993. *Muscles testing and function*. 4th edition. Baltimore, MD: Williams & Wilkins

Lafon, Y., Smith, F.W. & Beillas, P. 2010. Combination of a model-deformation method and a positional MRI to quantify the effects of posture on the anatomical structures of the trunk. *Journal of Biomechanics*, 43(7):1269-1278.

Law, M., Stewart, D., Pollock, N., Letts, L., Bosch, J. & Westmoreland, M. 1998a. *Critical review form – quantitative studies.* Hamilton, ON: McMaster University.

Law, M., Stewart, D., Pollock, N., Letts, L., Bosch, J. & Westmoreland, M. 1998b. *Critical review form - quantitative studies.* McMaster University. [Online] Available: http://www.srs-mcmaster.ca/Portals/20/pdf/ebp/quanreview.pdf [2012, May 31].

Law, M., Stewart, D., Pollock, N., Letts, L., Bosch, J. & Westmoreland, M. 1998c. *Guidelines for critical review form - quantitative studies*. McMaster University. [Online] Available: http://www.srs-mcmaster.ca/Portals/20/pdf/ebp/quanguidelines.pdf [2012, May 31].

Liddle, J., Williamson, M. & Irwig, L. 1996. *Method for evaluating research and guideline evidence (MERGE)*. Sydney: New South Wales Department of Health.

Levine, D. & Whittle, M.W. 1996. The effects of pelvic movement on lumbar lordosis in the standing position. *Journal of Orthopaedic Sports and Physical Therapy*, 24(3):130-135.

Li, G. & Buckle, P. 1999. Current techniques for assessing physical exposure to work-related musculoskeletal risks, with emphasis on posture-based methods. *Ergonomics*, 42(5):674-695.

Li Lu, M.S. & Nawar, S. 2007. *Reliability analysis: Calculate and compare intra-class correlation coefficients (ICC) in SAS*. Northeast SAS Users Group (*NESUG).*

Lin, l.I. 1989. A concordance correlation coefficient to evaluate reproducibility. *Biometrics,* 45(1):255-268.

Lissoni, A., Caimmi, M., Rossini, M. & Terenghi, L. 2001. Three-dimensional analysis of the sitting posture*. Europa Medicophysica*, 37(2):101-109.

Lucas, N.P., Macaskill, P., Irwig, L. & Bogduk, N. 2010. The development of a quality tool for studies of diagnostic reliability (QAREL). *Journal of Clinical Epidemiology*, 63 (8), 854-861.

Marcus, M., Gerr, F., Monteilh, C., Ortiz, D.J., Gentry, E., Cohen, S., Edwards, A., Ensor, C. & Kleinbaum, D. 2002. A prospective study of computer users: II. Postural risk factors

for musculoskeletal symptoms and disorders. *American Journal of Industrial Medicine,* 41(4):236-249.

McEvoy, M.P. & Grimmer, K., 2005. Reliability of upright posture measurements in primary school children. *BMC Musculoskeletal Disorders,* 6:35

Mikkelsson, M., El-Metwally, A., Kautiainen, H., Auvinen, A., Macfarlane, G.J. & Salminen, J.J. 2008. Onset, prognosis and risk factors for widespread pain in schoolchildren: A prospective 4-year follow-up study. *Pain,* 138(3):681-687.

Moher, D., Liberati, A., Tetzlaff, J. & Altman, D.G. 2009. Preferred reporting items for systematic reviews and meta-analyses: The PRISMA statement. *PLOS Medicine*, 6(7):e1000097.

Morl, F. & Blickhan, R. 2006. Three-dimensional relation of skin markers to lumbar vertebrae of healthy subjects in different postures measured by open MRI. *European Spine*, 15(6):742-751.

Murphy, S., Buckle, P. & Stubbs, D. 2002. The use of the portable ergonomic observation method (PEO) to monitor the sitting posture of schoolchildren in the classroom. *Applied Ergonomics*, 33(4):365-370.

Murphy, S., Buckle, P. & Stubbs, D. 2004. Classroom posture and self-reported back and neck pain in school children. *Applied Ergonomics*, 35(2):113-120.

Murphy, S., Buckle, P. & Stubbs, D. 2007. A cross-sectional study of self-reported back and neck pain among English schoolchildren and associated physical and psychosocial risk factors. *Applied Ergonomics*, 38(6):797-804.

Naslund, A., Jesinkey, K., Sundelin, G., Von Wendt, L. & Hirschfeld, H. 2005. Effects of dynamic ankle-foot orthoses on standing in children with severe spastic diplegia. *International Journal of Therapy and Rehabilitation*, 12:200-207.

Negrini, S. & Negrini, A. 2007. Postural effects of symmetrical and asymmetrical loads on the spines of schoolchildren. *Scoliosis,* 2(8):8-14.

Neiva, P.D, Kirkwood, R.N. & Godinho, R. 2009. Orientation and position of head posture, scapula and thoracic spine in mouth-breathing children. *International Journal of Pediatric Otorhinolaryngology*, 73:227-236.

Norkin, C.C. & Levangie, P.K. 1992. Joint *structure and function: A comprehensive analysis*. 2nd edition. Philadelphia, PA Davids.

Normand, M.C., Harrison, D.E., Calliet, R., Black, P., Harrison, D.D. & Holland, B. 2002. Reliability and measurement error of the Biotonix Video Posture Evaluation system – Part I: Inanimate objects. *Journal of Manipulative and Physiological Therapeutics*, 25(4):246-250.

Normand, M.C., Descarreaux, M., Harrison, D.D., Harrison, D.E., Perron, D.L., Ferrantelli, J.R. & Janik, T.J. 2007. Three dimensional evaluation of posture in standing with the PosturePrint: An intra- and inter-examiner reliability study. *Chiropractic & Osteopathy*, 15(15):15-25.

Norton, B.J. & Ellison, J.B. 1993. Reliability and concurrent validity of the Metrecom for length measurements on inanimate objects. *Physical Therapy*, 73(4):266-274.

Olsen, K.A. & Joder, D. 2001. Diagnosis and treatment of cervical spine clinical instability. *Journal of Orthopaedic & Sports Physical Therapy*, 31(4):194-206.

O'Sullivan, P.B., Grahamshaw, K.M., Kendell, M., Lapenskie, S.C., Moller, N.E. & Richards, K.V. 2002, The effect of different standing and sitting postures on trunk muscle activity in a pain fee population. *Spine,* 27(11) 1238-1244.

O'Sullivan, P., Dankaerts, W., Burnett, A., Straker, L., Bargon, G., Moloney, N., Perry, M. & Tsang, S. 2006. Lumbopelvic kinematics and trunk muscle activity during sitting on stable and unstable surfaces. *Journal of Orthopaedic & Sports Physical Therapy*, 36(1):19-25.

O'Sullivan, K., O'Dea, P., Dankearts, W., O'Sullivan, P., Clifford, A. & O'Sullivan, L. 2010. Neutral lumbar spine sitting posture in pain free subjects. *Manual Therapy,* 15(6):557-561.

O'Sullivan, P., Beales, D., Jensen, L., Murray, K. & Myers, T. 2011a. Characteristics of chronic non-specific musculoskeletal pain in children and adolescents attending a rheumatology outpatients clinic: A cross-sectional study. *BMC Pediatric Rheumatology*, 9:3

O'Sullivan, P.B., Smith, A.J., Beales, D.J. & Straker, L.M. 2011b. Association of biopsychosocial factors with degree of slump in sitting posture and self-report of back pain in adolescents: a cross-sectional study. *Physical Therapy*, 91(4):470-483.

Paananen, M., Taimela, S.P., Auvinen, J.P., Tammelin, T.H., Kantomaa, M.T., Ebeling, H.E., Taanila, A.M., Zitting, P.J. & Karppinen, J.I. 2010. Risk factors for persistence of multiple musculoskeletal pains in adolescence: A 2-year follow up study. *European Journal of Pain*, 14(10):1026-1032.

Panabi, M.M. 1992. The stabilizing system of the spine. Part II. Neutral zone and instability hypothesis. Journal of Spinal Disorders & Techniques, 5(4):390-397.

Pazos, V., Cheriet, F., Song, L., Labelle, H. & Dansereau, J. 2005. Accuracy assessment of human trunk surface 3D reconstructions from an optical digitising system. *Medical & Biological Engineering & Computing,* 43(1):11-15.

Pazos, V., Cheriet, F., Dansereau, J., Ronsky, J., Zernicke, R.F. & Labelle, H. 2007. Reliability of trunk shape measurements based on 3-D surface reconstructions. *European Spine Journal*, 16(11):1882-1891.

Pearcy, M.J. & Hindle, R.J. 1989. New method for the non-invasive three-dimensional measurement of human back movement. *Clinical Biomechanics*, 4(2):73-79.

Perry, M., Smith, A., Straker, L., Coleman, J. & O'Sullivan, P. 2008a. Reliability of sagittal photographic spinal posture assessment in adolescents. *Advances in Physiotherapy,* 10(2):66-75.

Perry, M.C., Straker, L.M., O'Sullivan, P.B., Smith, A.J. & Hands, B. 2008b. Fitness, motor competence and body composition as correlates of adolescent neck/shoulder pain: An exploratory cross-sectional study. *BMC Public Health*, 8: 290.

Portney, L.G., Watkins, M.P. 2009. *Foundations of clinical research: Applications to practice.* 2nd edition. Upper Saddle River, NJ: Pearson Education.

Poussa, M.S., Heliovaara, M.M., Seitsamo, J.T., Kononen, M.H., Hurmerinta, K.A. & 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.

Prins, Y. 2008. *The aetiology of upper quadrant musculoskeletal pain in high school learners using desktop computers: A prospective study.* Stellenbosch: Stellenbosch University. [Online] Available: http://hdl.handle.net/10019.1/1996 [2012, July 18].

Prins, Y., Crous, L.C. & Louw, Q.A. 2008. A systematic review of posture and psychosocial factors as contributors to upper quadrant musculoskeletal pain in children and adolescents. *Physiotherapy Theory and Practice*, 24(4):221-242.

Raine, S. & Twomey, L.T. 1994. Posture of the head, shoulders and thoracic spine in comfortable erect standing. *Australian Physiotherapy*, 40(1):25-32.

Ramos, E.M.A., James, C.A. & Bear-Lehman, J. 2005. Children's computer usage: Are they at risk of developing repetitive strain injury? *Work*, 25:143-154.

Rees, C.S., Smith, A.J., O'Sullivan, P.B., Kendall, G.E. & Straker, L.M. 2011. Back and neck pain are related to mental health problems in adolescence. *BMC Public Health,* 11:382.

Rempel, D., Barr, A., Brafman, D. & Young, E. 2007. The effect of six keyboard designs on wrist and forearm postures. *Applied Ergonomics*, 38(3):293-298.

Rodacki, C.L.N., Fowler, N.E., Rodacki, A.L.F. & Birch, K. 2001. Repeatability of measurement in determining stature in sitting and standing postures. *Ergonomics*, 44(12):1076-1085.

Schulz, K.F. & Grimes, D.A. 2005. Epidemiology 1: Sample size calculations in randomized trials: Mandatory and mystical. *The Lancet*, 356(9467):1348-1353.

Sheeran, L., Sparkes, V., Busse, M. & 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.

Shoukri, M.M., Colak, D., Kaya, N. & Donner, A. 2008. Comparison of two dependent within subject coefficients of variation to evaluate the reproducibility of measurement devices. *BMC Medical Research Methodology,* 8:24.

Siivola, S.M., Levoska, S., Latvala, K., Hoskio, E., Vanharanta, H., & Keinanen-Kiukaanniemi, S. 2004. Predictive factors for neck and shoulder pain: A longitudinal study in young adults. *Spine,* 29(15):1662-1669.

Silva, A.G., Punt, T.D., Sharples, P., Vilas-Boas, J.P. & Johnson, M.I. 2009. Head posture and neck pain of chronic non traumatic origin: A comparison between patients and pain-free persons. *Archives of Physical Medicine Rehabilitation.* 90(4):669-674.

Sjolie, A.N. 2004. Persistence and change in nonspecific low back pain among adolescents: A 3-year prospective study. *Spine*, 29(21):2452-2457.

Skalli, W., Zeller, R.D., Miladi, L., Bourcereau, G., Savidan, M., Lavaste, F. & Dubousset, J. 2006. Importance of pelvic compensation in posture and motion after posterior spinal fusion using CD instrumentation for idiopathic scoliosis. *Spine*, 31(12):E359-E366.

Smidt, G.L., McQuade, K.J. & Wei, S. 1992. Evaluation of the Metrecom and its use in quantifying skeletal landmark locations. *Journal of Orthopaedic Sports and Physical Therapy*, 16(4):182-188.

Smith, L. 2007. *Computer-related musculoskeletal dysfunction among adolescent school learners in the Cape metropolitan region*. Stellenbosch: Stellenbosch University. [Online] Available http://hdl.handle.net/10019.1/1545 [2012, July 18].

Smith, L., Louw, Q.A., Crous, L.C. & Grimmer-Somers, K. 2009. Prevalence of neck pain and headaches: Impact of computer use and other associative factors. *Cephalalgia*, 29(2):250-257.

Stahl, M., Mikkelsson, M., Kautiainen, H., Hakkinen, A., Ylinen, J. & Salminen, J.J. 2004. Neck pain in adolescence. A 4-year follow up of pain-free preadolescents. *Pain,* 110(1-2):427-431.

Stokes, I.A.F., Armstrong, J.G. & Moreland, M.S. 1988. Spinal deformity and back surface asymmetry in idiopathic scoliosis. *Journal of Orthopaedic Research*, 6:129-137.

Straker, L., Briggs, A. & Greig, A. 2002. The effect of individually adjusted workstations on upper quadrant posture and muscle activity in school children. *Work,* 18(3):239-248.

Straker, L.M., O'Sullivan, P.B., Smith, A. & Perry M. 2007. Computer use and habitual spinal posture in Australian adolescents. *Public Health Reports,* 122(5):634-643.

Straker, L.M., O'Sullivan, P.B., Smith, A.J., Perry, M.C. & Coleman J. 2008a. Sitting spinal posture in adolescents differs between genders, but is not clearly related to neck/shoulder pain: An observational study. *Australian Journal of Physiotherapy,* 54(2):127-133.

Straker, L.M., Burgess-Limerick, R., Pollock, C., Coleman, J., Skoss, R. & Maslen, B. 2008b. Children's posture and muscle activity at different computer display heights and during paper information technology use. *Human Factors,* 5(1):49-61.

Straker, L.M., Burgess-Limerick, R., Pollock, C., Murray, K., Netto, K., Coleman, J. & Skoss, R. 2008c. The impact of computer display height and desk design on 3D posture during information technology work by young adults. *Journal of Electromyography and Kinesiology*, 18(2):336-349.

Straker, L., Pollock, C., Burgess-Limerick, R., Skoss, R. & Coleman, J. 2008d. The impact of computer display height and desk design on muscle activity during information

technology work by young adults. *Journal of Electromyography and Kinesiology,* 18(4): 606-617.

Straker, L.M., O'Sullivan, P., Smith, A.J. & Perry, M.C. 2009a. Relationship between prolonged neck/shoulder pain and sitting spinal posture in male and female adolescents. *Manual Therapy*, 14(3):321-329.

Straker, L., Maslen, B., Burgess-Limerick, R. & Pollock, C. 2009b. Children have less variable postures and muscle activities when using new electronic information technology compared with old paper-based information technology. *Journal of Electromyography and Kinesiology,* 19(2):e132-e143.

Straker, L., Burgess-Limerick, R., Pollock, C. & Maslen, B. 2009c. The effect of forearm support on children's head, neck and upper limb posture and muscle activity during computer use. *Journal of Electromyography and Kinesiology,* 19(5):965-974.

Straker, L.M., Smith, A.J., Bear, N., O'Sullivan, P.B. & De Klerk, N.H. 2011. Neck/shoulder pain, habitual spinal posture and computer use in adolescents: The importance of gender. *Ergonomics,* 54(6):539-546.

Sunblad, G.B., Jansson, A., Saartok, T., Renström, P. & Engström, L.M.T. 2008. Self-rated pain and perceived health in relation to stress and physical activity among school-students: A 3-year follow-up. *Pain,* 136(3):239-249.

Syazwan, A.L., Azhar, M.N.M., Anita, A.R., Azizan, H.S., Shaharuddin, M.S., Hanafiah, J.M., Muhaimin, A.A., Nizar, A.M., Rafee, B.M., Ibthisham, A.M. & Kasani, A. 2011. Poor sitting posture and a heavy schoolbag as contributors to musculoskeletal pain in children: An ergonomic school education intervention program. *Journal of Pain Research,* 4:287-296.

Szeto, G.P.Y., Straker, L. & Raine, S. 2002. A field comparison of neck and shoulder postures in symptomatic and asymptomatic office workers. *Applied Ergonomics,* 33(1):75-84.

Szeto, G.P.Y., Straker, L. & O'Sullivan, P.B. 2005. A comparison of symptomatic and asymptomatic office workers performing monotonous keyboard work- 2: Neck and shoulder kinematics. *Manual Therapy,* 10(4):281-291.

Thalheimer, W. & Cook, S. 2002. *How to calculate effect sizes from published research articles: A simplified methodology.* [Online] Available http://work-learning.com/effect_sizes.htm [2012, May 31].

Theisen, C., Van Wagensveld, A., Timmesfeld, N., Efe, T., Heyse, T.J., Fuchs-Winkelmann, S. & Schofer, M.D. 2010. Co-occurrence of outlet impingement syndrome of the shoulder and restricted range of motion in the thoracic spine – a prospective study with ultrasound-based motion analysis. *BMC Musculoskeletal Disorders*, 11:135-144.

Torsheim, T., Eriksson, L., Schnohr, C.W., Hansen, F., Bjarnason, T. & Valimaa, R. 2010. Screen-based activities and physical complaints among adolescents from the Nordic countries. *BMC Public Health*, 10:324.

Trobina, M. 1995. Error Model of a Coded-light Range Sensor, Internal Report, Communication Technology Laboratory, Image Science Group, ETH-Zentrum.

Van der Westhuizen, G. 2011. *Design, implementation and analysis of a low-cost, portable, medical measurement system through computer vision.* Stellenbosch: Stellenbosch University. [Online] Available http://hdl.handle.net/10019.1/6764 [2012, July 18].

Van Niekerk, S., Louw, Q., Vaughan, C., Grimmer-Somers, K. & Schreve, K. 2008. Photographic measurement of upper body sitting posture of high school students: A reliability and validity study. *BMC Musculoskeletal Disorders,* 9:113

Vikat, A., Rimpela, M., Salminen, J.J., Rimpela, A., Salvolainen, A. & Virtanen, S.M. 2000. Neck or shoulder pain and low back pain in Finnish adolescents. *Scandinavian Journal of Public Health*, 28(3):164-173.

Vieira, E.R. & Kumar, S. 2004. Working postures: A literature review. *Journal of Occupational Rehabilitation,* 14(2):143-159.

Von-Baeyer, C.L. & Spagrud, L.J. 2007. Systematic review of observational (behavioural) measures of pain for children and adolescents aged 3 to 18 years. *Pain,* 127(1-2):140-150.

Vrtovec, T., Pernus, F. & Likar, B. 2009. A review of methods for quantitative evaluation of spinal posture. *European Spine Journal*, 18(5):593-607.

Wagner, M., Bowing, B., Deimling, M., Rascher, W. & Rupprecht, T. 2001. Low field thoracic MRI – a fast and radiation free routine imaging modality in children. *Magnetic Resonance Imaging*, 19(7):975-983.

Warren, J.G., Bettany-Saltikov, J., Van Schaik, P. & Papastefanou, S.: Evidence-based postural assessment for use in therapy and rehabilitation. *International Journal of Therapy and Rehabilitation*, 12(12):527-532.

Weber Hellstenius, S.A. 2009. Recurrent neck pain and headaches in preadolescents associated with mechanical dysfunction of the cervical spine: A cross-sectional observational study with 131 students. *Journal of Manipulative and Physiological Therapeutics*, 32(8):625-634.

White, S.A. & Van den Broek, N.R. 2004. Methods for assessing reliability and validity for a measurement tool: A case study and critique using WHO haemoglobin colour scale. *Statistics in Medicine,* 23(10):1603-1619.

Whiting, P., Rutjes, A.W.S., Reitsma, J.B., Bossuyt, P.M.M. & Kleijnen, J. 2003. The development of QUADAS: A tool for quality assessment of studies of diagnostic accuracy included in systematic reviews. *BMC Medical Research Methodology*, 3:25

Whittle, M.W. & Levine, D. 1997. Measurement of lumbar lordosis as a component of clinical gait analysis. *Gait and Posture*, 5(2):101-107.

Yip, C.H.T., Chio, T.T.W. & 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.

8 September 2008

UNIVERSITEIT·STELLENBOSCH·UNIVERSITY
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Mrs. Y Brink
Dept of Physiotherapy

Dear Mrs. Brink

RESEARCH PROJECT: "The risk factors predicted of neck, shoulder and arm pain amid high school students using desk top computers."

PROJECT NUMBER : N08/08/209

At a meeting of the Committee for Human Research that was held on 3 September 2008 the above project was approved on condition that further information that was required, be submitted.

This information was supplied and the project was finally approved on 8 September 2008 **for a period of one year from this date**. This project is therefore now registered and you can proceed with the work.

Please quote the above-mentioned project number in ALL future correspondence.

Please note that a progress report (obtainable on the website of our Division: www.sun.ac.za/knowledgepartner/committees_CHR.htm) should be submitted to the Committee before the year has expired. The Committee will then consider the continuation of the project for a further year (if necessary). Annually a number of projects may be selected randomly and subjected to an external audit.
Translations of the consent document in the languages applicable to the study participants should be submitted.

Federal Wide Assurance Number: 00001372
Institutional Review Board (IRB) Number: IRB0005239
The Committee for Human Research complies with the SA National Health Act No.61 2003 as it pertains to health research and the United States Code of Federal Regulations Title 45 Part 46. This committee abides by the ethical norms and principles for research, established by the Declaration of Helsinki, the South African Medical Research Council Guidelines as well as the Guidelines for Ethical Research: Principles Structures and Processes 2004 (Department of Health).

Kind regards

pp
Prof PJT de Villiers
Chairperson: Committee for Human Research
RESEARCH DEVELOPMENT AND SUPPORT (TYGERBERG)
Tel: +27 21 938 9207 / E-mail: mertrude@sun.ac.za

Approval Date: 8 September 2008 **Expiry Date: 8 September 2009**

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Fakulteit Gesondheidswetenskappe • Faculty of Health Sciences

Verbind tot Optimale Gesondheid • Committed to Optimal Health
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21 September 2009

MAILED

Ms Y Brink
Department of Physiotherapy
4th Floor, Teaching building
Stellenbosch University
Tygerberg campus
7505

Dear Ms Brink

"Risk factors predictive of neck,shoulder and arm pain amid high school students using desk top computers."

ETHICS REFERENCE NO: N08/08/209

RE : PROGRESS REPORT

At a meeting of the Health Research Ethics Committee that was held on 16 September 2009, the progress report for the abovementioned project has been approved and the study has been granted an extension for a period of one year from this date.

Please remember to submit progress reports in good time for annual renewal in the standard HREC format.

Yours faithfully

MRS EL ROHLAND
RESEARCH DEVELOPMENT AND SUPPORT
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21 September 2009 12:00

Page 1 of 1

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16 September 2010 **MAILED**

Ms Y Brink
Department of Physiotherapy
4th Floor, Teaching building
Stellenbosch University
Tygerberg campus
7505

Dear Ms Brink

"Risk factors predictive of neck,shoulder and arm pain amid high school students using desk top computers."

ETHICS REFERENCE NO: N08/08/209

RE : PROGRESS REPORT

At a meeting of the Health Research Ethics Committee that was held on 15 September 2010, the progress report for the abovementioned project has been approved and the study has been granted an extension for a period of one year from this date.

Please remember to submit progress reports in good time for annual renewal in the standard HREC format.

Please note that you have to submit an amendment for the mannequin -validity study.

Approval Date: 15 September 2010 Expiry Date:15 September 2011

Yours faithfully

MRS MERTRUDE DAVIDS
RESEARCH DEVELOPMENT AND SUPPORT
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22 July 2011

MAILED

Ms Y Brink-Prins
P.O. Box 87
Paarl
7620

Dear Ms Brink-Prins

"Risk factors predictive of neck,shoulder and arm pain amid high school students using desk top computers."

ETHICS REFERENCE NO: N08/08/209

RE : AMENDMENT

Your letter dated 14 July 2011 refers.

The Chairperson of the Health Research Ethics Committee approved the amended documentation in accordance with the authority given to him by the Committee.

The following amendments were approved:
1. Changes to protocol.

Yours faithfully

MRS MERTRUDE DAVIDS
RESEARCH DEVELOPMENT AND SUPPORT
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27 September 2011 **MAILED**

Ms Y Brink
P.O. Box 87
Paarl
7620

Dear Ms Brink

"Risk factors predictive of neck,shoulder and arm pain amid high school students using desk top computers."

ETHICS REFERENCE NO: N08/08/209

RE : PROGRESS REPORT

At a review panel of the Health Research Ethics Committee that was held on 14 September 2011, the progress report for the abovementioned project has been approved and the study has been granted an extension for a period of one year from this date.

Please remember to submit progress reports in good time for annual renewal in the standard HREC format.

Approval Date: 14 September 2011 Expiry Date: 14 September 2012

Yours faithfully

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Brink et al. BMC Musculoskeletal Disorders 2011, 12:93
http://www.biomedcentral.com/1471-2474/12/93

BMC Musculoskeletal Disorders

RESEARCH ARTICLE Open Access

The quality of evidence of psychometric properties of three-dimensional spinal posture-measuring instruments

Yolandi Brink[1*], Quinette Louw[1] and Karen Grimmer-Somers[2]

Abstract

Background: Psychometric properties include validity, reliability and sensitivity to change. Establishing the psychometric properties of an instrument which measures three-dimensional human posture are essential prior to applying it in clinical practice or research.

Methods: This paper reports the findings of a systematic literature review which aimed to 1) identify non-invasive three-dimensional (3D) human posture-measuring instruments; and 2) assess the quality of reporting of the methodological procedures undertaken to establish their psychometric properties, using a purpose-build critical appraisal tool.

Results: Seventeen instruments were identified, of which nine were supported by research into psychometric properties. Eleven and six papers respectively, reported on validity and reliability testing. Rater qualification and reference standards were generally poorly addressed, and there was variable quality reporting of rater blinding and statistical analysis.

Conclusions: There is a lack of current research to establish the psychometric properties of non-invasive 3D human posture-measuring instruments.

Keywords: posture measurement psychometric properties, reliability and validity

Background

Postural assessment is a standard and essential component of examining individuals with neuromusculoskeletal disorders [1,2]. Prolonged static postures are widely recognised as a risk factor of neuromusculoskeletal pain among children, adolescents and adults [3-9]. No uniform definition for "ideal" posture exists and therefore researchers and clinicians continue to seek the best way of assessing and describing posture. Ideal spinal posture is proposed as neutral spinal alignment, however the relationship between spinal segments in a normal population remains unknown [10,11]. The spine is a complex three-dimensional (3D) anatomical structure, whose segmental position in space should be described in all three planes (sagittal, frontal and transverse) [12-14]. Precise positional data can be derived from a number of biomechanical measurement tools, of which non-invasive 3D instruments are preferred.

It is essential that a spinal posture-measuring instrument is shown to be reliable and valid. Without this assurance, it cannot facilitate diagnosis, chart variability in 'usual' posture or assist objective monitoring of patient progress with treatment [1]. Researchers and clinicians should therefore be familiar with the psychometric properties of spinal posture-measuring instruments, and choose the ones with the best evidence of performance [15].

Two core elements of psychometric properties are reliability and validity [16]. Reliability and validity are interlinked of which reliability is a prerequisite to validity. A measurement tool cannot be recommended with confidence if there is a lack of evidence about its reliability and validity [17]. Reliability, refers to being able to

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estimate the inherent variability of posture, as well as error that can be attributed to the rater and the measurement instrument [17]. Error can relate to the consistency with which measurements are taken by the same or different raters, or over multiple occasions of testing [16]. Reliability is variously classified as test-retest reliability, inter-and intra-rater reliability. Test-retest reliability describes the stability of the measurement instrument in obtaining the same results with repeated measurements using the identical test on two or more separate occasions, keeping all testing conditions as constant as possible [17]. Intra-rater reliability is defined as the stability of data recorded by one observer across two or more test occasions. Inter-rater reliability is the extent to which two or more observers obtain similar scores when rating the same individuals [16,17].

Validity is the extent to which an instrument measures what it is intended to measure [18]. Criterion-related validity is the ability of one test (index test) to predict results obtained on an external criterion (gold standard/ reference standard) which is assumed to be valid. When both tests are performed on the same subjects, the scores from the index test are correlated with those achieved by the criterion measure. Construct validity is the ability of an instrument to measure an abstract concept, which cannot be observed directly and which has been constructed to represent an abstract trait [17]. There are two types of criterion-related validity. Concurrent validity is evaluated when the index test and the criterion measure are taken at the same time so that it reflects the same incident of behaviour while predictive validity is tested when the index test is performed and measured prospectively to ascertain the relationship between the index test and the criterion scores to determine whether the index test is a valid predictor of the outcome [17]. There are three types of construct validity. Convergent validity indicates that two measures, which are believed to reflect the same construct, will have similar results or will correlate highly [17]. Whereas divergent validity indicates that two measures, which are believed to measure different constructs, will correlate poorly [19]. Convergent and divergent validity assess the sensitivity and specificity of a measurement respectively [19]. Discriminative validity is the extent to which measures from a measurement instrument distinguishes between individuals or populations that would be expected to differ [19].

Establishing the psychometric properties of spinal posture-measuring instruments is not a trivial task, given the complex nature of human posture. Thus, convincing evidence of reliability and validity of any posture-measuring instrument can only be established by assessing the methodological quality of the underpinning developmental studies. Specific psychometric study design features are therefore essential to establish and assess, for instance, controls that are put in place for systematic bias, non-systematic bias and inferential error. An important requirement for psychometric testing of posture measurement is that the instrument be tested under a given set of conditions on a specific population within the context of the instrument's intended use. Therefore it is essential that posture-measuring instruments be tested on humans at some stage of development, and not just on inanimate objects [17].

The purpose of the systematic review reported in this paper was 1) to identify the non-invasive 3D tools which measure human static sitting or standing spinal posture and 2) to review the quality of the evidence of reliability and validity of the identified 3D posture-measuring instruments.

Methods

Search Strategies

Two inter-related search strategies (A and B) were implemented to ensure that all eligible papers were included. Strategy A sought any primary research studies which reported the use of 3D non-invasive instruments measuring static sitting or standing spinal posture. Strategy B sought primary research into the psychometric testing of these instruments. One reviewer searched six electronic databases that were available at the Stellenbosch University Library. The databases were BioMed Central, CINAHL, PEDRO, PROQUEST, PUBMED and SCIENCE DIRECT. The publication date was restricted to papers published from 1980 to June 2010. The search was limited to full-text papers published in English. MESH terms were used in PUBMED. See additional file 1 for a detailed description of the database searches.

In addition, secondary searching was performed on the reference list of the included papers. Experts in this field of research, and authors who failed to provide references to studies which tested an instrument's psychometric properties, were contacted.

Keywords and synonyms

The following keywords were used: three-dimensional, measurement tool, assessment tool, instrument, measurement, assessment, spinal posture, posture, validity, reliability, accuracy and reproducibility.

Inclusion and exclusion criteria for selection of papers

Papers were included if they reported testing an instrument's psychometric properties, specifically reliability and/or validity, using humans, or the instrument's validity using objects. A core inclusion criteria was that static standing or sitting spinal posture had to be evaluated with an instrument that could quantitatively calculate

3D spinal posture without using a baseline reference value such as zero. This was because a reference value requires that the subject be required to first assume a neutral or resting posture at which point the instrument is zeroed before the instrument can measure static spinal posture. For the purpose of the review, static posture should be assessed instantaneously without any guiding from the researcher.

Papers were excluded if (1) they reported neither reliability nor validity testing (2) they did not report on static spinal posture (e.g. reported on the 3D motion of the spine, scapulo-humeral girdle or pelvis); (3) the study reported on the validity testing of an instrument using motion (as motion was not incorporated in this review, and we argue that validity be evaluated within the context of the instrument's intended use; (4) the instrument only measured cadaver or in vitro spinal posture; (5) the instrument was invasive e.g. biplanar radiography and stereoradiography; (6) only an algorithm or a mathematical formula were reported.

Study selection

One reviewer excluded papers by screening all the titles and reading the abstracts after which two independent reviewers selected the eligible papers after reading the full text version of the remaining papers. Figure 1 describes the procedures of study selection for each of the two search strategies.

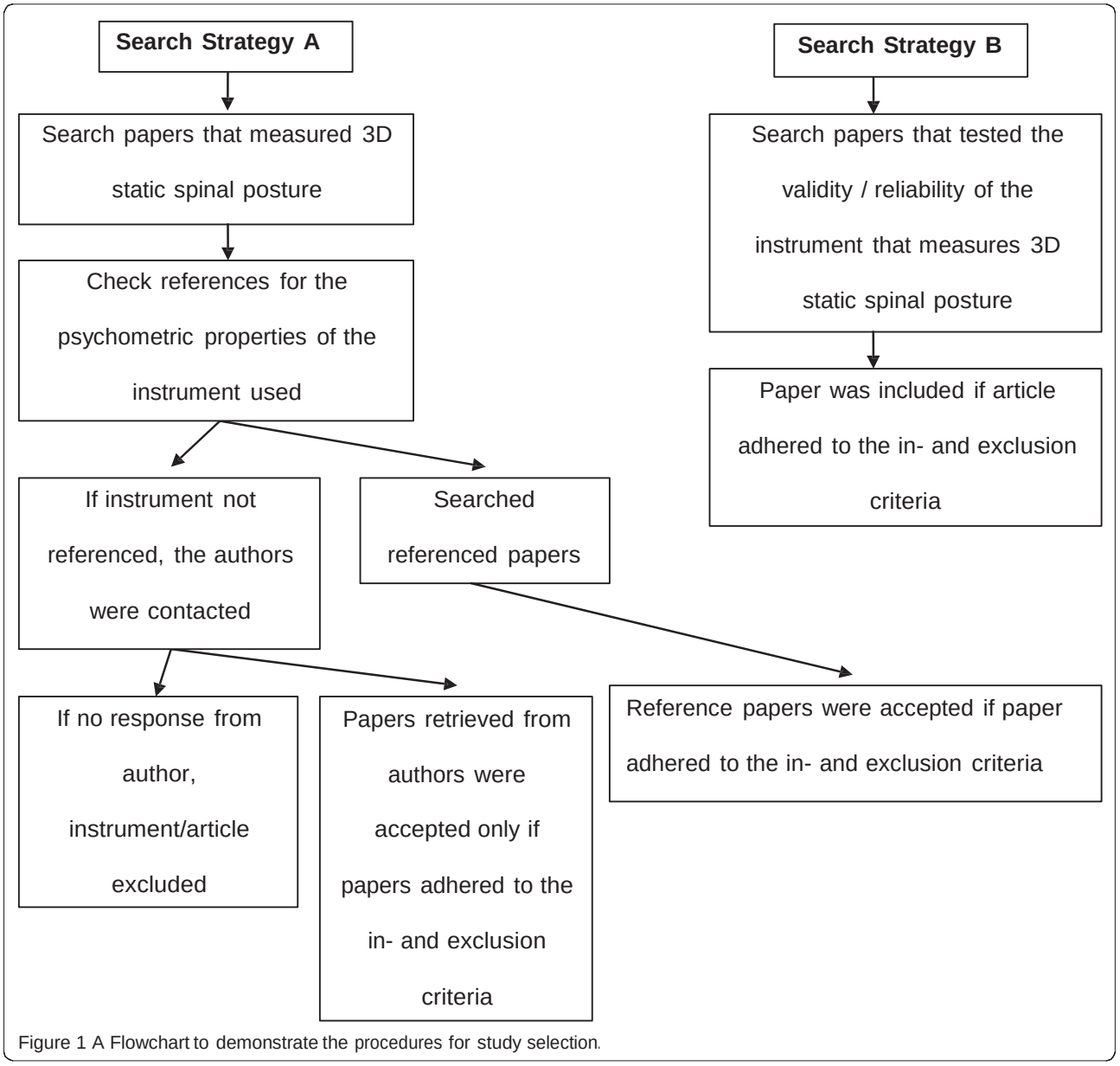

Figure 1 A Flowchart to demonstrate the procedures for study selection.

Methodological Quality Appraisal

The full text eligible papers were then subjected to methodological critical appraisal. The Critical Appraisal Tool (CAT) applied in this review was purpose-built, in the absence of any other relevant CAT. It was adapted from the Quality Assessment of Diagnostic Accuracy Studies (QUADAS) [20] and the Quality Appraisal of Reliability Studies (QAREL) [21]. The purpose-built CAT has 13 items, however its data is not designed to be reported as a composite quality score (see additional file 2). The CAT was designed to assess the impact of each individual item on the quality of the methodological procedures implemented in each paper. Prior to critical appraisal of the included articles, three papers were randomly selected and assessed independently by three reviewers using the purpose-built CAT. Disagreements were discussed to ensure that interpretation of the CAT items were consistent.

Results

Results from the search strategies

One hundred and thirty possible papers were considered, of which 30 papers were deemed to be eligible. Nine additional papers were identified after searching the reference lists of these papers. Two further papers were included after experts and authors had been contacted. Figure 2 provides a consort diagram to demonstrate the selection of papers.

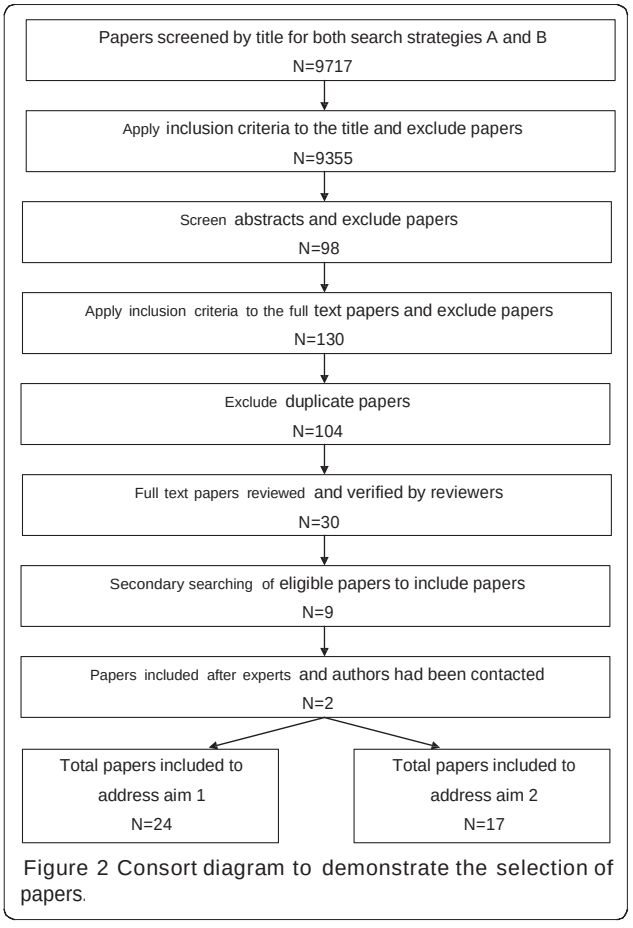

Figure 2 Consort diagram to demonstrate the selection of papers.

Volume of literature

Eighteen instruments were identified from the two literature searches, 15 from Search A, one from Search B and two from author contacts. The instruments are listed in the first column of Table 1, the papers addressing aim one appear in the second column and those addressing aim two are in the third column. Papers reporting these instruments, are identified by bold script if from strategy A, italics if from strategy B, normal script if from author search and with a * if from secondary searching. The Automatic Scoliosis Analyser System (Auscan) (Italy), the Elite system (Italy), the Optotrak 3020 (Canada), the Peak Motus (USA), the PosturePrint (Canada), the Qualysis Proreflex Motion Capture Unit system (Sweden), the Vicon 370 (England) and an Optoelectronic camera system (Canada) are optoelectronic analysis systems. The Fonar upright positional MRI (USA) uses magnetic resonance imaging. The INSPECK (Canada) is an optical 3D digitizer. The Lumbar Motion Monitor (LMM) (USA) is a electrogoniometer. The Metrecom (USA), the Articulated Arm for Computerized Surface Measurement (BACES) (Italy) and the Microscribe 3DX Digitizer (USA) are computerized electromechanical 3D digitizers. Rasterstereography is a photogrammetric method based on triangulation. The 3 Space Isotrak or Fastrak (USA) and the Electromagnetic tracking system (USA) are electromagnetic devices. The Zebris (Germany) is an ultrasound analysis system.

Seventeen papers reported on reliability and/or validity of the included instruments and were thus assessed to address Aim two (see Table 1 third column). One paper by Smidt et al. [22] reported on both reliability and validity, and was therefore reviewed as if it was two separate papers, due to the nature of this review. Drerup et al. [23] tested a new algorithm for processing data presented in a previous paper [24]. These papers were reviewed as if they were one paper, because the previous paper reported on the study procedure in more detail whereas the latter paper discussed the latest improvement made on the data processing procedure.

Aim of the reliability studies

The aim of six studies was to test the reliability of a 3D instrument in assessing the spinal posture of humans [22,25-29].

Aim of the validity studies

The aim of eleven studies was to test the validity of a 3D posture instrument. Four studies [23,30-32] used

Table 1 Recent three-dimensional instruments used to measure static spinal posture

Instrument	Addresses Aim 1: Used to measure posture	Addresses Aim 2: Reports on psychometric properties	N
BACES	D'Osualdo et al. 2002 [41]		
AUSCAN	Negrini et al. 2007 [42]		
Electromagnetic tracking system	Claus et al. 2009 [43]		
Elite optoelectronic system	Lissoni et al. 2001 [44]; Naslund et al. 2005 [45]		
Inspek		Pazos et al. 2005* [35]; Pazos et al. 2007 [27]	2
Lumber Motion Monitor (LMM)	Jang et al. 2007 [46]		
FONAR Upright positional MRI	Morl et al. 2006 [47]; Cargill et al. 2007 [48]; Lafon et al. 2010 [49]		
Metrecom	Franklin et al. 1995* [50]; Black et al. 1996 [51]; Gram et al. 1999 [52]	Smidt et al. 1992* [22]; Norton et al. 1993* [38]	2
Microscribe 3DX Digitizer		Warren et al. 2005 [28]	1
Optoelectronic camera system	Duong et al. 2009 [53]		
Optotrak 3020	Rempel et al. 2007 [54]		
Peak Motus	Straker et al. 2009 [55]		
Postureprint		Normand et al. 2002 [37]; Harrison et al. 2007 [33]; Janik et al. 2007 [34]; Normand et al. 2007 [26]	4
Qualysis Proreflex Motion Capture Unit system	Grip et al. 2007 [56]; Neiva et al. 2009 [57]		
Rasterstereography		Stokes et al. 1988* [32]; Hackenberg et al 2003a [30]; Hackenberg 2003b [31]; Drerup et al. 1994* [23] and 1996* [24]	5
3 Space Isotrack/Fastrak	O' Sullivan et al. 2006* [58]; Caneiro et al. 2010 [59]; Astfalck et al. 2010 [60]	Pearcy et al. 1989* [36]	1
Vicon three-dimensional kinematic system	Levine et al. 1996 [61}; Szeto et al. 2005 [9]; Skalli et al. 2006 [62]	Whittle et al. 1997 [29]	1
Zebris CMS70P; Zebris CMS20	Theisen et al. 2010 [63]	Geldhof et al. 2007 [25]	1

N: number of papers addressing aim 2; Bold script: Papers from search A; Italic script: Papers from search B;*: Papers from secondary search; Normal script: Papers from author search

human subjects to measure 3D spinal posture and to compare the results with those obtained from a reference standard. The other seven studies either used mannequins [33-35], wooden wedges [36], a steel frame [22], parallelograms [37] or other objects with known parameters [38] to test the validity of an instrument that could be used to assess 3D spinal posture of humans in future.

Study design for reliability and validity studies

The type of reliability and validity tested, as well as the time interval for the reliability studies and the reference standard for the validity studies, are reported in Table 2.

Statistical analysis

Table 3 summarizes the statistical procedures implemented in the reliability and validity studies. Comparing the findings in this table with the types of reliability and validity testing reported in Table 2, highlights the variability in choice and application of statistical tests to assess the same constructs.

Methodological Quality Appraisal

Table 4 reports the findings from the critical appraisal of the papers, related to reliability and validity testing.

Item 1: If human subjects were used, did the authors give a detailed description of the sample of subjects used to perform the (index) test?

Nine papers [22,25-32] scored "yes" because a detailed description of the sample characteristics was stated. Drerup et al. [23] scored "no" as the authors did not mention how their subjects were recruited and merely stated that only scoliosis patients were included. Seven papers [22,33-38] scored "not applicable" because these studies used inanimate objects.

Table 2 The type and time interval for reliability studies and the type and reference standard for validity studies

Author	Type of reliability	Time interval	Type of validity	Reference standard
Stokes et al (1988)	N/A	N/A	Criterion-related validity	Stereoradiography
Pearcy et al (1989)	N/A	N/A	Concurrent validity	Precision optical inclinometer
Smidt et al (1992)	N/A	N/A	Concurrent validity	Not specified
	Intra- and interrater reliablity	On the same day	N/A	N/A
Norton et al (1993)	N/A	N/A	Concurrent validity	Type measure or ruler
Drerup et al (1996)	N/A	N/A	Criterion-related validity	Stereoradiography
Normand et al (2002)	N/A	N/A	Concurrent validity	Not specified
Hackenberg et al (2003a)	N/A	N/A	Criterion-related validity	Stereoradiography
Hackenberg et al (2003b)				
Pazos et al (2005)	N/A	N/A	Concurrent validity	Coordinate measuring machine
Harrison et al (2007) and Janik et al (2007)	N/A	N/A	Concurrent validity	Not specified
Whittle et al (1997)	Intrarater reliability	On the same day	N/A	N/A
Warren et al 2005	Intrarater reliability	One minute	N/A	N/A
Geldhof et al (2007)	Intrarater reliability	One week	N/A	N/A
Pazos et al (2007)	Test retest reliability	30 seconds	N/A	N/A
Normand et al (2007)	Intra- and interrater reliability	One day	N/A	N/A

N/A: Not Applicable

Item 2: Did the authors clarify the qualification, or competence of the rater(s) who performed the (index) test?

Eleven validity studies [22,23,30-38] and four reliability studies [25,27-29] scored "no". The qualifications of the operators of the instruments were not reported, as there was no description of their past experience with operating these instruments. The reliability studies of Smidt et al. [22] and Normand et al. [26] scored "yes" as they stated that the operators were "familiar and competent" in its use.

Item 3: Was the reference standard explained?

Table 3 Statistical procedures of the reliability and validity studies

Author	Statistical analysis
Stokes et al (1988)	• linear regression analysis and Pearson correlation coefficient ®
Pearcy et al (1989)	• means; estimate of error, regression analysis and ICC
Smidt et al (1992)	• Dunnett's comparison test
Norton et al (1993)	• Pearson product moment correlation coefficient ® and repeated measures t test
Drerup et al (1996) and Hackenberg et al (2003a and b)	• Root mean square (RMS) deviations of the surface curves from the radiographic curves
Whittle et al (1997)	• ICC and Pearson correlation coefficient
Normand et al (2002)	• means, SD, SEM, 95% Confidence Intervals (CI) and mean differences
Pazos et al (2005)	• multiway ANOVA
Warren et al 2005	• Pearson correlation coefficient and ICC
Harrison et al (2007) and Janik et al (2007)	• error analyses of mean differences and SD
Geldhof et al (2007)	• ICC for test-retest reliability
Pazos et al (2007)	• bivariate ANOVA; typical error of measurement (TEM); 95% CI of the TEM; smallest detectable difference (SDD) and multivariate ANOVA
Normand et al (2007)	• mean absolute values of differences within examiner and between examiner measurements; ANOVA; Shapiro-Wilk test and SEM for conservative and liberal ICC methods

Table 4 Summary of the methodological quality appraisal results of the studies (n = 17)

Authors	Item 1	Item 2	Item 3	Item 4	Item 5	Item 6	Item 7	Item 8	Item 9	Item 10	Item 11	Item 12	Item 13
Stokes et al (1988)	√	x	√	n/a	n/a	n/a	√	n/a	√	√	√	√	√
Pearcy et al (1989)	n/a	x	√	n/a	n/a	n/a	n/a	n/a	√	√	√	n/a	√
Smidt et al (1992) (validity)	n/a	x	x	n/a	n/a	n/a	n/a	n/a	x	√	x	n/a	√
Smidt et al (1992) (reliability)	√	√	n/a	√	√	x	n/a	√	n/a	√	n/a	x	√
Norton et al (1993)	n/a	x	x	n/a	n/a	n/a	n/a	n/a	√	√	√	n/a	x
Drerup et al (1994; 1996)	x	x	√	n/a	n/a	n/a	√	n/a	√	√	√	√	√
Whittle et al (1997)	√	x	n/a	n/a	x	x	n/a	√	n/a	√	n/a	√	√
Normand et al (2002)	n/a	x	x	n/a	n/a	n/a	n/a	n/a	x	√	x	n/a	√
Hackenberg et al (2003a)	√	x	√	n/a	n/a	n/a	√	n/a	√	x	√	x	√
Hackenberg et al (2003b)	√	x	√	n/a	n/a	n/a	√	n/a	√	x	√	x	√
Warren et al (2005)	√	x	n/a	n/a	X	x	n/a	√	n/a	√	n/a	x	√
Pazos et al. (2005)	n/a	x	√	n/a	n/a	n/a	n/a	n/a	√	√	√	n/a	√
Harrison et al (2007)	n/a	x	x	n/a	n/a	n/a	n/a	n/a	x	√	x	n/a	√
Janik et al (2007)	n/a	x	x	n/a	n/a	n/a	n/a	n/a	x	√	x	n/a	√
Geldhof et al (2007)	√	x	n/a	n/a	√	x	n/a	√	n/a	√	n/a	√	√
Pazos et al (2007)	√	x	n/a	n/a	n/a	n/a	n/a	√	n/a	√	n/a	x	√
Normand et al (2007)	√	√	n/a	√	√	√	n/a	√	n/a	√	n/a	√	√

Drerup et al. [23], Hackenberg et al. [30,31] and Stokes et al. [32] scored "yes" as they provided references for the methods used to digitize the radiographs. Pazos et al. [35] and Pearcy et al. [36] scored "yes" because the authors named and stated the accuracy of the instruments used as the reference standard. Norton et al. [38] scored "no" because the ruler or tape measure was inappropriately used as a reference standard for calculating 3D coordinates of a point in space. Harrison et al. [33], Janik et al. [34], Normand et al. [37] and Smidt et al. [22] scored "no" because the authors used an object with known 3D parameters as reference standards, but the methods to measure these 3D locations, angles or distances were not explained.

Item 4: If interrater reliability were tested, were raters blinded to the findings of other raters?

Normand et al. [26] and Smidt et al. [22] scored "yes" because subjects were evaluated separately by the different raters. Geldhof et al. [25], Warren et al. [28] and Whittle and Levine [29] only tested intrarater reliability and scored "not applicable". Pazos et al. [26] scored "not applicable" because no rater reliability was evaluated but instead test-retest reliability of the instrument, when using different postures, was evaluated.

Item 5: If intrarater reliability were tested, were raters blinded to their own prior findings of the test under evaluation?

Geldhof et al. [25], Normand et al. [26] and Smidt et al. [22] scored "yes" because the raters were sufficiently blinded to their own prior measurements as either repeated digitizing of the anatomical landmarks took place one week apart, all photographs were numbered and were not identifiable by subject name, occasion or characteristics, and no skin markings were made on subjects. Warren et al. [28] and Whittle and Levine [29] scored "no" because passive and skin markings respectively were placed only once on the subject and were not removed between repeated measurements. Pazos et al. [27] scored "not applicable" because they did not test rater reliability.

Item 6: Was the order of examination varied?

Normand et al. [26] scored "yes" because subjects were evaluated in random order. Warren et al. [28] and Whittle and Levine [29] scored "no" because repeated measurements were performed consecutively without changing the order of subjects during testing. Geldhof et al. [25] scored "no" as the order of testing was kept the same for the repeated measurements one week apart. Smidt et al. [22] scored "no" as insufficient information was provided. Pazos et al. [27] scored "not applicable" because no rater reliability was tested.

Item 7: If human subjects were used, was the time period between the reference standard and the index test short enough to be reasonably sure that the target condition did not change between the two tests?

Drerup et al. [23], Hackenberg et al. [30,31] and Stokes et al. [32] scored "yes" because the radiographs and the rasterstereographs were taken on the same day. The other seven articles [22,33-38] scored "not applicable" because inanimate objects which cannot deform with passage of time were used.

Item 8: Was the stability (or theoretical stability) of the variable being measured taken into account when

determining the suitability of the time-interval between repeated measures?

Six papers scored "yes" because repeated measurements of posture were either taken on the same day [22,27-29] one week [25] or one day apart [26].

Item 9: Was the reference standard independent of the index test?

Seven papers [23,30-32,35,36,38] scored "yes" because the index test and the reference standard were independant instruments. Harrison et al. [33], Janik et al. [34], Normand et al. [37] and Smidt et al. [22] scored "no" due to insufficient information provided.

Item 10: Was the execution of the (index) test described in sufficient detail to permit replication of the test?

Nine validity [22,23,32-38] and six reliability papers [22,25-29] scored "yes" because clear descriptions of how the instruments were applied to the subjects or to the inanimate objects were provided. Hackenberg et al. [30,31] scored "no" as the authors did not explain how raterstereographs were performed on the subjects, nor did they provide any citations for the methodology.

Item 11: Was the execution of the reference standard described in sufficient detail to permit its replication?

Seven papers scored "yes" because clear descriptions of how the reference standard were used on the subjects [23,32] or on the inanimate objects [35,36,38] or citations for the methodology [30,31] were provided. Harrison et al. [33], Janik et al. [34], Smidt et al. [22] and Normand et al. [37] scored "no" for the reasoning provided for item 3.

Item 12: Were withdrawals from the study explained?

Drerup et al. [23], Geldhof et al. [25], Normand et al. [26], Stokes et al. [32] and Whittle and Levine [29], scored "yes" because the number of subjects who participated in the studies was reflected in the results sections of the studies. Hackenberg et al. [30,31] scored "no" as the authors did not explain why 48 instead of 52 and 24 instead of 25 subjects participated in the pre operative evaluations respectively. Pazos et al. [27], Warren et al. [28] and Smidt et al. [22] scored "no" due to insufficient information provided. Seven papers [22,33-38] scored "not applicable" because these studies used inanimate objects.

Item 13: Were the statistical methods appropriate for the purpose of the study?

All but one paper by Norton et al. [38] implemented appropriate statistical analysis and thus scored "no". Although the other sixteen papers reported appropriate statistical analysis only six papers [23,30,31,26,28] provided a justification or motivation for using their chosen statistical measures.

Discussion

This review attempted to evaluate the quality of reporting of psychometric properties of 18 3D human posture measuring instruments. It identified a lack of well-documented studies testing the psychometric properties of these instruments, as papers describing the development of only eight instruments were found (see Table 1 column C). The review suggests that the PosturePrint and rasterstereography had relatively more psychometric testing than the other tools included in this review. However, the methodological quality of the testing procedures for all instruments was flawed, when considering the methodological criteria applied in this review.

Rater qualification

Both reliability and validity studies should provide descriptions of the qualifications of the rater(s) used in the studies because the rater(s) professional background, expertise and prior training operating these instruments will affect psychometric property assessment. Appropriate training of raters is important to minimise measurement error, and to facilitate interpretation of findings. These factors should therefore be considered when interpreting study findings, and extrapolating them for applicability and generalisability to other clinical and research settings [39].

Reference standard

Four studies, which used inanimate objects, did not identify the instruments used to obtain the known values of objects which provided the reference standard data. In order to test validity, it is important that the psychometric properties of the reference standard be known to confirm that the reference standard is suitable [39]. The most suitable non-invasive 3D reference standard for postural measurements has not been unanimously determined in this field of research. The validity studies that used humans also used stereoradiography as reference standard, as radiography remains the most accurate assessment for posture. This situation continues, even though there is a possible health risk for repeated X-ray exposure to healthy spines and organs [40].

Norton et al. [38] used a ruler or tape measure as a reference standard. The x, y, z coordinates obtained from the index test had to be mathematically transformed to distances between pairs of points before the reference data, obtained from the ruler or tape measure, could be used. It would have been better had these authors used a reference standard with known accuracy to measure 3D coordinates directly. The ruler or tape measure was also a poor reference standard to use when measuring the distance between pairs of points on the human skeleton.

Blinding for intra- or interrater reliability

The repeated measurements by Geldhof et al. [25] were performed one week apart however the order of the

subjects was fixed. Therefore this enhances the possibility for the raters to recall the test outcomes of the previous measurements and potentially incurs increased bias. Warren et al. [28] and Whittle and Levine [29] tested intrarater reliability however the marking of the anatomical landmarks was only undertaken once before repeated measurements were taken, without allowing for removal and replacement of the markers between repeated measurements. Both raters in these studies were not blinded to their previous measurements of the same subjects. Consequently this potentially introduced bias and compromised the quality of the studies and findings.

Statistical analysis

Given the complexity of posture measurement and interpretation, no statistical strategy for psychometric property testing is without its disadvantages. Therefore it seems sensible to report the findings of two or more different statistical analysis approaches in order to validate findings [21]. This did not occur in any of the included papers. For example Pearcy et al. [36] used linear regression analysis to demonstrate that as the magnitude of the one variable increases so does the amount of error however there is no indication of a cut off value (e.g. 95% CI and SD) up to where the 3 Space Isotrak can be expected to accurately measure an angle.

As a variety of statistical measures were reported in this review, another method to improve reporting quality would be for authors to justify why they chose a particular statisical test, relevant to the purpose of testing. This would provide the reader with better insight into the results, and would perhaps guide future authors in choice, and interpretation of more appropriate statisical analysis. For example Norton et al. [38] used multiple analysis to determine whether there is agreement between measures. However Pearson product moment correlation only reports on the correlation between two different measurements and cannot quantify the amount of aggreement or indicate whether there is systematic error. Repeated t-tests are also inappropriate to test systematic differences, as this testing will inflate the type I error and compromise interpretation of significance.

Limitations

One limitation to this review comes from our inability to retrieve potentially eligible papers from authors who failed to respond to email inquiries. It could be that there are other relevant instruments which have been adequately evaluated for reliability and validity, however these papers were not available despite using multiple search methods (database, internet and author searches).

Conclusions

This review described 18 non-invasive ways of measuring static human 3D sitting or standing spinal posture, and the methodological procedures of testing reliability and validity of a subset of these instruments. The review concludes that further research into the reliability and validity testing of these instruments is required to improve the quality of reliability and validity evidence of posture-measuring instruments. Psychometric property testing should be improved by addressing rater qualification, clearer definitions of the reference standards, applying appropriate methodological procedures to enhance rater blinding and improving the quality of reported statistical analysis. By improving the methodological rigor of reliability and validity testing, it would consequently enhance users' confidence in the psychometric evidence of static human 3D sitting or standing spinal posture in clinical and research settings.

Acknowledgements

The authors would like to acknowledge Dr Susan Hillier who assisted with the conceptualizing of the study, Sjan-mari Van Niekerk for assisting with the development of the critical appraisal tool and the Faculty of Health Sciences at Stellenbosch University and the Medical Research Council of South Africa for funding to conduct the study.

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Authors' contributions

YB and QL contributed to the conception and design of the study, YB acquired and analyzed the data and all authors YB, QL and KGS contributed to the interpretation of data, the drafting and critically appraising of the content of the manuscript. All authors read and approved the final manuscript.

Competing interests

The authors declare that they have no competing interests.

Received: 14 October 2010 Accepted: 13 May 2011
Published: 13 May 2011

References

1. Bullock-Saxton J: Postural alignment in standing: A repeatability study. Aust Physiother 1993, 39:25-29.
2. Sheeran L, Sparkes V, Busse M, Van Deursen R: Preliminary study: reliability of the spinal wheel. A novel device to measure spinal postures applied to sitting and standing. Eur Spine J 2010, 19:995-1003.
3. Ariens GAM, Bongers PM, Douwes M, Miedema MC, Hoogendoorn WB, Van der Wal G, Bouter LM, Van Mechelen W: Are neck flexion, neck rotation, and sitting at work risk factors for neck pain? Results of a prospective cohort study. Occup Environ Med 2001, 58:200-207.
4. Auvinen BM, Tammelin T, Taimela S, Zitting P, Karppinen J: Neck and shoulder pains in relation to physical activity and sedentary activities in adolescence. Spine 2007, 32:1038-1044.
5. Niemi SM, Levoska S, Kemila J, Rekola K, Keinanen-Kiukaanniemi SM: Neck and shoulder symptoms and leisure time activities in high school students. J of Orthop Sports and Phys Ther 1996, 24:25-29.
6. Prins Y, Crous LC, Louw QA: A systematic review of posture and psychosocial factors as contributors to upper quadrant musculoskeletal pain in children and adolescents. Physio Theory and Prac 2008, 24:221-242.

7. Ramos EMA, James CA, Bear-Lehman J: Children's computer usage: Are they at risk of developing repetitive strain injury? Work 2005, 25:143-154.
8. Saarni L, Nygard C, Rimpela A, Nummi T, Kaukiainen A: The working postures among schoolchildren - A controlled intervention study on the effects of newly designed workstations. J of School Health 2007, 77:240-247.
9. Szeto GPY, Straker L, O'Sullivan PB: A comparison of symptomatic and asymptomatic office workers performing monotonous keyboard work-2: Neck and shoulder kinematics. Man Ther 2005, 10:281-291.
10. Barrero M, Hedge A: Computer environment for children: A review of design issues. Work 2002, 18:227-237.
11. Li G, Buckle P: Current techniques for assessing physical exposure to work-related musculoskeletal risks, with emphasis on posture-based methods. Ergon 1999, 42:674-695.
12. Hay O, Hershkovitz I, Rivlin E: Spine curve modelling for quantitative analysis of spinal curvature. 31st Ann Int Conf of the IEEE EMBS Minneapolis, Minnesota, USA; 2009, 6356-6359.
13. Vieira ER, Kumar S: Working postures: A literature review. J Occup Rehabil 2004, 14:143-159.
14. Vrtovec T, Pernus F, Likar B: A review of methods for quantitative evaluation of spinal posture. Eur Spine J 2009, 18:593-607.
15. White SA, Van den Broek NR: Methods for assessing reliability and validity for a measurement tool: a case study and critique using WHO haemoglobin colour scale. Stat Med 2004, 23:1603-1619.
16. Karanicolas PJ, Bhandari M, Kreder H, Moroni A, Richardson M, Walter SD, Norman GR, Guyatt GH: Evaluating agreement: conducting a reliability study. J Bone Joint Surg 2009, 91:99-106.
17. Portney LG, Watkins MP: Foundations of clinical research: applications to practice. New Jersy: Pearson Education;, 3 2009.
18. Brink H: Fundamentals of research methodology for health care professionals. Cape Town: Juta;, 2 2006.
19. Bannigan K, Watson R: Reliability and validity in a nutshell. J Clin Nursing 2009, 18:3237-3243.
20. Whiting P, Rutjes AWS, Reitsma JB, Bossuyt PMM, Kleijnen J: The development of QUADAS: a tool for quality assessment of studies of diagnostic accuracy included in systematic reviews. BMC Med Res Methodol 2003, 3:25-37.
21. Lucas NP, Macaskill P, Irwig L, Bogduk N: The development of a quality tool for studies of diagnostic reliability (QAREL). J Clin Epidemiol 2010, 63:854-861.
22. Smidt GL, McQuade KJ, Wei S: Evaluation of the Metrecom and its use in quantifying skeletal landmark locations. J Orthop Sports and Phys Ther 1992, 16:182-188.
23. Drerup B, Hierholzer E: Assessment of scoliotic deformity from back shape asymmetry using an improved mathematical model. Clin Biomech 1996, 11:376-383.
24. Drerup B, Hierholzer E: Back shape measurement using video rasterstereography and three-dimensional reconstruction of spinal shape. Clin Biomech 1994, 9:28-36.
25. Geldhof E, Cardon G, De Bourdeaudhuij I, Daneels L, Coorevits P, Vanderstraeten G, De Clerq D: Effects of back posture education on elementary schoolchildren's back function. Eur Spine J 2007, 16:829-839.
26. Normand MC, Descarreaux M, Harrison DD, Harrison DE, Perron DL, Ferrantelli JR, Janik TJ: Three dimensional evaluation of posture in standing with the PosturePrint: an intra- and inter-examiner reliability study. Chiropractic & Osteopathy 2007, 15:15-25.
27. Pazos V, Cheriet F, Dansereau J, Ronsky J, Zernicke RF, Labelle H: Reliability of trunk shape measurements based on 3-D surface reconstructions. Eur Spine J 2007, 16:1882-1891.
28. Warren JG, Bettany-Saltikov J, Van Schaik P, Papastefanou S: Evidence-based postural assessment for use in therapy and rehabilitation. Int J of Ther and Rehabil 2005, 12:527-532.
29. Whittle MW, Levine D: Measurement of lumbar lordosis as a component of clinical gait analysis. Gait and Posture 1997, 5:101-107.
30. Hackenberg L, Hierholzer E, Potzl W, Gotze C, Liljenqvist U: Rasterstereographic back shape analysis in idiopathic scoliosis after anterior correction and fusion. Clin Biomech 2003a, 18:1-8.
31. Hackenberg L, Hierholzer E, Potzl W, Gotze C, Liljenqvist U: Rasterstereographic back shape analysis in idiopathic scoliosis after posterior correction and fusion. Clin Biomech 2003b, 18:883-889.
32. Stokes IAF, Armstrong JG, Moreland MS: Spinal deformity and back surface asymmetry in idiopathic scoliosis. J Orthop Res 1988, 6:129-137.
33. Harrison DE, Janik TJ, Calliet R, Harrison DD, Normand MC, Perron , Ferrantelli JR: Validation of a computer analysis to determine 3-D rotations and translations of the ric cage in upright posture from three 3-D digital images. Eur Spine J 2007, 16:213-218.
34. Janik TJ, Harrison DE, Calliet R, Harrison DD, Normand MC, Perron DL: Validity of a computer postural analysis to estimate 3-Dimensional rotations and translations of the head from three 2-Dimensional digital images. J Manipul and Physiol Ther 2007, 30:124-129.
35. Pazos V, Cheriet F, Song L, Labelle H, Dansereau J: Accuracy assessment of human trunk surface 3D reconstructions from an optical digitising system. Med & Biol Eng & Comp 2005, 43:11-15.
36. Pearcy MJ, Hindle RJ: New method for the non-invasive three-dimensional measurement of human back movement. Clin Biomech 1989, 4:73-79.
37. Normand MC, Harrison DE, Calliet R, Black P, Harrison DD, Holland B: Reliability and measurement error of the Biotonix Video Posture Evaluation system - Part I: Inanimate objects. J of Manipul and Physiol Ther 2002, 25:246-250.
38. Norton BJ, Ellison JB: Reliability and concurrent validity of the Metrecom for length measurements on inanimate objects. Phys Ther 1993, 73:266-274.
39. Bossuyt PM, Reitsma JB, Bruns DE, Gatsonis CA, Glasziou PP, Irwig LM, Moher D, Rennie D, De Vet HCW, Lijmer JG: The STARD Statement for reporting studies of diagnostic accuracy: Explanation and elaboration. Clin Chem 2003, 49:7-18.
40. Wagner M, Bowing B, Deimling M, Rascher W, Rupprecht T: Low field thoracic MRI - a fast and radiation free routine imaging modality in children. Magnetic Resonance Imaging 2001, 19:975-983.
41. D'Osualdo F, Schierano S, Soldano M, Isola M: New tridimensional approach to the evaluation of the spine through surface measurement: the BACES system. J Med Eng & Technol 2002, 26:95-105.
42. Negrini S, Negrini A: Postural effects of symmetrical and asymmetrical loads on the spines of schoolchildren. Scoliosis 2007, 2:8-14.
43. Claus AP, Hides JA, Moseley GL, Hodges P: Is 'ideal' sitting posture real?: Measurement of spinal curves in four sitting postures. Man Ther 2009, 14:404-408.
44. Lissoni A, Caimmi M, Rossini M, Terenghi L: Three-dimensional analysis of the sitting posture. Europa Medicophysica 2001, 37:101-109.
45. Naslund A, Jesinkey K, Sundelin G, von Wendt L, Hirschfeld H: Effects of dynamic ankle-foot orthoses on standing in children with severe spastic diplegia. Int J Ther and Rehabil 2005, 12:200-207.
46. Jang R, Karwowski W, Quesadas PM, Rodrick D, Sherehiy B, Cronin SN, Layer JK: Biomechanical evaluation of nursing tasks in a hospital setting. Ergonomics 2007, 50:1835-1855.
47. Morl F, Blickhan R: Three-dimensional relation of skin markers to lumbar vertebrae of healthy subjects in different postures measured by open MRI. Eur Spine 2006, 15:742-751.
48. Cargill SC, Pearcy M, Darrell Barry M: Three-dimensional lumbar spine postures measured by magnetic resonance imaging reconstruction. Spine 2007, 32:1242-1248.
49. Lafon Y, Smith FW, Beillas P: Combination of a model-deformation method and a positional MRI to quantify the effects of posture on the anatomical structures of the trunk. J of Biomech 2010, 43:1269-1278.
50. Franklin ME, Chenier TC, Brauninger L, Cook H, Harris S: Effect of positive heel inclination on posture. J of Orthop Sports and Phys Ther 1995, 21:94-99.
51. Black KM, McClure P, Polansky M: The influence of different sitting positions on cervical and lumbar posture. Spine 1996, 21:65-70.
52. Gram M, Hasan Z: The spinal curve in standing and sitting posture in children with idiopathic scoliosis. Spine 1999, 24:169-177.
53. Duong L, Mac-Thiong J, Labelle H: Real time non-invasive assessment of external trunk geometry during surgical correction of adolescent idiopathic scoliosis. Scoliosis 2009, 4:5-15.
54. Rempel D, Barr A, Brafman D, Young E: The effect of six keyboard designs on wrist and forearm postures. Appl Ergon 2007, 38:293-298.
55. Straker LM, Maslen B, Burgess-Limerick R, Pollock C: Children have less variable postures and muscle activities when using new electronic information technology compared with old paper-based information technology. J of Electromyography and Kinesiology 2009, 9:e132-e143.

56. Grip H, Sundelin G, Gerdle B, Karlsson JS: Variations in the axis of motion during head repositioning - A comparison of subjects with whiplash-associated disorders or non-specific neck pain and healthy controls. Clin Biomech 2007, 22:865-873.
57. Neiva PD, Kirkwood RN, Godinho R: Orientation and position of head posture, scapula and thoracic spine in mouth-breathing children. Int J of Pediatric Otorhinolaryngology 2009, 73:227-236.
58. O'Sullivan P, Dankaerts W, Burnett A, Straker L, Bargon G, Moloney N, Perry M, Tsang S: Lumbopelvic kinematics and trunk muscle activity during sitting on stable and unstable surfaces. J of Orthop Sports and Phys Ther 2006, 36:19-25.
59. Caneiro JP, O'Sullican P, Burnett A, Barach A, O'Neil D, Tveit O, Olafsdottir K: The influence of different sitting postures on head/neck posture and muscle activity. Man Ther 2010, 15:54-60.
60. Astfalck RG, O'Sullivan P, Straker LM, Smith AJ, Burnett A, Caneiro JP: Sitting postures and trunk muscle activity in adolescent with and without nonspecific chronic low back pain. Spine 2010, 35:1387-1395.
61. Levine D, Whittle MW: The effects of pelvic movement on lumbar lordosis in the standing position. J of Orthop Sports and Phys Ther 1996, 24:130-135.
62. Skalli W, Zeller RD, Miladi L, Bourcereau G, Savidan M, Lavaste F, Dubousset J: Importance of pelvic compensation in posture and motion after posterior spinal fusion using CD instrumentation for idiopathic scoliosis. Spine 2006, 31:E359-366.
63. Theisen C, van Wagensveld A, Timmesfeld N, Efe T, Heyse TJ, Fuchs-Winkelmann S, Schofer MD: Co-occurence of outlet impimgement syndrome of the shoulder and restricted range of motion in the thoracic spine - a prospective study with ultrasound-based motion analysis. BMC Musculoskeletal Disorders 2010, 11:135-144.

Pre-publication history
The pre-publication history for this paper can be accessed here:
http://www.biomedcentral.com/1471-2474/12/93/prepub

doi:10.1186/1471-2474-12-93
Cite this article as: Brink et al.: The quality of evidence of psychometric properties of three-dimensional spinal posture-measuring instruments. BMC Musculoskeletal Disorders 2011 12:93.

Database		Keywords	Limits	Hits	Exclude by title	Exclude by abstract	Exclude by article	Duplicate	Accepted
Biomed central									
	1	3D; posture	1997-2010	152	136	6	8	0	2 **(Normand 07;** *Theisen 2010*)*
	2	3D; spinal posture	1997-2010	79	77	0	0	2 (Normand 07**;** *Theisen 2010*)*	0
	3	3D; measurement; posture	1997-2010	99	85	4	6	2 (Normand 07**;** *Theisen 2010*)*	0
	4	3D; assessment; posture	1997-2010	92	88	0	2	2 (Normand 07**;** *Theisen 2010*)*	0
	5	3D; instrument; posture	1997-2010	24	23	0	0	1 *(Theisen 2010*)*	0
	6	3D; measurement; spinal posture	1997-2010	50	48	0	0	2 (Normand 07**;** *Theisen 2010*)*	0
	7	3D; assessment; spinal posture	1997-2010	49	46	1	0	2 (Normand 07**;** *Theisen 2010*)*	0
	8	3D; instrument; spinal posture	1997-2010	14	13	0	0	1 *(Theisen 2010*)*	0
	9	3D; measurement tool	1997-2010	14	13	0	0	1 (Normand 07*)*	0
	10	3D; assessment tool	1997-2010	19	19	0	0	0	0
	11	3D; instrument	1997-2010	311	307	2	0	1 *(Theisen 2010*)*	1 (*Duong 09**)
	12	3D; posture; validity	1997-2010	50	48	0	0	2 (Normand 07**;** *Theisen 2010*)*	0
	13	3D; posture; reliability	1997-2010	59	56	0	0	2 (Normand 07*; Theisen 2010*)*	1 (*Negrini 07**)
	14	3D; posture; reproducibility	1997-2010	22	21	0	0	1 (*Theisen 2010**)	0
	15	3D; posture; accuracy	1997-2010	62	61	0	0	1 (Normand 07)	0
	16	3D; spinal posture; validity	1997-2010	26	24	0	0	2 (Normand 07**;** *Theisen 2010*)*	0
	17	3D; spinal posture; reliability	1997-2010	30	27	0	0	3 (Normand 07**;** *Negrini 07*; Theisen 2010*)*	0
	18	3D; spinal posture; reproducibility	1997-2010	14	13	0	0	1 *(Theisen 2010*)*	0
	19	3D; spinal posture; accuracy	1997-2010	29	28	0	0	1 (Normand 07)	0
	20	3D; validity; assessment, instrument, measurement	1997-2010	48	47	0	0	1 *(Theisen 2010*)*	0

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Biomed central									
	21	3D; reliability; assessment, instrument, measurement	1997-2009	61	59	0	0	2 (*Theisen 2010**)	0
	22	3D; accuracy; assessment, instrument, measurement	1997-2010	56	54	0	0	2 (*Theisen 2010**)	0
	23	3D; reproducibility; assessment, instrument, measurement	1997-2009	32	31	0	0	1 *(Theisen 2010*)*	0
CINAHL									
	1	3D; posture	English; 1980-2010	100	66	17	11	1 (Normand 07)	5 (*Szeto 2005*; Naslund 2005*Skalli 06*; Jang 07*; Astfalk 2010**)
	2	3D; spinal posture	English; 1980-2010	34	30	3	0	1 (*Astfalk 2010**)	0
	3	3D; measurement; posture	English; 1980-2010	32	28	1	0	0	3 *(Levine 96*; Black 96*; Gram 99**)
	4	3D; assessment; posture	English; 1980-2010	35	33	1	0	0	1 *(Lissoni 01**)
	5	3D; instrument; posture	English; 1980-2010	13	12	0	0	1 (Lissoni 01*)	0
	6	3D; measurement; spinal posture	English; 1980-2010	15	15	0	0	0	0
	7	3D; assessment; spinal posture	English; 1980-2010	19	19	0	0	0	0
	8	3D; instrument; spinal posture	English; 1980-2010	0	0	0	0	0	0
	9	3D; measurement tool	English; 1980-2010	4	3	1	0	0	0
	10	3D; assessment tool	English; 1980-2010	8	8	0	0	0	0
	11	3D; instrument	English; 1980-2010	84	82	1	0	1 (*Lissoni 01**)	0
	12	3D; posture; validity	English; 1980-2010	24	24	0	0	0	0
	14	3D; posture; accuracy	English; 1980-2010	16	16	0	0	0	0

Database		Keywords	Limits	Hits	Exclude by title	Exclude by abstract	Exclude by article	Duplicate	Accepted
CINAHL									
	15	3D; posture; reproducibility	English; 1980-2010	11	9	0	0	2 (*Cargill 09*; Lissoni 01**)	0
	16	3D; spinal posture; validity	English; 1980-2010	15	15	0	0	0	0
	17	3D; spinal posture; reliability	English; 1980-2010	20	20	0	0	0	0
	18	3D; spinal posture; accuracy	English; 1980-2010	9	9	0	0	0	0
	19	3D; spinal posture; reproducibility	English; 1980-2010	4	4	0	0	0	0
	20	3D; validity; assessment, instrument, measurement	English; 1980-2010	17	17	0	0	0	0
	21	3D; reliability; assessment, instrument, measurement	English; 1980-2010	18	18	0	0	0	0
	22	3D; accuracy; assessment, instrument, measurement	English; 1980-2010	8	8	0	0	0	0
	23	3D; reproducibility; assessment, instrument, measurement	English; 1980-2010	6	6	0	0	0	0
Pedro									
	1	three-dimensional		20	19	1	0	0	0
	2	Posture		180	176	3	1	0	0
	3	spinal posture		22	21	1	0	0	0
	4	measurement tool		36	36	0	0	0	0
	5	assessment tool		77	77	0	0	0	0
	6	Instrument		339	339	0	0	0	0
	7	3D; validity		2	2	0	0	0	0
	8	3D; reliability		1	1	0	0	0	0
	9	3D; accuracy		0	0	0	0	0	0
	10	3D; reproducibility		0	0	0	0	0	0
Proquest									
	1	3D; posture	1980-2010	80	70	1	7	1 (Pazos 07)	1 (*Morl 06**)
	2	3D; spinal posture	1980-2010	25	20	0	3	1 (Pazos 07)	1 **(Geldhof 07**)
	3	3D; measurement tool	1980-2010	243	240	1	2	0	0
	4	3D; assessment tool	1980-2010	399	395	0	3	1 (Pazos 07)	0
	5	3D; instrument	1980-2010	114	114	0	0	0	0
	6	3D; posture; measurement	1980-2010	16	15	0	0	1 (Pazos 07)	0

Database		Keywords	Limits	Hits	Exclude by title	Exclude by abstract	Exclude by article	Duplicate	Accepted
Proquest									
	7	3D; posture; assessment	1980-2010	16	16	0	0	0	0
	8	3D; posture; instrument	1980-2010	2	2	0	0	0	0
	9	3D; spinal posture; measurement	1980-2010	25	24	0	0	1 (Pazos 07)	0
	10	3D; spinal posture; assessment	1980-2010	18	13	0	0	1 (Pazos 07)	0
	11	3D; spinal posture; instrument	1980-2010	8	7	0	0	1 (Geldof 07)	0
	12	3D; posture; validity	1980-2010	15	14	0	0	1 (Harrison 07)	0
	13	3D; posture; reliability	1980-2010	4	3	0	0	1 (Pazos 07)	0
	14	3D; posture; accuracy	1980-2010	5	5	0	0	0	0
	15	3D; posture; reproducibility	1980-2010	10	9	0	0	1 (Pazos 07)	0
	16	3D; spinal posture; validity	1980-2010	9	8	0	0	1 (Pazos 07)	0
	17	3D; spinal posture; reliability	1980-2010	12	10	0	0	2 (Geldof 07; Pazos 07)	0
	18	3D; spinal posture; accuracy	1980-2010	18	16	0	0	2 (Geldof 07; Pazos 07)	0
	19	3D; spinal posture; reproducibility	1980-2010	6	4	0	0	2 (Geldof 07; Pazos 07)	0
	20	3D; measurement; assessment; instrument; validity	1980-2010	0	0	0	0	0	0
	21	3D; measurement; assessment; instrument; reliability	1980-2010	3	3	0	0	0	0
	22	3D; measurement; assessment; instrument accuracy	1980-2010	2	2	0	0	0	0
	23	3D; measurement; assessment; instrument reproducibility	1980-2010	3	3	0	0	0	0
Pubmed									
	1	3D [MESH]; posture [MESH]	English; 1980-2010; Human	206	185	7	14	0	1 **(Pazos 07)**
	2	3D [MESH]; spinal posture	English; 1980-2010; Human	37	31	0	5	1 (Pazos 07)	0

Database		Keywords	Limits	Hits	Exclude by title	Exclude by abstract	Exclude by article	Duplicate	Accepted
Pubmed									
	3	3D [MESH]; posture [MESH]; measurement	English; 1980-2010; Human	21	15	2	2	1 (Normand 07)	1 *(Cargill 07*)*
	4	3D [MESH]; posture [MESH]; assessment	English; 1980-2010; Human	15	15	0	0	0	0
	5	3D [MESH]; posture [MESH]; instrument	English; 1980-2010; Human	3	3	0	0	0	0
	6	3D [MESH]; spinal posture; assessment	English; 1980-2010; Human	4	4	0	0	0	0
	7	3D [MESH]; spinal posture; instrument	English; 1980-2010; Human	0	0	0	0	0	0
	8	3D [MESH]; spinal posture; measurement	English; 1980-2010; Human	3	3	0	0	0	0
	9	3D [MESH]; measurement tool	English; 1980-2010; Human	136	132	4	0	0	0
	10	3D [MESH]; assessment tool	English; 1980-2010; Human	227	225	0	0	2 (Pazos 07; Normand 02)	0
	11	3D [MESH]; instrument	English; 1980-2010; Human	160	158	1	0	0	1 (D'Osualdo 02*)
	12	3D [MESH]; posture [MESH]; validity	English; 1980-2010; Human	9	7	0	0	1 (Janik 07)	2 **(Normand 02; Harrison 07)**
	13	3D [MESH]; posture [MESH]; reliability	English; 1980-2010; Human	19	13	0	3	3 (Pazos 07; Normand 02; *Cargill 07**)	0
	14	3D [MESH]; posture [MESH]; accuracy	English; 1980-2010; Human	32	31	0	0	1 (Janik 07)	0
	15	3D [MESH]; posture [MESH]; reproducibility	English; 1980-2010; Human	60	57	0	0	3 (Pazos 07; Janik 07; Normand 02)	0
	16	3D [MESH]; spinal posture; validity	English; 1980-2010; Human	1	0	0	0	1 (Harrison 07)	0
	17	3D [MESH]; spinal posture; reliability	English; 1980-2010; Human	5	1	0	2	2 (Pazos 07; *Cargill 07**)	0

Database		Keywords	Limits	Hits	Exclude by title	Exclude by abstract	Exclude by article	Duplicate	Accepted
Pubmed									
	18	3D [MESH]; spinal posture; accuracy	English; 1980-2010; Human	8	7	0	1	0	1 **(Hackenberg 03a)**
	19	3D [MESH]; spinal posture; reproducibility	English; 1980-2010; Human	11	8	0	0	3 (Pazos 07; Hackenburg 03a*; Cargill 07**)	0
	20	3D [MESH]; measurement, instrument, assessment, validity	English; 1980-2010; Human	0	0	0	0	0	0
	21	3D [MESH]; measurement, instrument, assessment, reliability	English; 1980-2010; Human	1		0	0	0	0
	22	3D [MESH]; measurement, instrument, assessment, accuracy	English; 1980-2010; Human	0	0	0	0	0	0
	23	3D [MESH]; measurement, instrument, assessment, reproducibility	English; 1980-2010; Human	3	3	0	0	0	0
Science Direct									
	1	3D; measurement tool; spinal posture	1980-2010	656	607	23	19	1 (Harrison 07)	6 **(Janik 07, Hackenberg 03b**; *Neiva 09*; Claus 09*; Grip 07*; Lafon 2010**)*
	2	3D; assessment tool; spinal posture	1980-2010	631	601	9	18	2 (Janik 07*; Lafon 2010**)*	1 (Straker 09*)
	3	3D; instrument; spinal posture	1980-2010	547	539	1	1	*4 (Neiva 09*; Grip 07*;* Straker 09*; Cargill 06*)	2 (***Whittle 1997***; *Caneiro 2010**)*
	4	3D; measurement tool; spinal posture; validity	1980-2010	310	299	2	6	3 (Harrison 07) Janik 07; *Lafon 2010**)*	0
	5	3D; measurement tool; spinal posture; accuracy	1980-2010	365	361	0	2	2 (Harrison 07; *Lafon 2010**)*	0
	6	3D; measurement tool; spinal posture; reliability	1980-2010	353	349	1	1	2 (Janik 07; *Lafon 2010**)*	0

Database		Keywords	Limits	Hits	Exclude by title	Exclude by abstract	Exclude by article	Duplicate	Accepted
Science Direct									
	7	3D; measurement tool; spinal posture; reproducibility	1980-2010	152	149	2	0	1 (*Lafon 2010*)*	0
	8	3D; assessment tool; spinal posture; validity	1980-2010	310	307	0	1	2 (Janik07; Harrison 07)	0
	9	3D; assessment tool; spinal posture; accuracy	1980-2010	347	342	0	3	2 (Straker 09*; *Lafon 2010*)*	0
	10	3D; assessment tool; spinal posture; reliability	1980-2010	355	348	0	5	2 (Straker 09*; *Lafon 2010*)*	0
	11	3D; assessment tool; spinal posture; reproducibility	1980-2010	144	139	2	1	2 (Janik 07 *Lafon 2010*)*	0
	12	3D; instrument; spinal posture; validity	1980-2010	269	269	0	0	0	0
	13	3D; instrument; spinal posture; accuracy	1980-2010	268	264	0	2	2 ***(****Whittle 1997;* Straker 09*)	0
	14	3D; instrument; spinal posture; reliability	1980-2010	309	306	0	0	3 *(Neiva 09*;* Straker 09*; *Caneiro 2010*)*	0
	15	3D ;instrument; spinal posture; reproducibility	1980-2010	110	109	0	1	1 *(Neiva 09*)*	0

*Those papers addressing aim one are shown in italics with * and those papers addressing aim two are shown in bold script*

		Item	Explanation
Validity and reliability studies	1	If human subjects were used, did the authors give a detailed description of the sample of subjects used to perform the (index) test?	This item can be scored yes if: 1. the sample characteristics (e.g. height, weight, age, diagnosis, symptom status) were described or the manner of recruiting subjects were stated or if selection criteria were applied If none of the above have been described or if insufficient information was provided, select “no”. If inhuman or inanimate objects were used, select N/A.
Validity and reliability studies	2	Did the authors clarify the qualification, or competence of the rater(s) who performed the (index) test?	This item can be scored yes if: 1. the rater(s) characteristics (e.g. qualification, specialization, amount of experience using the instrument under investigation) have been described If the above have not been described or insufficient information was provided, select “no”.
Validity studies	3	Was the reference standard explained?	This item can be scored yes if: 1. the reference standard is likely to produce correct measurements 2. the reference standard is the best method available 3. details (name of the instrument, references to the accuracy of the instrument) of the reference standard is reported If none of the above is applicable to the reference standard’s description then select “no”.
Reliability studies	4	If interrater reliability were tested, were raters blinded to the findings of other raters?	This item can be scored yes if: 1. it is stated that the raters were blinded to each other’s findings or if a description, that implies that the raters were blinded, were reported If no information is provided then select “no”. If intrarater reliability were examined then select “N/A”.
Reliability studies	5	If intrarater reliability were tested, were raters blinded to their own prior findings of the test under evaluation?	This item can be scored yes if: 1. rater(s) have examined the same subjects on more than one occasion, it should be stated whether the rater(s) were blinded to the subjects they have examined previously If insufficient information is provided then select “no”. If interrater reliability were examined then select “N/A”.
Reliability studies	6	Was the order of examination varied?	This item can be scored yes if: 1. the order in which subjects were tested varied between raters if interrater reliability were tested. 2. the order of subjects were varied when intrarater reliability were tested If insufficient information is provided then select “no”. If varied order of examination is unnecessary or impractical (e.g. rater(s) digitizing or reading X-rays) then select “N/A”.
Validity studies	7	If human subjects were used, was the time period between the reference standard and the index test short enough to be reasonably sure that the target condition did not change between the two tests?	This item can be scored yes if: 1. results from the index test and the reference standard were collected on the same subjects at the same time 2. a delay between measurements occurs, it is important that the target condition should not change between measurements. If the time period between performing the index test and the reference standard was sufficiently long that the target condition may have changed between the two tests or if insufficient information is provided then select "no". If inhuman or inanimate objects were used then select N/A.
Reliability studies	8	Was the stability (or theoretical stability) of the variable being measured taken into account when determining the suitability of the time-interval between repeated measures?	This item can be scored yes if: 1. the stability of the variable is known or reported and reviewers then decide on an appropriate time interval between repeated measures (stability of a test variable can only be determined if there is a reference standard) 2. there is no reference standard then the reviewers should agree upon the theoretical stability of the variable and decide on an appropriate time interval between repeated measures
Validity studies	9	Was the reference standard independent of the index test?	This item can be scored yes if: 1. it is clear from the study that the index test did not form part of the reference standard If it appears that the index test formed part of the reference standard then select "no".
Validity and reliability studies	10	Was the execution of the (index) test described in sufficient detail to permit replication of the test?	This item can be scored yes if: 1. the study reported a clear description of the measurement procedure (e.g. the positioning of the instrument or rater, execution sequence of events) 2. if citations of methodology were supplied The extent to which details is expected to be reported depends on the ability of different procedures to influence the results and on the type of instrument or test under evaluation If insufficient information is provided then select “no”.

Validity studies	11	Was the execution of the reference standard described in sufficient detail to permit its replication?	This item can be scored yes if: 1. the study reported a clear description of the measurement procedure (e.g. the positioning of the instrument or rater, execution sequence of events) 2. if citations were supplied If insufficient information is provided then select "no".
Validity and reliability studies	12	Were withdrawals from the study explained?	This item can be scored yes if: 1. it is clear what happened to all subjects who entered the study 2. if subjects who entered but did not complete the study is taken into account If it appears that subjects who entered but did not complete the study were not accounted for or if insufficient information is provided then select "no " If inhuman or inanimate objects were used then select N/A.
Validity and reliability studies	13	Were the statistical methods appropriate for the purpose of the study?	This item can be scored yes if: 1. the analysis is appropriate in terms of the research question 2. the analysis is appropriate in terms of the type of data 3. a justification for the choice of statistical tests is provided 4. statistical analysis were reported using appropriate statistical measures 5. where possible, statistical analysis for validity and reliability studies incorporates measures of variability e.g. 95% CI If the analysis is not appropriate then an explanation should be provided If insufficient information was provided then select "no".

(index test / test = measurements from the tested instrument)

Definitions

Validity: The degree to which an instrument measures what it is intended to measure and the extent to which the values obtained are similar to the true values (Portney and Watkins 2009).

Criterion-related validity: The ability of one test (index test) to predict results obtained on an external criterion (gold standard/reference standard) that is already established or assumed to be valid. When both tests are performed on the same subjects, the scores from the index test are correlated with those achieved by the criterion measure (Portney and Watkins 2009).

Concurrent validity: When the index test and the criterion measure are taken at the same time so that it reflects the same incident of behaviour (Portney and Watkins 2009).

Predictive validity: When the index test is performed and followed by a period of time after which the criterion measure is obtained, the relationship between the index test and the criterion scores determines whether the index test is a valid predictor of the outcome of the criterion measure (Portney and Watkins 2009).

Construct validity: The ability of an instrument to measure an abstract concept, which cannot be observed directly and which has been constructed to represent an abstract trait (Portney and Watkins 2009).

Convergent validity: Indicates that two measures, which are believed to reflect the same construct, will have similar results or will correlate highly (Portney and Watkins 2009).

Divergent validity: Indicates that two measures, which are believed to measure different constructs, will correlate poorly (Bannigan and Watson 2009).

Discriminative validity: The extent to which measures from a measurement instrument distinguishes between individuals or populations that would be expected to differ (Bannigan and Watson 2009).

Reliability: The degree of consistency with which an instrument or observer(s) measure a variable and to which extent the measurement is free from error (Portney and Watkins 2009).

Test-retest reliability: Describes the stability of the assessment instrument in obtaining the same results with repeated measurements using the identical test on two or more separate occasions, keeping all testing conditions as constant as possible (Portney and Watkins 2009)

Intrarater reliability: The stability of data recorded by one observer across two or more trials of which the variables being rated are fixed and time is the only factor that varies between administrations (Karanicolas et al. 2009).

Interrater reliability: The extent to which two or more observers obtain similar scores when rating the same individuals (Karanicolas et al. 2009).

Journal of Evaluation in Clinical Practice
International Journal of Public Health Policy and Health Services Research

Journal of Evaluation in Clinical Practice ISSN 1365-2753

Clinical instruments: reliability and validity critical appraisal

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Keywords
appraisal tool, clinical tool, reliability, validity

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Accepted for publication: 14 April 2011

doi:10.1111/j.1365-2753.2011.01707.x

Abstract

Rationale, aim and objectives There is a lack of health care practitioners using objective clinical tools with sound psychometric properties. There is also a need for researchers to improve their reporting of the validity and reliability results of these clinical tools. Therefore, to promote the use of valid and reliable tools or tests for clinical evaluation, this paper reports on the development of a critical appraisal tool to assess the psychometric properties of objective clinical tools.

Method A five-step process was followed to develop the new critical appraisal tool: (1) preliminary conceptual decisions; (2) defining key concepts; (3) item generation; (4) assessment of face validity; and (5) formulation of the final tool.

Results The new critical appraisal tool consists of 13 items, of which five items relate to both validity and reliability studies, four items to validity studies only and four items to reliability studies. The 13 items could be scored as 'yes', 'no' or 'not applicable'.

Conclusion This critical appraisal tool will aid both the health care practitioner to critically appraise the relevant literature and researchers to improve the quality of reporting of the validity and reliability of objective clinical tools.

Introduction

Health practitioners, especially physiotherapists, often manage patients with syndromes by addressing the underlying physical impairments. The most common physical impairments assessed include muscle length, muscle strength, posture or range of movement. Clinical tools are used to assess these impairments and the findings serve as a crucial guide to plan the management strategy. The validity and reliability of these objective clinical tools are therefore important, particularly as there is an increased demand on health practitioners to provide objective, evidence-based data about the effect of interventions on these impairments [1].

To facilitate the objective assessment of physical impairments, health practitioners should select the most appropriate clinical tool based on its psychometric properties. Considering that there is generally a lack of validity and reliability testing of objective clinical tools, there is a need to educate health practitioners about the important concepts related to validity and reliability of clinical tools [2]. To our knowledge, there is no appraisal tool which can be used by clinicians and researchers to appraise the validity and reliability reporting of objective clinical tools.

The validity and reliability of a clinical tool is specific to the study design under which it was tested [3]. However, factors including the person performing the test or taking the measurement, the target population, the environment, the execution of the study procedure or the instrument itself could influence the psychometric properties of the tool [4]. Validity and reliability can therefore not be established by a single study and researchers should identify and address these gaps in the literature to ensure that a specific clinical tool is psychometrically sound for the clinical setting where it is required [3,5].

Jette *et al*. [5] reported that two of the barriers to evidence-based practice is (1) health care practitioners lacking or not being confident in their technical skills to critically appraise the literature and (2) the belief of health care practitioners that research often do not address the existing gap in knowledge because the research question, as formulated by the researcher, is not appropriate for the clinical setting. Rothstein [1] also stated that the integration of clinical practice and research is often compromised by the manner in which journals present research data and that authors should improve their reporting of patient characteristics and study designs as a means to enhance knowledge transfer between practice and research. Furthermore, it is imperative that researchers report on the reliability and validity of their primary data and not merely a secondary reference of published reports [6]. The methodological quality of a study describes how well the design, procedures and statistical analysis of the research study protects the findings from systematic bias, non-systematic bias and inferential error [7]. Bossuyt *et al*. [8] have also found that studies often fail to report

on these key elements and that there is a need to improve the quality of reporting of research into the validity and reliability of clinical tools.

To address this gap in current knowledge and to promote the use of valid and reliable tools for clinical evaluation, this paper reports on the development of a critical appraisal tool (CAT) to assess the psychometric properties of objective clinical tools.

Methods

The procedure for the development of the new CAT was similar to the methods used by Whiting *et al*. [9] and Lucas *et al*. [10]. The procedural process included the following steps: (1) preliminary conceptual decisions; (2) defining key concepts; (3) item generation; (4) assessment of face validity; and (5) formulation of the final tool. Figure 1 is a flow chart demonstrating the development of the new CAT.

Preliminary conceptual decisions

We decided that the new tool was required to
1 be used in systematic reviews of studies testing validity and reliability of objective clinical tools;
2 critically appraise the methodological quality of studies reporting on the validity and reliability testing of objective clinical tools;
3 be easy to use by reviewers with different academic experience; and
4 be used as a checklist for constructing and designing validity and reliability studies of objective clinical tools.

Each item must be weighted equally important and must be considered individually for its impact on the methodological quality of the study. The CAT in its entirety must be used for appraisal of review studies without attaching a numerical score to its value. The items pertaining to reliability and validity methodological procedures could be grouped together in one tool because the tool does not incorporate a quality score and each item is considered individually.

Defining key concepts

Index test: Refers to the test which is under investigation [8]. **Validity:** The degree to which an instrument measures what it is intended to measure and the extent to which the values obtained are similar to the true values [3]. **Accuracy:** Accuracy refers to the amount of agreement between the results from the index test and those from the reference standard [8]. **Criterion-related validity:** The ability of the index test to predict results obtained on an external criterion (gold standard/reference standard) that is already established or assumed to be valid. When both tests are performed on the same subjects, the scores from the index test are correlated with those achieved by the criterion measure [3]. **Concurrent validity:** When the index test and the criterion measure are taken at the same time so that it reflects the same incident of behaviour [3]. **Reliability:** The degree of consistency with which an instrument or observer(s) measures a variable and to which extent the measurement is free from error [3]. **Test–retest reliability:** The extent to which one observer rating one sample of individuals with the identical test on two or more separate occasions, achieve similar results keeping all testing conditions as constant as possible [3]. **Intrarater reliability:** The stability of data recorded by one observer across two or more trials of which the variables being rated are fixed and time is the only factor that varies between administrations [3]. **Interrater reliability:** The extent to which two or more observers obtain similar scores when rating the same individuals [3].

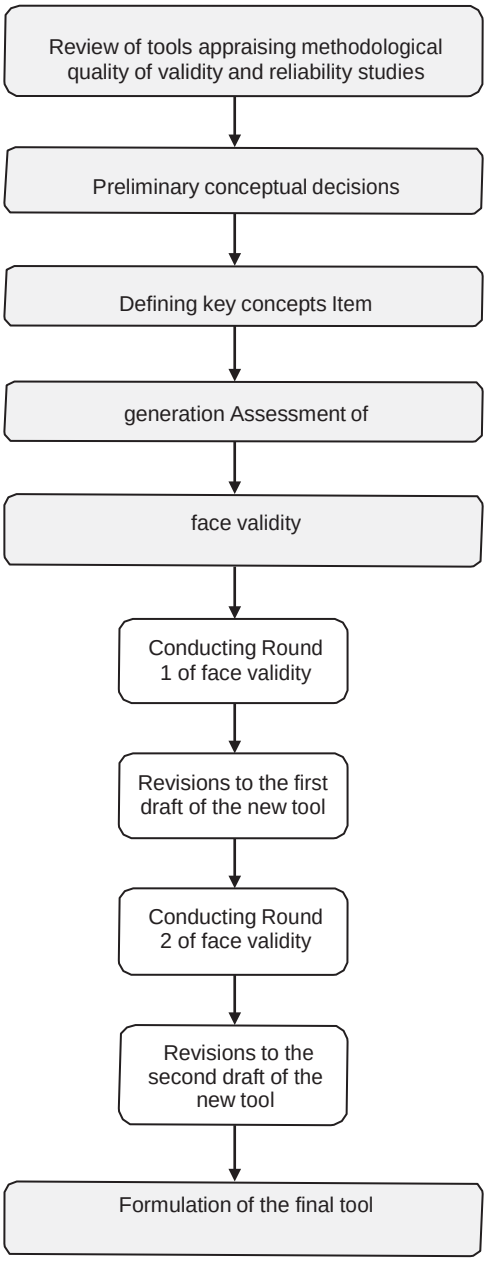


Figure 1 Flow chart demonstrating the developmental process of the new critical appraisal tool.

Item generation

Two existing CATs were selected to use as a guideline for the development of the new CAT. The Quality Assessment of

Table 1 Reasons for item exclusion

Item	QUADAS Item description	Reason for exclusion
5	Did the whole sample or a random selection of the sample receive verification using a reference standard?	There is no disease status which needs to be verified by the reference standard and therefore it is unlikely that only a sample of the subjects would be assessed with the reference standard.
6	Did patients receive the same reference standard regardless of the index test result?	As there is no disease status which can be detected with the index test and thus influence the decision to use a different reference standard, it is unlikely that more than one reference standard would be used.
10	Were the index test results interpreted without knowledge of the results of the reference standard?	Knowledge about the results obtained from the objective instrument (index test) should not influence the results obtained from the reference standard and vice versa.
11	Were the reference standard results interpreted without knowledge of the results of the index test?	
12	Were the same clinical data available when test results were interpreted as would be available when the test is used in practice?	There is no disease status that needs to be diagnosed; therefore the lack or presence of any clinical data would be irrelevant.
13	Were uninterpretable/intermediate test results reported?	Uninterpretable data are only important when there is a correlation between the data and the outcome of a disease status and as there is no disease status with diagnostic criteria to consider, it is unlikely that uninterpretable data would be removed from the analysis.
Item	QAREL Item description	Reason for exclusion
5	Were raters blinded to the results of the accepted reference standard or disease status for the target disorder (or variable) being evaluated?	There is no disease status of which prior knowledge thereof can influence the rater's measurement of the variable.
6	Were raters blinded to clinical information that was not intended to be provided as part of the testing procedure or study design?	There is no disease status of which clinical information or additional cues thereof could affect the interpretation of the measurement variable.
7	Were raters blinded to additional cues that were not part of the test?	

QUADAS, Quality Assessment of Diagnostic Accuracy Studies; QAREL, Quality Appraisal of Diagnostic Reliability Studies.

Diagnostic Accuracy Studies (QUADAS) was chosen for its similarity in items referring to the methodological procedures of diagnostic accuracy testing and the validity testing of an objective instrument or clinical tool [9]. The Quality Appraisal of Diagnostic Reliability Studies (QAREL) was selected because the tool's items resemble the items required for the methodological quality assessment of studies, testing the reliability of an objective instrument or clinical tool [10]. Both these existing tools could not be used in its original format because diagnostic studies aim to evaluate a test with the purpose of detecting or predicting a target condition and as one objective clinical test, performed by a physiotherapist, does not result in formulating a diagnosis, the QUADAS and the QAREL were not appropriate [9].

Eight items from the QUADAS and eight items from the QAREL were combined. Duplicate and inappropriate quality appraisal items were excluded. Six items from the QUADAS (items 5, 6, 10–13) and three items from the QAREL (items 5–7) were excluded. Table 1 provides reasons for the item exclusion for both the QUADAS and the QAREL.

Assessment of face validity

Round 1

The first draft of the new tool was given to three independent reviewers. The reviewers appraised three papers, which formed part of a systematic review that was being conducted during this period. The reviewers have previously conducted systematic reviews and therefore had experience with using CATs. Any discrepancies between the answers were discussed and changes were made to the phrasing of items and the explanation of items.

Round 2

The revised second draft of the new tool was given to three physiotherapy master degree students to appraise two papers. These three students were not experienced users of CATs, of which English was not the first language for two of the three students. A discussion session was held between the students and the principal author (Y. B.). Any vague or unclear phrasing was discussed.

Formulation of the final tool

Once the assessment of face validity was completed, the authors responded to the suggestions of the reviewers and revisions were made to the drafts in order to produce the final tool.

Results

Once the first phase of the face validity assessment was completed, changes were made to the phrasing of items 4 and 5 and the phrasing of the explanation of items 4, 6, 8 and 10. These changes are shown in Table 2. After phase 2, no changes were made to the

Table 2 Changes made to the item phrasing

Item	First draft	Second draft
4	Were raters blinded to the findings of other raters during the study?	If interrater reliability was tested, were raters blinded to the findings of other raters?
5	Were raters blinded to their own prior findings of the test under evaluation?	If intrarater reliability was tested, were raters blinded to their own prior findings of the test under evaluation?
	Explanation	
4	1. two or more raters were used in the study, it should be stated whether the raters were blinded to each others' findings. If insufficient information is provided then select 'no'. If only one rater was used then select 'N/A'.	1. it is stated that the raters were blinded to each other's findings or if a description that implies that the raters were blinded was reported. If no information is provided then select 'no'. If intrarater reliability was examined then select 'N/A'.
6	1. the order of two or more raters was varied when testing subjects. 2. the order of subjects was varied when one rater is used.	1. the order in which subjects were tested varied between raters if interrater reliability was tested. 2. the order of subjects was varied when intrarater reliability was tested.
8	1. the stability of the variable is known and reviewers then decide on an appropriate time interval between repeated measures (stability of a test variable can only be determined if there is a reference standard).	1. the stability of the variable is known or reported and reviewers then decide on an appropriate time interval between repeated measures (stability of a test variable can only be determined if there is a reference standard). 2. there is no reference standard, then the reviewers should agree upon the theoretical stability of the variable and decide on an appropriate time interval between repeated measures.
10	2. if citations were supplied.	2. if citations of methodology were supplied.

second draft of the new tool, although a list of definitions for validity and reliability and an introductory statement of how to use the CAT were added as the discrepancies found among the students, and were related to their lack of knowledge concerning validity and reliability studies in general.

The new CAT consists of 13 items, of which five items relate to both validity and reliability studies, four items to validity studies only and four items to reliability studies. The 13 items could be scored as 'yes', 'no' or 'not applicable'. When using this new CAT for evaluating only validity studies, all items referring to only reliability studies should be scored 'not applicable' and vice versa. Refer to Table 3 for the final version of the new CAT.

Item 1: If human subjects were used, did the authors give a detailed description of the sample of subjects used to perform the (index) test on?

Why the criterion should be evaluated: The validity and reliability of a test will be affected by the sample characteristics or composition and therefore the study has to report on the sample characteristics because the validity and reliability scores will then only be applicable to that particular population. A study does not contribute to validity and reliability testing if the subjects were not recruited appropriately.

Explanation: This item can be scored yes if:

1 the sample characteristics (e.g. height, weight, age, diagnosis, symptom status) were described or the manner of recruiting subjects was stated or if selection criteria were applied.

If none of the above have been described or if insufficient information was provided, select 'no'. If inhuman or inanimate objects were used, select N/A.

Item 2: Did the authors clarify the qualification, or competence of the rater(s) who performed the (index) test?

Why the criterion should be evaluated: The amount of experience of the rater(s), performing the (index) test, will influence the validity and reliability scores and needs to be explained.

Explanation: This item can be scored yes if:

1 the rater(s) characteristics (e.g. qualification, specialization, amount of experience using the instrument under investigation) have been described.

If the above have not been described or insufficient information was provided, select 'no'.

Item 3: Was the reference standard explained?

Why the criterion should be evaluated: The index test scores need to be compared to the scores obtained from the reference standard in order to test validity, therefore the reference standard needs to be explained appropriately.

Explanation: This item can be scored yes if:

1 the reference standard is likely to produce correct measurements;

2 the reference standard is the best method available; and

3 details (name of the instrument, references to the accuracy of the instrument) of the reference standard are reported.

Table 3 Critical appraisal tool for validity and reliability studies of objective clinical tools

	Item	
1	If human subjects were used, did the authors give a detailed description of the sample of subjects used to perform the (index) test?	Validity and reliability studies
2	Did the authors clarify the qualification, or competence of the rater(s) who performed the (index) test?	Validity and reliability studies
3	Was the reference standard explained?	Validity studies
4	If interrater reliability was tested, were raters blinded to the findings of other raters?	Reliability studies
5	If intrarater reliability was tested, were raters blinded to their own prior findings of the test under evaluation?	Reliability studies
6	Was the order of examination varied?	Reliability studies
7	If human subjects were used, was the time period between the reference standard and the index test short enough to be reasonably sure that the target condition did not change between the two tests?	Validity studies
8	Was the stability (or theoretical stability) of the variable being measured taken into account when determining the suitability of the time interval between repeated measures?	Reliability studies
9	Was the reference standard independent of the index test?	Validity studies
10	Was the execution of the (index) test described in sufficient detail to permit replication of the test?	Validity and reliability studies
11	Was the execution of the reference standard described in sufficient detail to permit its replication?	Validity studies
12	Were withdrawals from the study explained?	Validity and reliability studies
13	Were the statistical methods appropriate for the purpose of the study?	Validity and reliability studies

If none of the above is applicable to the reference standard's description, then select 'no'.

Item 4: If interrater reliability was tested, were raters blinded to the findings of other raters?

Why the criterion should be evaluated: When raters have access to the findings of other raters, it compromises the quality of the reliability testing procedure by inflating the agreement among the raters, therefore blinding needs to be performed.

Explanation: This item can be scored yes if:

1 it is stated that the raters were blinded to each other's findings or if a description that implies that the raters were blinded was reported.

If no information is provided then select 'no'. If intrarater reliability was examined then select 'N/A'.

Item 5: If intrarater reliability was tested, were raters blinded to their own prior findings of the test under evaluation?

Why the criterion should be evaluated: If raters have knowledge of their prior own findings, it will influence the findings of their repeated measurements and could inflate the rater agreement, therefore appropriate measures, depending on the characteristics or the study design of the research study, need to be applied to ensure blinding.

Explanation: This item can be scored yes if:

1 rater(s) has/have examined the same subjects on more than one occasion, it should be stated whether the rater(s) was/were blinded to the subjects they have examined previously.

If insufficient information is provided then select 'no'. If interrater reliability was examined then select 'N/A'.

Item 6: Was the order of examination varied?

Why the criterion should be evaluated: If the order is varied, in which the raters examine the subjects when interrater reliability is tested, it reduces the risk of systematic bias. If the order is varied in which subjects are examined by one rater when intrarater reliability is tested, it reduces the risk of the rater recalling the previous test scores and reduces bias.

Explanation: This item can be scored yes if:

1 the order in which subjects were tested varied between raters if interrater reliability was tested;

2 the order of subjects was varied when intrarater reliability was tested.

If insufficient information is provided then select 'no'. If varied order of examination is unnecessary or impractical (e.g. rater(s) digitizing or reading X-rays) then select 'N/A'.

Item 7: If human subjects were used, was the time period between the reference standard and the index test short enough to be reasonably sure that the target condition did not change between the two tests?

Why the criterion should be evaluated: The index test and the reference standard should be performed at the same time; however, this is not always possible. It becomes important to know whether it is possible that the test variable did not change between the two tests, otherwise it will affect the index test's validity performance.

Explanation: This item can be scored yes if:

1 results from the index test and the reference standard were collected on the same subjects at the same time;

2 a delay between measurements occurs, it is important that the target condition should not change between measurements.

If the time period between performing the index test and the reference standard was sufficiently long that the target condition may have changed between the two tests or if insufficient information is provided then select 'no'. If inhuman or inanimate objects were used then select N/A.

Item 8: Was the stability (or theoretical stability) of the variable being measured taken into account when determining the suitability of the time interval between repeated measures?

Why the criterion should be evaluated: For reliability, the test variable should not change between repeated measures, otherwise it will decrease the amount of agreement obtained between and within the rater(s).

Explanation: This item can be scored yes if:

1 the stability of the variable is known or reported and reviewers then decide on an appropriate time interval between repeated measures (stability of a test variable can only be determined if there is a reference standard);

2 there is no reference standard, then the reviewers should agree upon the theoretical stability of the variable and decide on an appropriate time interval between repeated measures.

If insufficient information is provided then select 'no'.

Item 9: Was the reference standard independent of the index test?

Why the criterion should be evaluated: If the reference standard and the index test are not independently performed, then the index test cannot replace the reference standard on its own.

Explanation: This item can be scored yes if:

1 it is clear from the study that the index test did not form part of the reference standard.

If it appears that the index test formed part of the reference standard then select 'no'.

Item 10: Was the execution of the (index) test described in sufficient detail to permit replication of the test?

Why the criterion should be evaluated: Variations in the execution of the reference standard and the (index) test might affect the agreement between the two tests and it is also important to be able to replicate the same study procedure in another setting when needed.

Explanation: This item can be scored yes if:

1 the study reported a clear description of the measurement procedure (e.g. the positioning of the instrument or rater, execution sequence of events);

2 citations of methodology were supplied.

The extent to which details is expected to be reported depends on the ability of different procedures to influence the results and on the type of instrument or test under evaluation. If insufficient information is provided then select 'no'.

Item 11: Was the execution of the reference standard described in sufficient detail to permit its replication?

Why the criterion should be evaluated: For the same reason as item 10.

Explanation: This item can be scored yes if:

1 the study reported a clear description of the measurement procedure (e.g. the positioning of the instrument or rater, execution sequence of events);

2 citations were supplied.

If insufficient information is provided then select 'no'.

Item 12: Were withdrawals from the study explained?

Why the criterion should be evaluated: The sample composition will influence the validity and reliability performance of the (index) test; therefore it is important to know whether any withdrawals from the sample might have changed the composition of the sample.

Explanation: This item can be scored yes if:

1 it is clear what happened to all subjects who entered the study;

2 subjects who entered but did not complete the study are taken into account.

If it appears that subjects who entered but did not complete the study were not accounted for or if insufficient information is provided, then select 'no'. If inhuman or inanimate objects were used then select N/A.

Item 13: Were the statistical methods appropriate for the purpose of the study?

Why the criterion should be evaluated: The aim of validity and reliability studies is to report on an estimate of validity and reliability for the particular test and appropriate statistical methods need to be implemented in order to produce this estimate.

Explanation: This item can be scored yes if:

1 the analysis is appropriate in terms of the type of data (e.g. categorical, continuous, dichotomous);

2 statistical analysis for validity studies incorporates, for example, means, differences between measurements, 95% confidence interval, ANOVA; and

3 statistical analysis for reliability studies incorporates, for example, interclass correlation coefficient, 95% confidence interval.

If the analysis is not appropriate or if insufficient information was provided, then select 'no'.

Discussion

A purpose-built CAT was developed specifically for appraising the methodological quality of studies testing the validity and reliability of objective clinical tools. Well-conducted clinical research provides the best information about what interventions are most effective, which diagnostic or clinical tool to use or a patient's likely prognosis [11]. If good quality clinical research is available, it takes precedence over theories and expert opinions. The appropriateness of a study design depends on the study question, for

example, studying the prognosis of patients is best answered by prospective cohort studies where the cohorts are monitored from an early and uniform point in the course of the condition [11]. Likewise, research questions concerning the validity and reliabil- ity of objective clinical tools are best answered by a study design which incorporates the components of the new CAT reported in this paper. Researchers aiming to conduct high methodological quality validity and reliability studies of objective clinical tools will aspire to report on the items listed in the new CAT.

Health care practitioners often do not have sufficient training in research methods to be able to distinguish between high- and low-quality studies; however, this problem is being addressed by teaching undergraduates the skills of critical appraisal, especially using methodological filters or methodological ratings from scales [11].

When health care practitioners use this new CAT, they must have an understanding of the concepts of validity and reliability in order to benefit from using the appraisal tool. If this appraisal tool is used in systematic reviews of validity and reliability studies, it is important that different reviewers have the same understanding of the items and that they have consensus regarding the interpretation and application of each item [10]. This appraisal tool will also require that the reviewers have proper content knowledge of the studies under review.

This appraisal tool does not incorporate a quality score, but instead the impact of each item on the study design should be considered individually. Whiting *et al*. [12] tested five different methods of weighting the items of the QUADAS in order to determine the effect of incorporating quality scores in systematic reviews. The study concluded that different approaches of weight- ing the individual items of the same instrument led to different quality scores for the same studies and using these scores in the results of a systematic review could lead to drawing the wrong conclusions. It is suggested that the results of a systematic review's quality assessment should report on the association between the individual items and the methodological quality of the study.

Conclusion

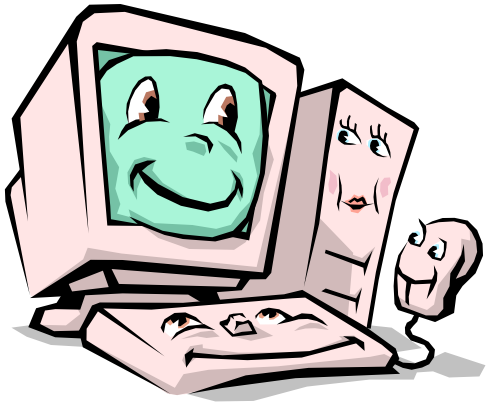
This paper documented the development of a CAT for studies testing the validity and reliability of objective clinical tools. This CAT has 13 items that can be scored 'yes', 'no' or 'not applicable'.

This CAT will aid both the health care practitioner to critically appraise the relevant literature and researchers to improve the quality of reporting of the validity and reliability of objective clinical tools.

References

1. Rothstein, J. M. (2004) The difference between knowing and applying. *Physical Therapy*, 84 (4), 310–311.
2. Brink, Y., Louw, Q. & Grimmer-Somers, K. (2011) The quality of evidence of psychometric properties of three-dimensional spine posture-measuring instruments. *BMC Musculoskeletal Disorders*, 12, 93.
3. Portney, L. G. & Watkins, M. P. (2009) Foundations of Clinical Research: Applications to Practice. Upper Saddle River, NJ: Pearson Education.
4. Brink, H. (2006) Fundamentals of Research Methodology for Health Care Professionals. Cape Town: Juta.
5. Jette, D. U., Bacon, K., Batty, C., Carlson, M., Ferland, A., Hemingway, R. D., Hill, J. C., Ogilvie, L. & Volk, D. (2003) Evidence-Based Practice: beliefs, attitudes, knowledge, and behaviours of physical therapists. *Physical Therapy*, 83 (9), 786–805.
6. Kaplan, D. (2004) The Sage Handbook of Quantitative Methodology for the Social Sciences. Thousand Oaks, CA: SAGE. p. 75.
7. Roberts, A. R. & Yeager, K. R. (2004) Evidence-Based Practice Manual: Research and Outcome Measures in Health and Human Sciences. Oxford: Oxford University Press. p. 22.
8. Bossuyt, P. M., Reitsma, J. B., Bruns, D. E., Gatsonis, C. A., Glasziou, P. P., Irwig, L. M., Moher, D., Rennie, D., De Vet, H. C. W. & Lijmer, J. G. (2003) The STARD Statement for reporting studies of diagnostic accuracy. Explanation and elaboration. *Clinical Chemistry*, 49 (1), 7–18.
9. Whiting, P., Rutjes, A. W. S., Reitsma, J. B., Bossuyt, P. M. M. & Kleijnen, J. (2003) The development of QUADAS: a tool for quality assessment of studies of diagnostic accuracy included in systematic reviews. *BMC Medical Research Methodology*, 3, 25–37.
10. Lucas, N. P., Macaskill, P., Irwig, L. & Bogduk, N. (2010) The development of a quality tool for studies of diagnostic reliability (QAREL). *Journal of Clinical Epidemiology*, 63 (8), 854–861. DOI: 10.1016/j.jclinepi.2009.10.002.
11. Herbert, R. D., Sherrington, C., Maher, C. & Moseley, A. M. (2001) Evidence-based practice – imperfect but necessary. *Physiotherapy Theory and Practice*, 17, 201–211.
12. Whiting, P., Harbord, R. & Kleijnen, J. (2005) No role for quality scores in systematic reviews of diagnostic accuracy studies. *BMC Medical Research Methodology*, 5, 19–27. DOI: 10.1186/1471-2288-5-19.

COMPUTER USAGE QUESTIONNAIRE for SCHOOL LEARNERS



TELL US ABOUT YOURSELF….

1. What is your **school's** name? _____
2. What is **your name?** _____
3. What is your **date of birth** (day, month, year)? _____
4. In which **grade** are you? _____
5. Are you: ☐ A **boy** ☐ A girl
6. Are you: ☐ **Mainly right handed** ☐ **Mainly left handed**
7. Do you wear: ☐ **Spectacles** ☐ **Contact Lenses** ☐ **None**
8. Do you suffer from any **medical condition/s**, e.g. Epilepsy, Diabetes, Asthma?
   ☐ Yes ☐ No

9. If **"Yes"**, do you use any **medication** for this condition?
   ☐ Yes ☐ No

10. Have you ever been involved in an **accident or sporting injury** where you injured your **back** or **neck**?
    ☐ Yes ☐ No

11. Have you had any **surgery** involving your **muscles** or **joints** done?
    ☐ Yes ☐ No

    If **"Yes"**, please list the **type of surgery** and when it was done.
    Year: _____ Surgery: _____
    Year: _____ Surgery: _____

COMPUTER USE AT SCHOOL…..

*Mark your answer with a **cross (X)**.*

12. How long have you been using a computer during **lessons at school**?
    ☐ Less than 1 year ☐ 2 years ☐ 3 years ☐ 4 years or more

13. Do you **use the computer** for any of the following **subjects**? Mark as many as you want.
    ☐ Mathematics ☐ Computer Studies ☐ Languages ☐ Compu-Typing ☐ Others, please list:_____

14. What do you **use** the **computer** for at **school**? Mark as many as you want.
    ☐ Typing ☐ View lessons ☐ Experiments ☐ Internet and e-mail
    ☐ Use educational programmes ☐ Other, please list:_____

15. How many **times per week** do you use the **computer at school**?
    ☐ Once or less per week ☐ Twice per week ☐ Three times per week ☐ Four times per week ☐ Five times or more per week

16. During **one session** at school, **how long** do you spend using the computer?
    ☐ Less than 30 minutes ☐ About 45 minutes ☐ 1 Hour ☐ 1 ½ Hours ☐ 2 Hours or more

17. How many **hours per week** do you spend working on the **school computer**?
☐ About 2 Hours per week ☐ About 4 Hours per week ☐ About 6 Hours per week ☐ 8 Hours or more per week

18. Did you receive any **instruction** on **how to sit** in front of the **computer**?
☐ Yes ☐ No
If **"Yes"**, who **instructed** you?_____

19. Do you take a **short break** of a few minutes at least **once an hour**, when using the **computer**? (A short computer break, means to stop using your hands at the keyboard/ mouse, e.g. to stand up, stretch out, use the bathroom, etc.)
☐ Yes ☐ No

20. Have you received any information on **stretches/ exercises** you can do during the above-mentioned short breaks?
☐ Yes ☐ No

If **"Yes"**, who provided the information?_____
Please describe the type of **stretches** or **exercises** that you do?_____

COMPUTER USE ELSEWHERE….

*Mark your answer with a **cross (X)**.*

21. **Where** do you use a computer **outside school**? Mark as many as you want.
☐ At your home ☐ Internet Café ☐ Relative/ friend's home ☐ Library ☐ Elsewhere (state where)_____

22. Roughly, **how long** have you been using the computer **outside school**?
☐ Less than a year ☐ 2-3 Years ☐ 4 Years ☐ 5 years or more

23. On average, how many **times per week** do you use the computer?
☐ Less than once a week ☐ 2 times per week ☐ 3 times per week ☐ 4 times per week ☐ Five times or more per week

24. On average, how many **hours per day** do you spend working on the computer **outside of school?**
☐ Less than 30 minutes ☐ 1 Hour ☐ 2-3 Hours ☐ 4 Hours or more

25. What **type of computer** do you use most of the time?
☐ Desktop computer ☐ Laptop computer ☐ Both

26. Where is the computer **positioned** when you are using it? Mark as many as you want.
☐ On a desk/ table ☐ On your lap ☐ On the floor ☐ On a chair
☐ Other, please list_____

27. Do you participate in any **other activity** whilst simultaneously working on the computer? Mark as many as you want.
☐ Talk to a friend ☐ Listen to music ☐ Talk on the phone ☐ Writing on a page
☐ Other, please list_____

YOUR SPORTS and MUSIC….

*Mark your answer with a **cross (X)**.*

28. Do you participate in **sports**?
☐ Yes ☐ No……

29. If **"Yes"**, **which sports** do you participate in? Mark as many as you want.
☐ Rugby ☐ Soccer ☐ Tennis ☐ Table tennis ☐ Netball
☐ Athletics ☐ Hockey ☐ Other, please list_____

30. How many **times per week** do you participate in your combined sporting activities?
☐ Less than once a week ☐ Once a week ☐ Twice a week ☐ Three times or more per week

31. On average, how many **hours per week** do you participate in all your sports?
☐ Less than an hour ☐ About 2 Hours ☐ About 4 Hours ☐ 6 Hours or more

32. Do you play a **musical** instrument?
☐ Yes ☐ No

33. If **"Yes"**, what **type** of musical instrument/ s do you play?_____

34. On average, how many **hours per week** do you play your musical instrument?

☐ Less than 1 hour ☐ About 2 Hours ☐ About 4 Hours ☐ Six Hours or more

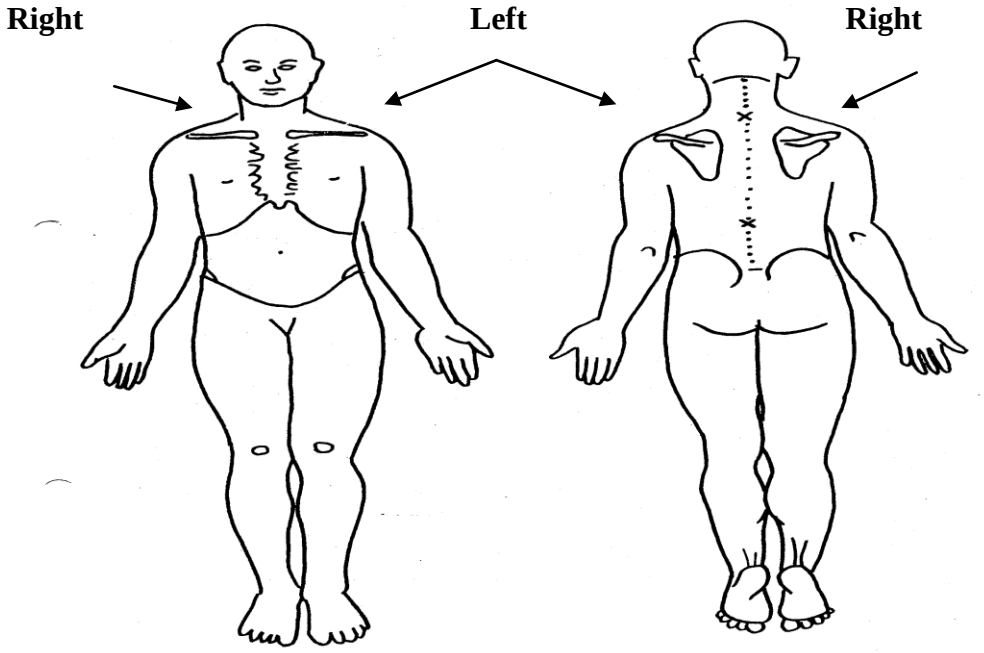
TELL US ABOUT YOUR ACHES and PAINS…

*Mark your answer with a **cross (X)**.*

35. Have you experienced any **headaches, discomfort, stiffness, pain,** or **tingling** in your **muscles** or **joints** in the **last month?**

☐ Yes ☐ No

36. If **"Yes"**, in which **areas of the body** did you experience these feelings in the last month? Mark the **areas** where you **felt** your **symptoms** with a "**X**"



37. Tell us **how bad** these feelings of **discomfort, stiffness, pain** or **tingling** has been in the **last month**

If you had **SLIGHT discomfort, stiffness, pain,** or **tingling**, mark (**X**):  .

If you had **A LOT** of **discomfort, stiffness, pain,** or **tingling,** mark (**X**): 

This is an example of how you should do it…

Neck	X	

Body Area	Slight Discomfort, Pain, etc	A lot of discomfort, pain, etc
Head		
Neck		
Upper Back		
Mid-Back		
Lower Back		
Right Shoulder		
Left Shoulder		
Right Elbow		
Left Elbow		
Right Wrist and Hand		
Left Wrist and Hand		

38. **When** did you feel the **headaches**, **discomfort, stiffness, pain** or **tingling** of your **muscles and joints?** Mark as many as you want.

☐ Sitting in front of your school desk ☐ During or after sports ☐ Working on the computer at school
☐ Writing in a book at school desk ☐ Working on the computer elsewhere ☐ Other (please list):_____

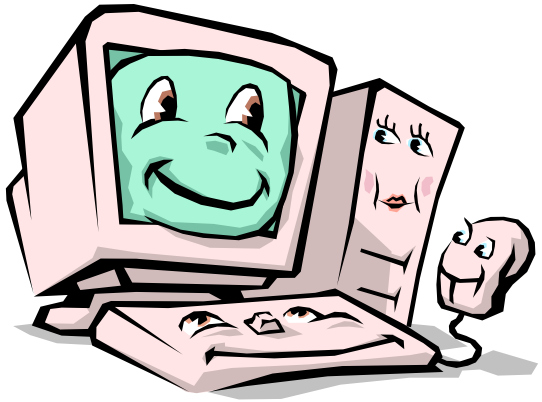
39. Have you ever felt like not using the computer because of **headaches, discomfort, stiffness, pain,** or **tingling** of your **muscles** and **joints?**

☐ Yes ☐ No

40. Have you **stopped** any of the following **activities** because of the **headaches, discomfort, stiffness, pain**, or **tingling** of your **muscles** and **joints** in the **last 3 months**? Mark as many as you want.
☐ Playing sports ☐ Working on the computer ☐ Writing in a book ☐ Playing a musical instrument ☐ List any other_____

41. In the **last month**, have you seen a **Doctor** or any other **medical professional** for any of your muscle and joint **complaints** mentioned above?
☐ Yes ☐ No

REKENAARGEBRUIKVRAELYS vir SKOOLLEERDERS



VERTEL ONS VAN JOUSELF…

1. Wat is jou **skool** se naam? _____
2. Wat is **jou naam**? _____
3. Wat is jou **geboorte datum** (dag, maand, jaar)? _____
4. In watter **graad** is jy? _____
5. Is jy: ☐ 'n Seun ☐ 'n Meisie
6. Is jy: ☐ Hoofsaaklik **regshandig** ☐ Hoofsaaklik **linkshandig**
7. Dra jy: ☐ 'n bril ☐ kontaklense ☐ **niks van die genoemde nie**
8. Ly jy aan enige **mediese toestand(e)**, byvoorbeeld epilepsie, diabetes, asma?
   ☐ Ja ☐ Nee

9. Indien "**Ja**" by vraag 8, gebruik jy enige **medikasie** vir hierdie toestand(e)?
☐ Ja ☐ Nee

10. Was jy al ooit in 'n **ongeluk of sportbesering** betrokke waar jou rug of nek seergekry het?
☐ Ja ☐ Nee

11. Het jy al enige **operasies** aan jou spiere of gewrigte gehad?
☐ Ja ☐ Nee
Indien **"Ja"** , noem asseblief die **tipe operasie** en ook **wanneer** dit gedoen is.
Jaar: _____ Operasie: _____
Jaar: _____ Operasie: _____

REKENAARGEBRUIK BY DIE SKOOL…

*Dui jou antwoord met 'n **kruisie (X)** aan.*

12. Hoe lank gebruik jy al 'n rekenaar gedurende **klastyd**?
☐ Minder as 'n jaar ☐ 2 jaar ☐ 3 jaar ☐ 4 jaar of langer

13. **Gebruik jy die rekenaar** vir enige van die volgende **vakke**? Merk soveel opsies as wat op jou van toepassing is.
☐ Wiskunde ☐ Rekenaarstudie ☐ Afrikaans/ Engels ☐ Rekenaartik ☐ Ander, noem asseblief:_____

14. Waarvoor **gebruik** jy die **skoolrekenaar**? Merk soveel opsies as wat op jou van toepassing is.
☐ Tikwerk ☐ Bestudeer lesse ☐ Eksperimente ☐ Internet en e-pos
☐ Gebruik opvoedkundige programme ☐ Ander, noem asseblief:_____

15. Hoeveel **keer per week** gebruik jy die **skoolrekenaar**?
☐ Een keer per week, of minder ☐ Twee keer per week ☐ Drie keer per week ☐ Vier keer per week ☐ Vyf keer per week, of meer

16. **Hoe lank** duur **een rekenaargebruiksessie** by die skool?
☐ Minder as 30 minute ☐ Omtrent 45 minute ☐ 1 uur ☐ 1½ uur ☐ 2 uur of langer

17. Hoeveel **uur per week** gebruik jy die **skoolrekenaar?**
☐ Ongeveer 2 uur per week ☐ Ongeveer 4 uur per week ☐ Ongeveer 6 uur per week ☐ 8 uur per week, of meer

18. Het enigiemand jou **gewys hoe** om voor die **rekenaar te sit?**
☐ Ja ☐ Nee
Indien wel, wie? _____

19. Neem jy ten minste **elke uur** 'n **kort ruskans** van 'n paar minute wanneer jy die **rekenaar** gebruik? ('n Kort **rekenaarruskans** beteken om op te hou om die sleutelbord/muis te gebruik, en byvoorbeeld op te staan, te strek, badkamer toe te gaan, ensovoorts.)
☐ Ja ☐ Nee

20. Het jy enige inligting oor **strek- of ander oefeninge** ontvang, wat jy gedurende bogenoemde kort ruskanse kan doen?
☐ Ja ☐ Nee

Indien wel, **wie** het die **inligting** verskaf? _____
Beskryf asseblief die tipe **strek- of ander oefeninge** wat jy doen? _____

REKENAARGEBRUIK ELDERS…

*Voltooi hierdie seksie indien jy 'n rekenaar buite die skool gebruik. Dui jou antwoord met 'n **kruisie (X)** aan.*

21. **Waar anders as by die skool** gebruik jy ook 'n rekenaar? Merk soveel opsies as wat op jou van toepassing is.
☐ By die huis ☐ Internetkafee ☐ By 'n familielid/vriend se huis ☐ Biblioteek
☐ Elders (noem waar) _____

22. Ongeveer **hoe lank** gebruik jy al 'n rekenaar **buiten die een by die skool?**
☐ Minder as 'n jaar ☐ 2-3 jaar ☐ 4 jaar ☐ 5 jaar of meer

23. Ongeveer hoeveel **keer per week** gebruik jy dié rekenaar?
☐ Minder as een keer per week ☐ 2 keer per week ☐ 3 keer per week ☐ 4 keer per week ☐ Vyf keer per week, of meer

24. Gemiddeld hoeveel **uur per dag** werk jy op dié rekenaar?
☐ Minder as 30 minute ☐ 1 uur ☐ 2 uur ☐ 3 uur ☐ 4 uur of meer

25. Watter **tipe rekenaar** gebruik jy meestal?
☐ Tafelrekenaar ☐ Skootrekenaar ☐ Beide

26. Waar **staan** die rekenaar wanneer jy dit gebruik? Merk soveel opsies as wat op jou van toepassing is.
☐ Op 'n lessenaar/tafel ☐ Op jou skoot ☐ Op die vloer ☐ Op 'n stoel ☐ Ander, noem asseblief: _____

27. Verrig jy enige **ander** gelyktydige **aktiwiteit** terwyl jy op die rekenaar werk? Merk soveel opsies as wat op jou van toepassing is.
☐ Gesels met 'n vriend ☐ Luister na musiek ☐ Praat oor die telefoon ☐ Skryf ☐ Ander, noem asseblief: _____

JOU SPORT en MUSIEK…

*Dui jou antwoord met 'n **kruisie (X)** aan.*

28. Neem jy aan **sport** deel?
☐ Ja ☐ Nee

29. Indien wel, aan **watter sport** neem jy deel? Merk soveel opsies as wat op jou van toepassing is.
☐ Rugby ☐ Sokker ☐ Tennis ☐ Tafeltennis ☐ Netbal
☐ Atletiek ☐ Hokkie ☐ Ander, noem asseblief: _____

30. Altesaam hoeveel **keer per week** neem jy aan sportaktiwiteite deel?
☐ Minder as een keer per week ☐ Een keer per week ☐ Twee keer per week ☐ Drie keer per week, of meer
☐ Drie keer per week, of meer

31. Altesaam hoeveel **uur per week** neem jy gemiddeld aan sport deel?
☐ Minder as 'n uur ☐ Ongeveer 2 uur ☐ Ongeveer 4 uur ☐ 6 uur of meer

32. Bespeel jy 'n **musiekinstrument**?
☐ Ja ☐ Nee

33. Indien wel, watter **tipe** musiekinstrument(e)?
_____

34. Gemiddeld hoeveel **uur per week** bespeel jy jou musiekinstrument?

☐ Minder as 'n uur ☐ Ongeveer 2 uur ☐ Ongeveer 4 uur ☐ 6 uur of meer

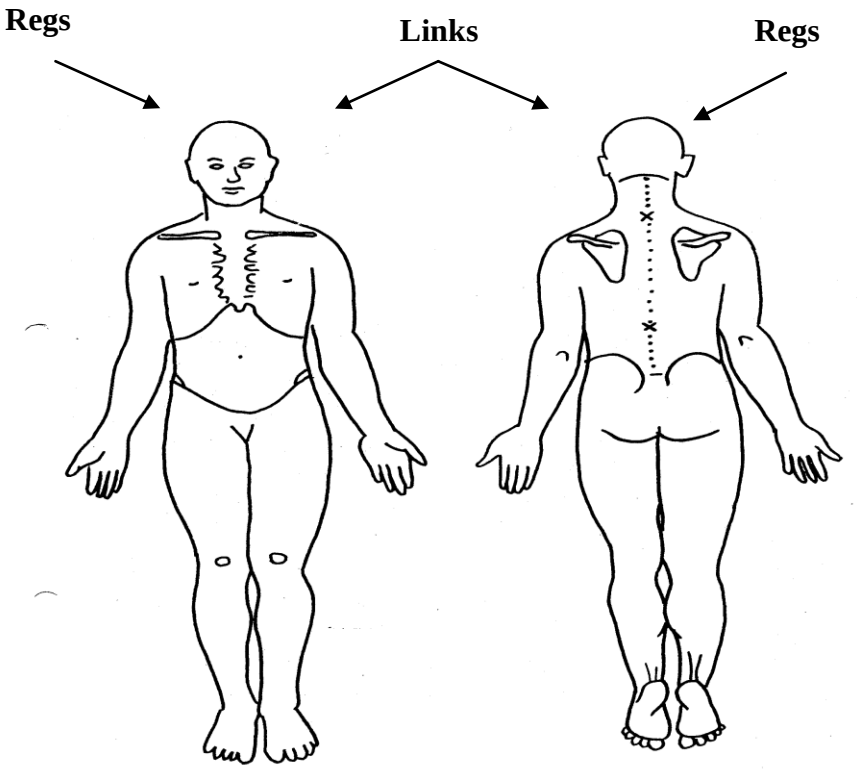
VERTEL ONS VAN JOU PYNE EN SKETE…

*Dui jou antwoord met 'n **kruisie (X)** aan.*

35. Het jy in die **afgelope maand** enige **hoofpyn, ongemak, styfheid, pyn** of 'n **tintelende** gevoel in jou spiere of gewrigte ervaar?

☐ Ja ☐ Nee

36. Indien wel, in watter **liggaamsdele** het jy hierdie pyn/gevoel ervaar? Merk (**X**) slegs die **dele** waar jy jou **simptome gevoel** het.



37. Vertel vir ons hoe **"erg"** hierdie **ongemak, styfheid, pyn of tinteling** in jou spiere en /of gewrigte was in die **afgelope maand**.
Inien jy slegs **GERINGE ongemak, styfheid, pyn** of **tinteling** ervaar het, merk (**X**)
Indien jy **BAIE ongemak, styfheid, pyn** of **tinteling** ervaar het, merk (**X**)

Hier is 'n voorbeeld van hoe jy dit moet doen..

Nek	X	

Liggaamsdeel	Geringe ongemak, pyn, ens	Baie ongemak, pyn,ens
Hoofpyn		
Nek		
Bo-Rug		
Middel Rug		
Lae Rug		
Regter Skouer		
Linker Skouer		
Regter Elmboog		
Linker Elmboog		
Regter Pols en Hand		
Linker Pols en Hand		

38. **Wanneer** het jy die **hoofpyn, ongemak, styfheid, pyn** of **tinteling** in jou **spiere** en **gewrigte** gevoel? Merk soveel opsies as wat op jou van toepassing is.

☐ Wanneer jy voor jou skoollessenaar sit ☐ Tydens of na sportdeelname ☐ Wanneer jy op die skoolrekenaar werk
☐ Wanneer jy by jou skoollessenaar in 'n boek skryf ☐ Wanneer jy elders op 'n rekenaar werk
☐ Ander (noem asseblief):_____

39. Het jy in die **afgelope maand** gevoel om nie op die **rekenaar** te werk nie a.g.v. die bogenoemde **ongemak, styfheid, pyn,** of **tinteling** in jou **spiere** en **gewrigte?** ☐ Ja ☐ Nee

40. Het jy in die afgelope **maand** enige van die volgende **aktiwiteite gestop** a.g.v die **ongemak, styfheid, pyn** of **tinteling** in jou **spiere** en **gewrigte?** Merk soveel opsies as wat op jou van toepassing is.
☐ Speel van 'n sport ☐ Werk op 'n rekenaar ☐ Skryf in 'n boek ☐ Speel van 'n musiek instrument
☐ Lys enige ander aktiwiteite_____

41. Het jy in die **afgelope maand** 'n **dokter** of enige ander **mediese praktisyn** oor die **spier- en gewrigprobleme** wat jy hierbo noem, gaan spreek?
☐ Ja ☐ Nee

Navrae
Enquiries **Dr RS Cornelissen**
IMibuzo
Telefoon
Telephone **(021) 467-2286**
IFoni
Faks
Fax **(021) 425-7445**
IFeksi

Verwysing
Reference **20090424-0039**
ISalathiso

Wes-Kaap Onderwysdepartement

Western Cape Education Department

ISebe leMfundo leNtshona Koloni

Mrs Yolandi Brink
P.O. Box 2101
WINDMEUL
7630

Dear Mrs Y. Brink

RESEARCH PROPOSAL: THE VALIDITY AND RELIABILITY OF THE THREE-DIMENSIONAL PHOTOGRAPHIC POSTURE ANALYSIS METHOD (3D-PPAM) WHEN DISCRIBING SITTING POSTURE OF COMPUTING HIGH SCHOOL STUDENTS.

Your application to conduct the above-mentioned research in schools in the Western Cape has been approved subject to the following conditions:

1. Principals, educators and learners are under no obligation to assist you in your investigation.
2. Principals, educators, learners and schools should not be identifiable in any way from the results of the investigation.
3. You make all the arrangements concerning your investigation.
4. Educators' programmes are not to be interrupted.
5. The Study is to be conducted from **6th May 2009 to 30th September 2009**.
6. No research can be conducted during the fourth term as schools are preparing and finalizing syllabi for examinations (October to December).
7. Should you wish to extend the period of your survey, please contact Dr R. Cornelissen at the contact numbers above quoting the reference number.
8. A photocopy of this letter is submitted to the principal where the intended research is to be conducted.
9. Your research will be limited to the list of schools as forwarded to the Western Cape Education Department.
10. A brief summary of the content, findings and recommendations is provided to the Director: Research Services.
11. The Department receives a copy of the completed report/dissertation/thesis addressed to:

    The Director: Research Services
    Western Cape Education Department
    Private Bag X9114
    CAPE TOWN
    8000

We wish you success in your research.

Kind regards.

Signed: Ronald S. Cornelissen
for: **HEAD: EDUCATION**
DATE: 6th May 2009

Aloe High School

Aloe Road
Lentegeur
Mitchell's Plain
7785

Principal: K DAMON

Tel: 021 371 0552
021 371 4377
Fax: 021 374 6233

E-mail: admin@aloe.wcape.school.za

Established 1982

Mei 2009

Re: Spinale Gesondheid Navorsingsprojek

Fisioterapie Divisie, Departement van Interdissiplinêre Gesondheidswetenskappe, Stellenbosch Universiteit, Posbus 19063, Tygerberg 7505

Titel: ***The Validity and Reliability of the Three-Dimensional Photographic Posture Analysis Method (3D-PPAM) when describing sitting posture of computing high school students***

Beste Yolandi Brink

Met hierdie skrywe aanvaar ek, namens Aloe Hoër Skool, die uitnodiging om deel te neem aan 'n spinale gesondheid navorsingsprojek wat deur die Fisioterapie Divisie van die Stellenbosch Universiteit uitgevoer word.

Ek aanvaar dat slegs graad tien en elf leerders, tussen die ouderdomme 15 en 18, wat CAT doen, uitgenooi sal word om deel te neem aan die studie. Slegs die leerders van wie skriftelike toestemming van beide leerder en ouers ontvang is, sal geskik wees om deel te neem. In totaal sal 10 leerders gekies word om deel te neem.

Ek aanvaar ook dat die studie tydens September/Oktober 2009 sal plaasvind en sal gedeeltelik by die skool asook by die Fisioterapie department op die Tygerberg Kampus uitgevoer word.Dit is die navorser se verantwoordelikheid om, saam met die verteenwoordigende onderwyser, 'n geskikte tyd te reël vir die leerders om deel te neem aan die studie. Die navorser moet ook in berekening bring dat enige datum vir die studie onderhewig is aan akademiese skoolaktiwiteite.

Baie dankie

Pinelands High School
Forest Drive
Pinelands
7405
Tel: (021) 531-7410
Fax: (021) 531-7415
e-mail: postmaster@phs.org.za

21 May 2009

Re: Spinal Health Research Project

Division of Physiotherapy
Department of Interdisciplinary Health Sciences
Stellenbosch University
PO Box 19063
Tygerberg
7505

Title: *The Validity and Reliability of the Three-Dimensional Photographic Posture Analysis Method (3D-PPAM) when describing sitting posture of computing high school students*

Dear Ms Brink

With this letter I, on behalf of **Pinelands High School**, accept the invitation to participate in a spinal health research project conducted by the Physiotherapy Division of Stellenbosch University.

I acknowledge that only grade ten and eleven students, between the ages of 15 and 18, that do CAT will be invited to participate in this study. Only the students from whom written informed consent from both student and parents, has been obtained, will be eligible to participate. In total only ten students will be selected.

I also acknowledge that the study will take place during September/October 2009 and will be conducted partly at the school and partly at the Physiotherapy department of the Tygerberg Campus. It is the researcher's responsibility to arrange, with the representative teacher, a suitable time for the students to participate in the study. The researcher also has to take into account that any selected date for the study is subject to academic school activities.

Yours sincerely

A D Reeler
Principal

We strive to be a world class school, rooted in Africa, that facilitates a quality all-round education in a caring and disciplined environment

RANGE

HIGH SCHOOL

Lower Balvenie Road
Elsies River
7490
Tel: 931-0892 Fax: 932-0842

e-mail: admin@rangess.wcape.school.za

HOËRSKOOL

Laer Balvenieweg
Elsiesrivier
7490
Tel: 931-0892 Faks: 932-0842

Code/Kode: 483532

e-pos: admin@rangess.wcape.school.za

May 2009

Re: Spinal Health Research Project

Division of Physiotherapy, Department of Interdisciplinary Health Sciences, Stellenbosch University, PO Box 19063, Tygerberg 7505

Title: *The Validity and Reliability of the Three-Dimensional Photographic Posture Analysis Method (3D-PPAM) when describing sitting posture of computing high school students*

Dear Yolandi Brink

With this letter I, on behave of **Range High School**, accept the invitation to participate in a spinal health research project conducted by the Physiotherapy Division of Stellenbosch University.

I acknowledge that only grade ten and eleven students, between the ages of 15 and 18, that do CAT will be invited to participate in this study. Only the students from who written informed consent, from both student and parents, have been obtained, will be eligible to participate. In total only ten students will be selected.

I also acknowledge that the study will take place during September/October 2009 and will partly be conducted at the school and at the Physiotherapy department of the Tygerberg Campus. It is the researcher's responsibility to arrange, with the representative teacher, a suitable time for the students to participate in the study. The researcher also has to take into account that any selected date for the study is subject to academic school activities.

Thank you

(Signed by the school principal)

RANGE HIGH SCHOOL
LOWER BALVENIE AVENUE
MATROOSPONTEIN
ELSIES RIVER 7490
TEL: 021 - 931 0892 FAX: 021- 932 0842

HOËRSKOOL SCOTTSDENE HIGH SCHOOL

KOOPMANSLAAN, SCOTTSDENE, 7570

POSBUS 321, KRAAIFONTEIN, 7569

TEL: (021) 988-2835
FAKS: (021) 987-3501

E-POS: admin@scottsdeness.wcape.school.za

KOOPMANS AVENUE, SCOTTSDENE, 7570

P.O. BOX 321, KRAAIFONTEIN, 7569

TEL: (021) 988-2835
FAX: (021) 987-3501

E-MAIL:admin@scottsdeness.wcape.school.za

Mei 2009

Re: Spinale Gesondheid Navorsingsprojek

Fisioterapie Divisie, Departement van Interdissiplinêre Gesondheidswetenskappe, Stellenbosch Universiteit, Posbus 19063, Tygerberg 7505

Titel: ***The Validity and Reliability of the Three-Dimensional Photographic Posture Analysis Method (3D-PPAM) when describing sitting posture of computing high school students***

Beste Yolandi Brink

Met hierdie skrywe aanvaar ek, namens Scottsdene Sekondêre Skool, die uitnodiging om deel te neem aan 'n spinale gesondheid navorsingsprojek wat deur die Fisioterapie Divisie van die Stellenbosch Universiteit uitgevoer word.

Ek aanvaar dat slegs graad tien en elf leerders, tussen die ouderdomme 15 en 18, wat CAT doen, uitgenooi sal word om deel te neem aan die studie. Slegs die leerders van wie skriftelike toestemming van beide leerder en ouers ontvang is, sal geskik wees om deel te neem. In totaal sal 10 leerders gekies word om deel te neem.

Ek aanvaar ook dat die studie tydens September/Oktober 2009 sal plaasvind en sal gedeeltelik by die skool asook by die Fisioterapie department op die Tygerberg Kampus uitgevoer word.Dit is die navorser se verantwoordelikheid om, saam met die verteenwoordigende onderwyser, 'n geskikte tyd te reël vir die leerders om deel te neem aan die studie. Die navorser moet ook in berekening bring dat enige datum vir die studie onderhewig is aan akademiese skoolaktiwiteite.

Baie dankie

(Geteken deur die skoolhoof)

HOËRSKOOL SCOTTSDENE HIGH SCHOOL
POSBUS 321, KRAAIFONTEIN, 7569
TEL: (021) 988-2835
FAX: (021) 987-3501

PARTICIPANT INFORMATION LEAFLET AND CONSENT FORM FOR USE BY PARENTS/LEGAL GUARDIANS

TITLE OF THE RESEARCH PROJECT
The Validity and Reliability of the Three-Dimensional Photographic Posture Analysis Method (3D-PPAM) when describing sitting posture of computing high school students

REFERENCE NUMBER: _____
PRINCIPAL INVESTIGATOR: Yolandi Brink
CONTACT NUMBER: 021 8728695
ADDRESS: Stellenbosch University
Tygerberg Campus
Parow

Your child *(or ward, if applicable*) is being invited to take part in a research project. Please take some time to read the information presented here, which will explain the details of this project. Please ask the study investigator any questions about any part of this project that you do not fully understand. It is very important that you are fully satisfied that you clearly understand what this research entails and how your child could be involved. Also, your child's participation is **entirely voluntary** and you are free to decline to participate. If you say no, this will not affect you or your child negatively in any way whatsoever. You are also free to withdraw him/her from the study at any point, even if you do initially agree to let him/her take part.
This study has been approved by the **Committee for Human Research at Stellenbosch University** and will be conducted according to the ethical guidelines and principles of the international Declaration of Helsinki, South African Guidelines for Good Clinical Practice and the Medical Research Council (MRC) Ethical Guidelines for Research.

What is the research project about?
The purpose of this project is to determine if the measurements taken by the three dimensional Photographic Posture Analysis Method (3D-PPAM) is as accurate as the measurements taken by the "Vicon". Both the 3D-PPAM and the "Vicon" assess how a child sits behind a desk or in front of a computer. The results of this project will enable the medical profession to use the portable 3D-PPAM in any environment such as schools instead of using the "Vicon".

In July 2009 the grade ten and eleven students from the participating schools will be asked to complete a questionnaire about muscle pain or discomfort. As a result of this questionnaire a sample of children will be chosen to participate in the research project.

In September/October 2009 the selected students will be asked to accompany the research team to the Stellenbosch University at the Tygerberg Campus where a laboratory is set up and where the measurements will be taken. Reflective markers will be placed on landmarks that include the eye, ear, neck and upper back vertebrae, upper point of the breastbone and shoulder. The students will not be asked to change clothing. The measurements will be taken by means of digital photographs. The students will be asked to sit behind a desk while the photographs are taken. These measurements will be completed within school hours. Follow up measurements will also be taken at the school.

Why has your child been invited to participate?

The schools that are selected all have CAT as a subject for grade ten and eleven students. Only students that take CAT at school can participate in this research project.

Will your child benefit from this project?

Because this is not an invasive study your child will not benefit directly from participating in this project, however if your child participates it makes it possible for the researcher to determine whether the 3D-PPAM can be used instead of other three-dimensional measurement tools to measure the sitting posture of students in their classrooms.

Are there any risks involved in your child taking part in this project?

There are no risks for your child participating in this project. The project will be conducted at the Tygerberg campus of the Stellenbosch University and at the school.

Who will have access to your child's postural measurements?

The answers from the questionnaire and data from the photographs are confidential and only the researcher has access to the information. Your child will be allocated a number so that he/she remains anonymous. If any of the results are published in a thesis, the child will still remain anonymous.

Will you or your child be paid to take part in this project and are there any costs involved?

You or your child will not be paid to take part in this project and there will be no costs involved for you if your child participates.

Any additional information that you would like to know?

You can contact the Committee for Human Research at 021 9389207 if you have any concerns or complaints that have not been adequately addressed by the study investigator. You will receive a copy of this information and consent form for your own records.

Assent of minor

I (*name of child*)…… have been invited to take part in the above research project.

- The study investigator and my parents have explained the details of the study to me and I understand what they have said to me.
- They have also explained that this study will involve: sitting for 15 minutes while the researcher takes measurements of my sitting position.
- I also know that I am free to withdraw from the study at any time if I am unhappy.
- By writing my name below, I voluntary agree to take part in this research project. I confirm that I have not been forced either by my parents or study investigator to take part.

....

Name of child **Independent witness**

(To be written by the child if possible)

Declaration by parent/legal guardian

By signing below, I *(name of parent/legal guardian)* …….. agree to allow my child (*name of child*) …… who is ……. years old, to take part in a research study entitled: The Validity and Reliability of the Three-Dimensional Photographic Posture Analysis Method (3D-PPAM) when describing sitting posture of computing high school students

I declare that:

- I have read or had read to me this information and consent form and that it is written in a language with which I am fluent and comfortable.
- My child is older than 7 years, therefore he/she must agree to take part in the study and his/her ASSENT must be recorded on this form.
- I have had a chance to ask questions and all my questions have been adequately answered.
- I understand that taking part in this study is **voluntary** and I have not been pressurised to let my child take part.
- I may choose to withdraw my child from the study at any time and my child will not be penalised or prejudiced in any way.

Signed at (*place*) .....…..…….... on (*date*) ……...…….. 2009.

....

Signature of parent/legal guardian **Signature of witness**

Declaration by investigator

I *(name)* ……..…… declare that:

- I explained the information in this document to …….
- I encouraged him/her to contact me and ask questions and took adequate time to answer them.
- I am satisfied that he/she adequately understand all aspects of the research, as discussed above
- I did/did not use a translator.

Signed at (*place*) .....…..…….. on (*date*) ……...…….. 2009.

....

Signature of investigator **Signature of witness**

DEELNEMERINLIGTINGSBLAD EN TOESTEMMINGSVORM VIR GEBRUIK DEUR OUERS/WETTIGE VOOGDE

TITEL VAN DIE NAVORSINGSPROJEK:
The Validity and Reliability of the Three-Dimensional Photographic Posture Analysis Method (3D-PPAM) when describing sitting posture of computing high school students

VERWYSINGSNOMMER:	_____
HOOFNAVORSER:	Yolandi Brink
KONTAKNOMMER:	021 8728695
ADRES:	Stellenbosch Universiteit Tygerberg Kampus Parow

U kind *(of pleegkind, indien van toepassing*) word genooi om deel te neem aan ’n navorsingsprojek. Lees asseblief hierdie inligtingsblad op u tyd deur aangesien die detail van die projek hierin verduidelik word. Indien daar enige deel van die projek is wat u nie ten volle verstaan nie, is u welkom om die navorser daaroor uit te vra. Dit is baie belangrik dat u ten volle moet verstaan wat die navorsing behels en hoe u kind daarby betrokke gaan wees. U kind se deelname is ook **volkome vrywillig** en dit staan u vry om deelname te weier. U kind sal op geen wyse hoegenaamd negatief beïnvloed word indien u sou weier om hom/haar te laat deelneem nie. U mag u kind ook te eniger tyd aan die projek onttrek, selfs al het u ingestem om hom/haar te laat deelneem.
Hierdie studie is deur die **Komitee vir Mensnavorsing van die Universiteit Stellenbosch** goedgekeur en sal uitgevoer word volgens die etiese riglyne en beginsels van die Internasionale Verklaring van Helsinki en die Etiese Riglyne vir Navorsing van die Mediese Navorsingsraad (MNR).

Wat behels die navorsingsprojek?
Die doel van die projek is om te bepaal of metings wat met die drie-dimensionele “Photographic Posture Analysis Method (3D-PPAM)” geneem word net so akkuraat is soos meetings wat deur die “Vicon” gedoen word. Beide die 3D-PPAM en die “Vicon’ meet hoe ‘n kind agter ‘n lessenaar of voor ‘n rekenaar sit. Die resultate van die projek sal die mediese professie in staat stel om eerder die 3D-PPAM, wat in enige omgewing bv skole, gebruik kan word, in plaas van die “Vicon” te gebruik om meetings van ‘n sittende postuur te doen.

In Julie 2009 sal die graad tien leerders van die deelnemende skole gevra word om ‘n vraelys oor spierpyn of ongemak in te vul. Volgens die vraelys sal sekere kinders gekies word om deel te neem aan die navorsingsprojek.

In September/Oktober 2009 sal die verkose leerders gevra word om die navorsingspan na die Stellenbosch Universiteit op die Tygerberg kampus te vergesel waar ‘n laboratorium opgestel is, sodat die meetings daar gedoen kan word. Reflekterende merkers sal op sekere landmerke, wat insluit die oog, oor, nek en rugwerwels, boonste deel van die borsbeen en die skouer geplaas word. Die leerders sal nie gevra word om ander klere aan te trek nie. Die metings sal met behulp van digitale foto’s geneem word. Die leerders sal gevra word om agter ‘n lessenaar te sit terwyl die foto’s geneem word. Die metings sal tydens skoolure gedoen word.

Waarom is u kind genooi om deel te neem?

Die skole wat genader word om deel te neem bied almal as vak aan. Slegs leerders wat rekenaartoepaslikheidstegnologie as vak het, mag deelneem aan hierdie navorsingsprojek.

Sal u kind voordeel trek deur deel te neem aan hierdie projek?

U kind sal nie direk voordeel trek by hierdie projek nie, maar deur deel te neem sal dit vir die navorser moontlik maak om te bepaal of the 3D-PPAM gebruik kan word in plaas van ander drie-dimensionele meetinstrumente om die sitpostuur van leerders in die klaskamer te meet.

Is daar enige risiko's verbonde aan u kind se deelname aan die projek?

Daar is geen risiko's verbonde aan u kind se deelname nie. Hierdie projek word by die Tygerberg kampus van due Stellenbosch Universitieit uitgevoer.

Wie sal toegang hê tot u kind se vraelys antwoorde en postuurmetings?

Die antwoorde van die vraelys en die data van die foto's is vertroulik en slegs die navorser het toegang daartoe. U kind sal 'n nommer gegee word sodat u kind anoniem bly. As enige van die resultate van die projek gepubliseer word in 'n tesis, sal u kind steeds anoniem bly.

Sal u of u kind betaal word vir deelname aan die projek en is daar enige koste verbonde aan deelname?

Nee, u of u kind sal nie betaal word vir deelname aan die projek nie. Deelname aan die projek sal u niks kos nie.

Enige addisionele inligting wat u wil weet?

U kan die Komitee vir Mensnavorsing kontak by 021 9389207 indien u enige bekommernis of klagte het wat nie bevredigend deur die navorser hanteer is nie. U sal 'n afskrif van hierdie inligtings- en toestemmingsvorm ontvang vir u eie rekords.

Instemming van minderjarige

Ek (*naam van minderjarige*) ……..... is genooi om deel te neem aan bogenoemde navorsingsprojek.

- Die navorser en my ouers het die besonderhede van bogenoemde navorsingsprojek aan my verduidelik en ek verstaan wat hulle aan my gesê het.
- Hulle het ook aan my verduidelik dat die projek die volgende insluit: 15 minute sit terwyl die navorsers metings van my sitpostuur neem.
- Ek weet ook dat ek te eniger tyd aan die navorsingsprojek kan onttrek indien ek ongelukkig is.
- Deur my naam hieronder in te vul, onderneem ek om **vrywillig** aan die navorsingsprojek deel te neem. Ek bevestig ook dat ek nie deur my ouers of die navorser gedwing is om deel te neem nie.

…….. ……..

Naam van kind **Onafhanklike getuie**

(*Deur kind geskryf indien moontlik*)

Verklaring deur ouer/wettige voog

Met die ondertekening van hierdie dokument onderneem ek, (*naam van ouer/wettige voog*) ……......, om my kind *(naam van kind)* ……......, wat ..... jaar oud is, te laat deelneem aan ’n navorsingsprojek getiteld: The Validity and Reliability of the Three-Dimensional Photographic Posture Analysis Method (3D-PPAM) when describing sitting posture of computing high school students

Ek verklaar dat:

- Ek hierdie inligtings- en toestemmingsvorm gelees het of aan my laat voorlees het en dat dit in ’n taal geskryf is waarin ek vaardig en gemaklik mee is.
- My kind moet instem om aan die navorsingsprojek deel te neem omdat hy/sy ouer as 7 jaar is, en dat sy/haar INSTEMMING op hierdie vorm aangeteken sal word.
- Ek geleentheid gehad het om vrae te stel en dat al my vrae bevredigend beantwoord is.
- Ek verstaan dat deelname aan hierdie projek **vrywillig** is en dat daar geen druk op my geplaas is om my kind te laat deelneem nie.
- My kind te eniger tyd aan die projek mag onttrek en dat hy/sy nie op enige wyse daardeur benadeel sal word nie.

Geteken te (*plek*) .....…….. op (*datum*) ……...…….. 2009.

..... **.....**

Handtekening van ouer/wettige voog **Handtekening van getuie**

Verklaring deur navorser

Ek (*naam*) ……..... verklaar dat:

- Ek die inligting in hierdie dokument verduidelik het aan …….....……..
- Ek hom/haar aangemoedig het om vrae te vra en voldoende tyd gebruik het om dit te beantwoord.
- Ek tevrede is dat hy/sy al die aspekte van die navorsingsprojek soos hierbo bespreek, voldoende verstaan.
- Ek ’n tolk gebruik het/nie ’n tolk gebruik het nie.

Geteken te (*plek*) .....…….. op (*datum*) ……...…….. 2009.

..... **.....**

Handtekening van navorser **Handtekening van getuie**

INCWADANA YOLWAZI ELUNGISELWE UMTHATHI-NXAXHEBA KUNYE NEPHEPHA-MVUME YOMZALI OKANYE UMGCINI WOMNTWANA NGOKUSEMTHETHWENI

ISIHLOKO SEPROJEKTHI YOPHANDO:
Ukunyaniseka nokuthembeka kweeNdlela ezintathu zoHlahlelo zokuThelekiswa kobume bamafoto (3D-PPAM) xa kuchazwa ubume bokuhlala kwafundi abakwizikolo zamabanga aphezulu

INOMBOLO SALATHISO:	_____
UMPHANDI OYINTLOKO:	Yolandi Brink
INOMBOLO YOMNXEBA:	021 8728695
IDILESI:	I-Yunivesithi yaseStellenbosch Tygerberg Campus Parow

Umntwana wakho (*okanye umntwana ophantsi kwegunya lomnye umntu ongengomzali wakhe ngokomthetho kaRhulumente, ukuba kuyenzeka)* uyacelwa ukuba athabathe inxaxheba kuphando olwenziwayo noluyiprojekthi. Nceda uzinike ithuba lokuba ufunde ulwazi olubhalwe apha, lona luza kunika iinkcukacha ngale projekthi. Nceda ubuze umphandi oyintloko nayiphi na imibuzo ongaba akuyiqondi ngokupheleleyo ngale projekthi. Kubalulekile ukuba uthi kanti waneliseke ngokupheleleyo ekuqondeni ukuba olu phando luphathelene nantoni na nokuba umntwana wakho angabandakanyeka njani. Kananjalo, ukubandakanyeka komntwana wakho **kusekuthandeni kwakhe** kwaye uvumelekile ukuba ungamrhoxisa kolu phando. Ukuba wena uyala ukuba athabathe inxaxheba, eso sigqibo asisayi kumchaphazela ngendlela egwenxa umntwana wakho. Uvumelekile ukuba ungayirhoxisa inxaxheba yakhe kolu phando nangaliphi na ixesha, nangona ubusele uyinikile imvume yokwenza njalo ngaphambili.
Olu phando lunikwe imvume **yiKomiti yoPhando ngentlalo yoMntu kwiYunivesithi yseStellenbosch** kwaye luza kuqhutywa ngokwesiKhokelo seMikhwa eseSikweni noMthetho-siseko wesiBhengezo saseHelsinki, isiKhokelo senKqubo yoNyango esikuMgangatho oPhezulu saseMzantsi Afrika kunye nesiKhokelo seMikhwa eseSikweni seBhunga loPhando ngamaChiza (BLC).

<u>Ingantoni le projekthi yophando?</u>
Injongo yale projekthi kukuqinisekisa ukuba uThelekiso olwenziwayo ngeeNdlela ezintathu zoHlahlelo lokuThelekisa ubume bamafoto (3D-PPAM) luchanekile njengokuthelekiswa okwenziwa nge“Vicon”. Zombini i-3D-PPAM ne“Vicon” zihlola indlela ahlala umntwana edesikeni okanye phambi kwekhompyutha. Iziphumo zale projekthi ziza kwenza ukuba iingcali zezempilo zisebenzise i-3D-PPAM ephathekayo nakowuphi na ummandla ofana nezikolo endaweni ye“Vicon”.

NgoJulayi ka-2009 abafundi beBakala leshumi neleshumi elinanye abaphuma kwizikolo ezithatha inxaxheba baza kucelwa ukuba bazalise amaphepha emibuzo malunga neentlungu zezihlunu okanye ukungaziva ukhululekile. Ngenxa yeli phepha lemibuzo kuza kukhethwa isampuli yabantwana abaza kuthatha inxaxheba kule projekthi yophando.

NgoSeptember/Oxtobha ku-2009, abafundi abakhethiweyo baza kucelwa ukuba bakhaphe iqela labaphandi ukuya kwiYunivesithi yaseStellenbosch ekwiKhampasi yaseTygerberg apho ilebhu ilungiswe khona nalapho ukuthelekiswa kuza kwenziwa khona. Iimpawu ezibonakalisayo ziza kubekwa kwiindawo ezibonakalayo kubandakanywa imehlo, indlebe, intambo nethambo lomqolo

elingaphezulu ngemva, umphezulu wethambo lesifuba negxalaba. Abafundi abazi kucelwa ukuba batshintshe impahla. Ukuthelekiswa kuza kweziwa ngokufotwa ngekhamera. Abafundi baza kucelwa ukuba bahlale kwiidesika zabo ngeli xa bafotwayo. Oku kuthelekiswa kuza kugqitywa ngexesha lesikolo. Okunye ukuthelekiswa nako kuza kwenziwa esikolweni.

Yintoni isizathu sokuba umntwana wakho acelwe ukuba athabathe inxaxheba?

Zonke izikolo ezikhethelwe olu phando zinezifundo zekhompyutha ezingesiso isinyanzelo nathi umfundi wegreyidi yeshumi azithathe ukuba uthandile. Ngabantwana abenza izifundo zekhompyutha nabasekwinqanaba lesikolo kuphela abanokuthabatha inxaxheba kule projekthi yophando.

Ingaba uza kuzuza umntwana wakho kule projekthi?

Kuba esi ingesiso isifundo esingumngeneleli, umntwana wakho akazi kuzuza ngokuthatha inxaxheba kwesi sifundo, ngapha koko ukuthatha inxaxheba komntwana wakho kuza kunceda abaphandi bakwazi ukuqinisekisa ukuba ingasetyenziswa kusini na i-3D-PPAM endaweni yezinye izixhobo zokuthelekisa kuthelekiswa ubume bokuhlala kwabafundi kumagumbi abo okufundela.

Ingaba bukhona ubungozi obukhoyo xa umntwana wakho ethatha inxaxheba kule projekthi?

Akukho bungozi bukhoyo ngokuthatha inxaxheba komntwana wakho kule projekthi. Iprojekthi iza kwenziwa kwikhampasi yaseTygerberg yeYunivesithi yaseStellenbosch nasesikolweni.

Ngubani oza kufikelela kuthelekiso olwenziweyo lomntwana wakho?

Iimpendulo ezikumaphepha emibuzo neenkcukacha ezikumafoto ziyimfihlelo kwaye ngabaphandi kuphela abaza kufikelela kwezi nkcukacha. Umntwana wakho uza kunikwa inombolo ukuze ahlale engaziwa. Ukuba kukho iziphumo eziza kupapashwa kwithisisi, umntwana wakho uza kuhlala engaziwa.

Ingaba umntwana wakho uza kuhlawulwa ngokuthabatha kwakhe inxaxheba kolu phando, yaye ingaba zikho na iindleko?

Wena nomntwana wakho anizi kuhlawulwa ngokuzibandakanya kwenu kule projekthi kwaye akukho ntlawulo uza kuyifumana ukuba umntwana wakho uthabatha inxaxheba.

Olunye ulwazi olongezelekileyo onokuthanda ukubanalo?

Ungaqhagamshelana neKomiti yoPhando ngentlalo yoLuntu kule nombolo 021 938 9207 ukuba kukho into ekuxhalabisayo okanye izikhalazo ezingakhange zabe umphandi oyintloko uziphendule kakuhle. Uza kufumana ikopi eza kunika ulwazi ngolu phando nephepha-mvume oza kuzigcina njengeziqinisekiso.

Imvume yomntwana

Mna (igama lomntwana) …… ndiceliwe ukuba ndithabathe inxaxheba kuphando oluyiprojekthi nolungentla apha.

- Umphandi oyintloko kunye nabazali bam bandicacisele ngeenkcukacha zolu phando kwaye ndiyayiqonda yonke into abayithethileyo kum.
- Bakwacacisile ukuba esi sifundo siza kubandakanya: ukuhlala imizuzu eli-15 ngeli xesha abaphandi bethelekisa indlela yokuhlala.
- Ndiyazi ukuba ndinalo ilungelo lokurhoxa kwezi zifundo nagaliphi na ixesha ukuba ndiziva ndingonwabanga.

- Ngokubhala igama lam ngezantsi, ndiyavuma ukuthabatha inxaxheba ngokuzikhethela kwam. Ndiyangqina ukuba abazali bam okanye umphandi oyintloko akhange andinyanzele ukuba ndithabathe inxaxheba.

....

Igama lomntwana **Ingqina elizimeleyo**

(Kufuneka libhalwe ngumntwana ukuba kuyenzeka)

Isibhengezo esenziwa ngumzali okanye umgcini womntwana ngokusemthethweni

Ngokusayina ngezantsi, Mna *(igama lomzali okanye umgcini womntwana ngokusemthethweni)* …….. ndiyavuma ukuba ndikhululele umntwana (igama lomntwana) …… oneminyaka e- ……. ubudala, ukuba athabathe inxaxheba kuphando olusihloko sithi: Ukunyaniseka nokuthembeka kweeNdlela ezintathu zoHlahlelo zokuThelekiswa kobume bamafoto (3D-PPAM) xa kuchazwa ubume bokuhlala kwafundi abakwizikolo zamabanga aphezulu

Ndibhengezisa ukuba:

- Ndilufundile okanye ndalufunda ulwazi ngolu phando kunye nephepha-mvume kwaye zibhalwe ngolwimi endilwazi ngendlela etyibilikayo.
- Umntwana wam ungaphezulu kwiminyaka esixhenxe, ngoko ke kufuneka enze imvume ngokwakhe malunga nokuthabatha inxaxheba kwaye imvume yakhe kufuneka ishicilelwe kweli phepha.
- Ndaye ndalifumana ithuba lokuphosa imibuzo kwaye yonke imibuzo yam yaphenduleka ngendlela eyanelisayo.
- Ndiyayiqonda into yokuba ukuthabatha inxaxheba kolu phando **kusentandweni yomntu** kwaye andikhange ndinyanzelwe ukuba ndikhululele umntwana wam ukuba azibandakanye nolu phando.
- Ndingamrhoxisa umntwana wam kolu phando nangaliphi na ixesha kwaye akasayi kufumana sohlwayo okanye adlelwe indlala nangaluphi na uhlobo.

Isayinwe e- (*indawo*) .....……. ngomhla (usuku) ……...…. 2009.

....

Isandla somzali okanye umgcini womntwana ngokusemthethweni **Isandla sengqina**

Isibhengezo somphandi oyintloko

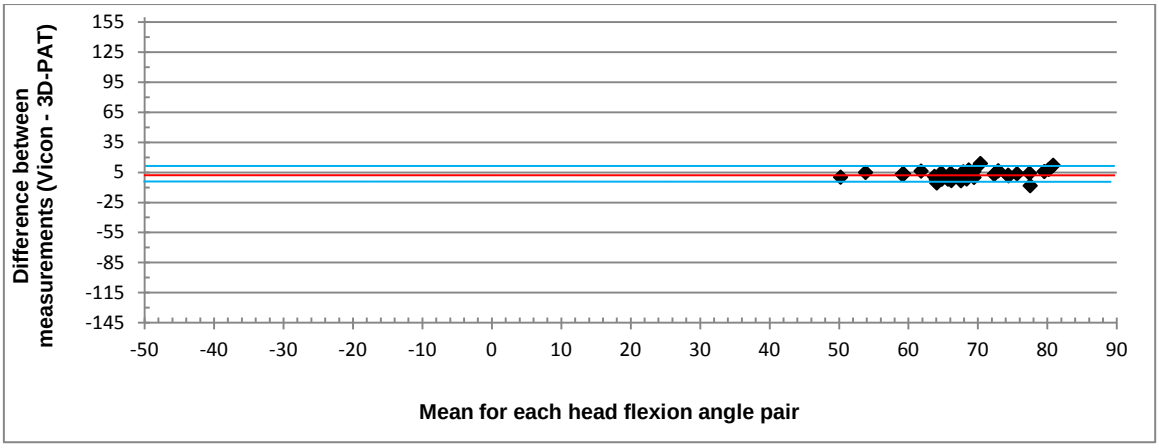
Mna (*igama)* ……..…… ndibhengezisa ukuba:

- Ndiyenzile ingcaciso ngolwazi olu kolu xwebhu ku……
- Ndimkhuthazile ukuba aqhagamshelane nam, abuze imibuzo kwaye ndizinike ithuba elaneleyo ndiyiphendula.
- Ndanelisekile kukuba wazi ngokwaneyo ngayo yonke imiba yophando, njengokuba kuchaziwe ngentla apha.
- Ndilusebenzisile okanye andikhange ndilusebenzise uncedo lomguquli wolwimi.

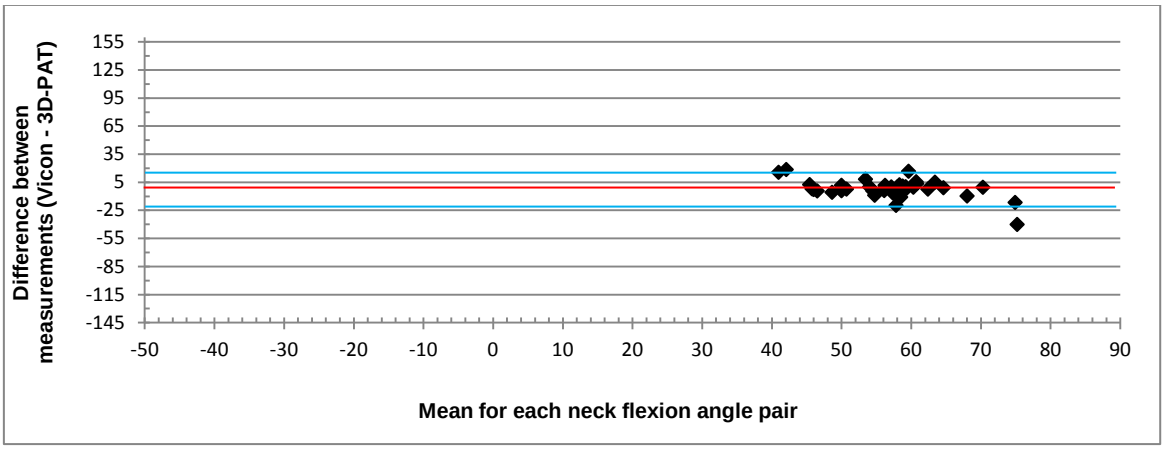
Isayinwe (indawo) .....…..…. ngomhla (usuku) ……...…….. 2009.

....

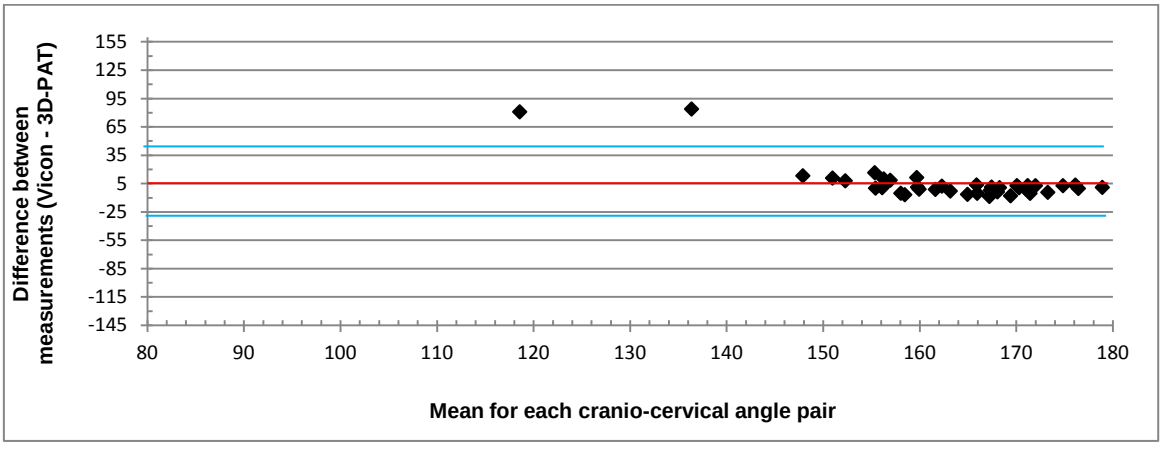
Isandla somphandi **Isandla sengqina**



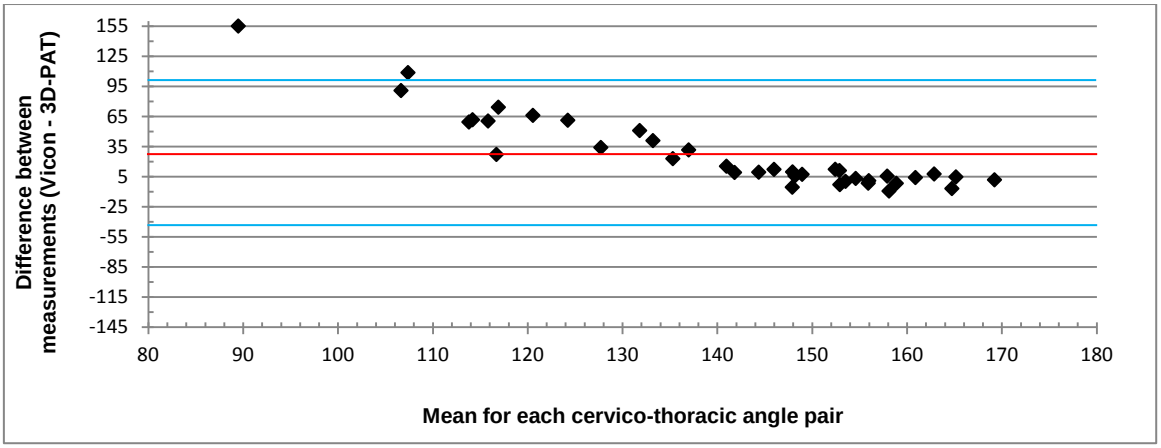
Bland-Altman plot for head flexion



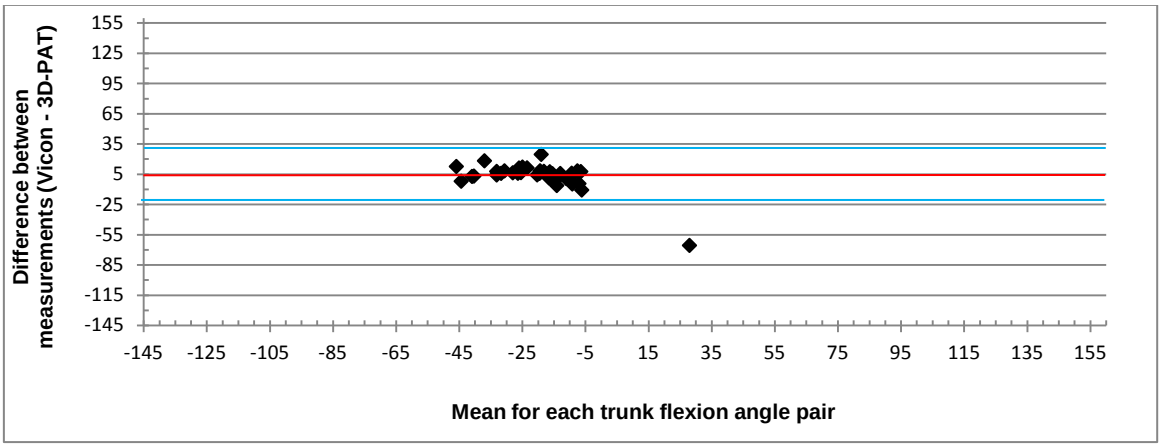
Bland-Altman plot for neck flexion



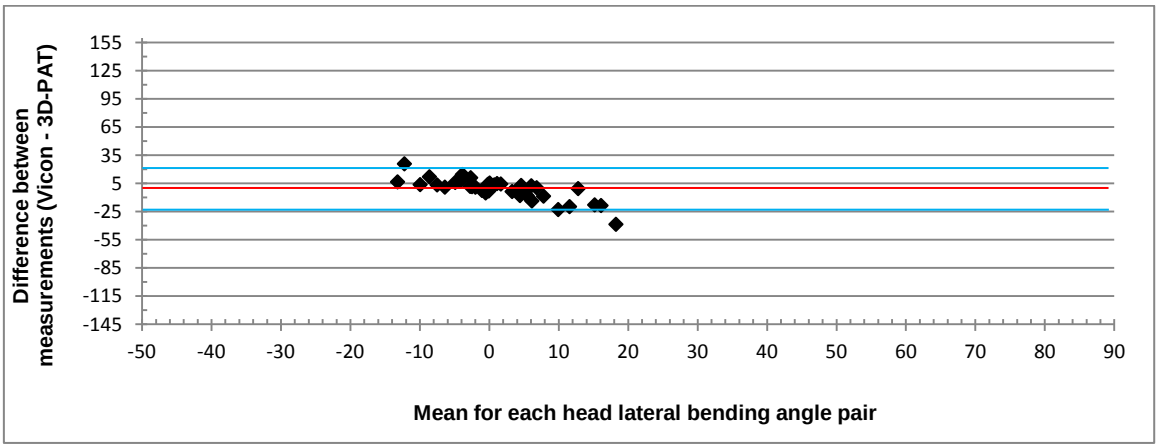
Bland-Altman plot for cranio-cervical angle



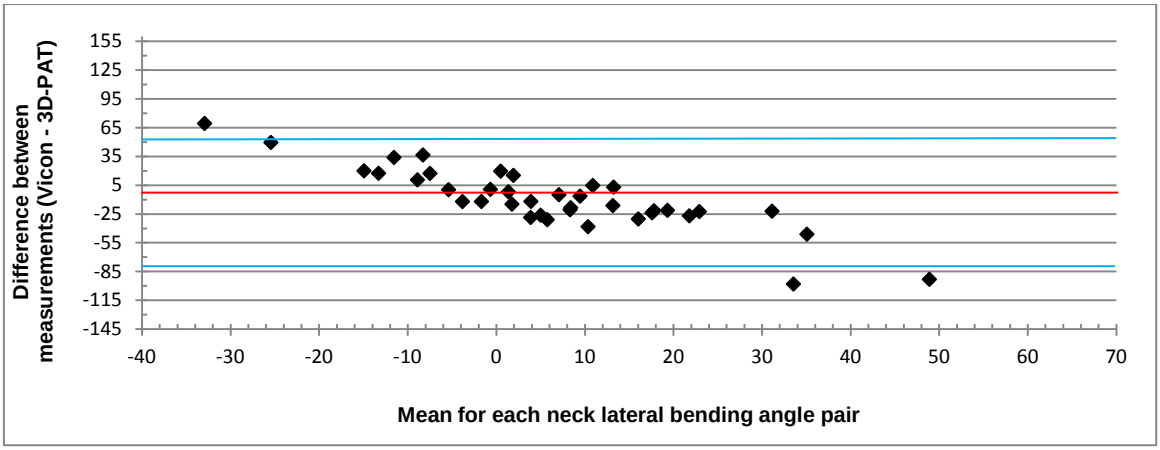
Bland-Altman plot for cervico-thoracic angle



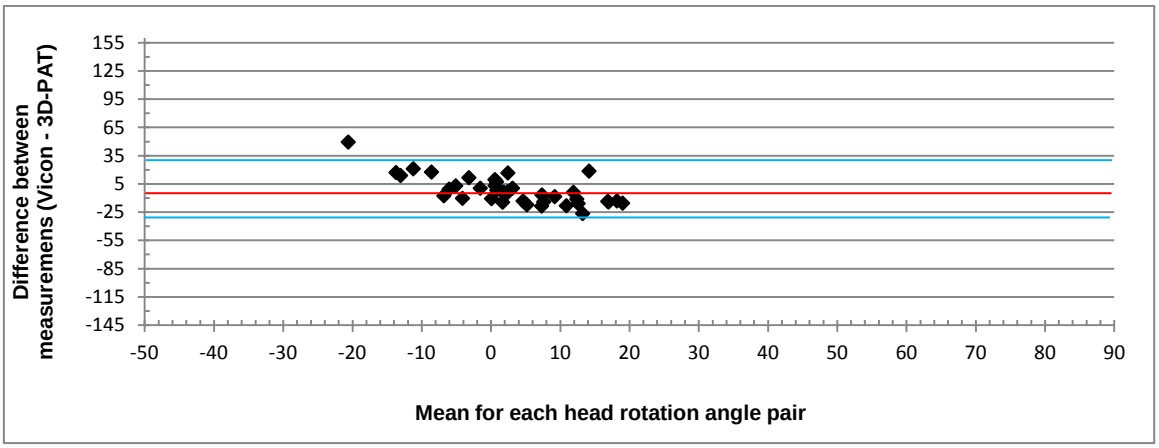
Bland-Altman plot for trunk flexion



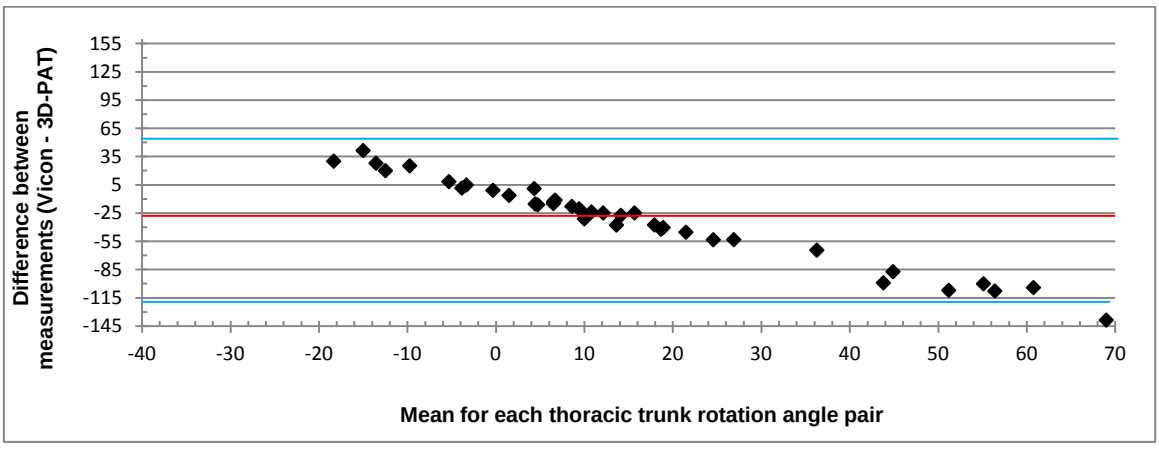
Bland-Altman plot for head lateral bending



Bland-Altman plot for neck lateral bending



Bland-Altman plot for head rotation



Bland-Altman plot for thoracic trunk rotation

PARTICIPANT INFORMATION LEAFLET AND CONSENT FORM FOR USE BY PARENTS/LEGAL GUARDIANS

TITLE OF THE RESEARCH PROJECT:
Ergonomic chair design for school computer laboratories in the Cape Metropole.

REFERENCE NUMBER:
PRINCIPAL INVESTIGATOR: Sjan-Mari van Niekerk (M.Sc Physiotherapy)
ADDRESS: 307 Nederberg, Moray Place, Oranjezicht, Cape Town, 8001
CONTACT NUMBER: 071 6739748

Your child is being invited to take part in a research project. Please take some time to read the information presented here, which will explain the details of this project. Please ask the study staff any questions about any part of this project that you do not fully understand. It is very important that you are fully satisfied that you clearly understand what this research entails and how your child could be involved. Also, your child's participation is **entirely voluntary** and you are free to decline to participate. If you say no, this will not affect you or your child negatively in any way whatsoever. You are also free to withdraw him/her from the study at any point, even if you do initially agree to let him/her take part.
This study has been approved by the **Committee for Human Research at Stellenbosch University** and will be conducted according to the ethical guidelines and principles of the international Declaration of Helsinki, South African Guidelines for Good Clinical Practice and the Medical Research Council (MRC) Ethical Guidelines for Research.

What is this research study all about?
The aim of this research project is to match the body measurements of high school students aged 13 to 18 years in the Cape Metropole area with the dimension of the school computer chair. In one of our previous studies it was found that 73% of high school students in the Cape Metropole experience pain while using a desktop computer. In a different study it has been reported that musculoskeletal symptoms are one of the top ten health problems among high school students. With this study we hope to be able to recommend the most appropriate chair for our students in Cape High schools.
Your child might be randomly selected to take part in one or more of the three phases of this project. In phase 1A each child's body dimensions will be measured three times by four different research assistants. In phase 1B each child will be measured once by one research assistant. The measurements will be made with a non-invasive measuring tool called an Anthropometer and all measurements will be done at the school. Four students will be measured simultaneously by four research assistants. In Phase 2 an appropriate computer chair will be selected; there are no students involved in this phase. In Phase 3 the students will be tested at the Motion Analysis Laboratory at the Stellenbosch University. The students' posture will be analysed while they sit in a school chair and then in the proposed chair. The analysis will be done by putting non-invasive markers on the students which will be visible to the Vicon Motion Analysis System. The students will remain fully clothed during all testing procedures. During phase 3 the students will also be photographed twice by a newly developed camera system, to test whether the new camera system can accurately measure sitting posture. This added measurement forms part of a separate research project, but which is also endorsed by Stellenbosch University's Physiotherapy department, for which ethical approval has been obtained.

During Phase 1A and B students will only miss one hour of school and during Phase 3 students will miss roughly 2 hours of school. The most appropriate times for testing will be agreed upon by the main researcher and the school principal.

Why has your child been invited to participate?
The school which your child attends was randomly selected from all schools which form part of the Cape Metropole. The 13 to 18 year old students from the school have been invited to participate in the study.

What will your responsibilities be?
Your responsibility is only to provide consent should you agree for your child to participate in the study. Data collection will only take up the time of one class per phase to avoid students missing significant school work.

Will your child benefit from taking part in this research?
Your child's participation will help the research team to develop educational guidelines on sitting posture and promotion of good spinal health. Your child and future students may benefit, since these guidelines may reduce the incidence of spinal and shoulder pain experienced by children using computers and thus prevent youth from developing long term joint and muscle problems.

Are there any risks involved in your child taking part in this research?
There are no risks involved in participating in this research project.

Who will have access to your child's records?
All the information collected with this project will be treated as confidential and will be protected. If this information is used in a thesis or publication, the identity of your child will remain anonymous. Only the researcher and her team will have access to the information. The records will be kept in safe storage in the Physiotherapy Department, Stellenbosch University.

What will happen in the unlikely event of your child getting injured in any way, as a direct result of taking part in this research study? The testing will take part at The Department Physiotherapy at Stellenbosch University. Transport will be provided by the school or Stellenbosch University and the third party insurance will cover your child if the vehicle should be involved in an accident.

Will you or your child be paid to take part in this study and are there any costs involved?
You or your child will not be paid to take part in the study. There will be no costs involved for you if your child does take part.

Is there anything else that you should know or do?
1 You can contact Sjan-Mari van Niekerk at tel 071 673 974 if you have any further queries or encounter any problems.
2 You can contact the Committee for Human Research at 021-938 9207 if you have any concerns or complaints that have not been adequately addressed by your child's study doctor.
3 You will receive a copy of this information and consent form for your own records.

Assent of Minor
I (*Name of Child/Minor*)……. have been invited to take part in the above research project.

- The study leader and my parents have explained the details of the study to me and I understand what they have said to me.
- I also know that I am free to withdraw from the study at any time if I am unhappy.
- By writing my name below, I voluntary agree to take part in this research project. I confirm that I have not been forced either by my parents or doctor to take part.

_____ _____

Name of child Independent witness
(To be written by the child if possible)

Declaration by Parent/Legal Guardian

By signing below, I *(name of Parent/Legal Guardian)* ……..…… agree to allow my child (name of child) ……..… who is ……. years old, to take part in a research study entitled 'The anthropometric match between high school students and their computer workstations'.

I declare that:

1. I have read or had read to me this information and consent form and that it is written in a language with which I am fluent and comfortable.
2. If my child is older than 7 years, he/she must agree to take part in the study and his/her ASSENT must be recorded on this form.
3. I have had a chance to ask questions and all my questions have been adequately answered.
4. I understand that taking part in this study is **voluntary** and I have not been pressurised to let my child take part.
5. I may choose to withdraw my child from the study at any time and my child will not be penalised or prejudiced in any way.
6. My child may be asked to leave the study before it has finished if the study doctor or researcher feels it is in my child's best interests, or if my child does not follow the study plan as agreed to.

Signed at (*place*) .....…..…….. on (*date*) ……...…… 2011.

_____..... _____

Signature of Parent/Legal Guardian Signature of witness

Declaration by investigator

I *(name)* ……..…… declare that:

- I explained the information in this document to ……..
- I encouraged him/her to ask questions and took adequate time to answer them.
- I am satisfied that he/she adequately understand all aspects of the research, as discussed above
- I did/did not use a translator (i*f a translator is used, then the translator must sign the declaration below).*

Signed at (*place*) .....…..…….. on (*date*) ……...…..... 2011.

_____ _____

Signature of investigator Signature of witnes

DEELNEMERINLIGTINGSBLAD EN -TOESTEMMINGSVORM VIR GEBRUIK DEUR OUERS/WETTIGE VOOGDE

TITEL VAN DIE NAVORSINGSPROJEK:
Die ontwikkeling van 'n ergonomies korrekte stoel vir rekenaar laboratoriums in die Kaapse Metropool.

VERWYSINGSNOMMER:
HOOFNAVORSER: Sjan-Mari van Niekerk (M.Sc. Fisioterapie)
ADRES: Nederberg 307, Moray Plek, Oranjezicht, Kaapstad, 8001.
KONTAKNOMMER: 071 673 9748

U kind *(of pleegkind, indien van toepassing*) word genooi om deel te neem aan ’n navorsingsprojek. Lees asseblief hierdie inligtingsblad op u tyd deur aangesien die besonderhede van die projek daarin verduidelik word. Indien daar enige deel van die projek is wat u nie ten volle verstaan nie, is u welkom om die navorsingspersoneel of dokter daaroor uit te vra. Dit is baie belangrik dat u ten volle moet verstaan wat die navorsing behels en hoe u kind daarby betrokke kan wees. U kind se deelname is ook **volkome vrywillig** en dit staan u vry om deelname te weier. U kind sal op geen wyse hoegenaamd negatief beïnvloed word indien u sou weier om hom/haar te laat deelneem nie. U mag u kind ook te enige tyd aan die studie onttrek, selfs al het u ingestem om hom/haar te laat deelneem.
Hierdie studie is deur die Komitee vir Mensnavorsing van die Universiteit Stellenbosch goedgekeur en sal uitgevoer word volgens die etiese riglyne en beginsels van die Internasionale Verklaring van Helsinki en die Etiese Riglyne vir Navorsing van die Mediese Navorsingsraad (MNR).

Wat behels hierdie navorsingsprojek?
Die doel van die studie is om die liggaamsmates van hoërskool leerlinge tussen die ouderdomme van 13 en 18 jaar, in die Kaapse Metropool area, met die afmetings van die skool se rekenaar stoele te vergelyk. In een van ons vorige studies is daar gevind dat 73% van hoërskool leerlinge pyn ervaar tydens die gebruik van 'n rekenaar. In 'n ander studie is daar gevind dat muskuloskeletale pyn een van die top tien gesondheidsprobleme van skoolleerlinge is. Die mees geskikte stoel moet vasgestel word.
U kind mag dalk lukraak gekies word om deel te neem aan een of meer van die drie fases van die projek. In Fase 1A word elke leerling drie maal gemeet deur vier verskillende navorsingsassistente. In Fase 1B word elke kind een maal deur een navorsingsassistent gemeet. Die afmetings sal met ‘n nie-indringende meet-instrument, ‘genaamd “Anthropometer” geneem word en alle afmetings sal by die skool geneem word. Vier leerlinge sal gelyktydig gemeet word deur vier navorsingsassistente. Gedurende Fase 2 word die mees toepslike stoel gekies vir hoërsool leerlinge; geen leerlinge word benodig tydens die fase nie. In Fase 3 sal leerlinge by Stellenbosch Universiteit se Beweginsanaliese Laboratorium getoets word Die leerlinge se sit-postuur sal geanaliseer word terwyl hulle eers in 'n stoel sit wat gewoonlik by die skool gebruik word en dan in die voorgeskrewe stoel sit. Die analiese word gedoen deur merkers op die leerlinge te plaas wat dan deur die VICON beweginsanaliese systeem geanaliseer word. Die leerlinge sal ten alle tye ten volle geklee bly. Gedurenede fase 3 sal die leerlinge ook twee keer afgeneem word met ‘n nuwe kamera sisteem, om te toets of die nuwe lamera ook sittende postuur akkuraat kan meet. Hierdie bykomstige metings vorm deel van ‘n aparte navorsingsprojek, maar wat steeds deel vorm van Stellenbosch Universiteit se fisioterapie department, en waarvoor etiese toestemming reeds verleen is.

Gedurende Fase 1A en B sal die lukraak gekose leerlinge slegs 1 uur van skool mis en gedurende Fase 3 om en by twee ure. Die mees gepaste tye vir die afmetings sal met die skoolhoof onderhandel word.

Waarom is u kind genooi om deel te neem?
Die skool waaraan u kind behoort is lukraak gekies uit al die skole in die Kaapse Metropool. Die 13 tot 18 jarige leerders van die skool is genooi om deel te neem aan die projek.

Wat sal u verantwoordelikhede wees?
U is slegs verandwoordelik om toestemming te gee vir u kind se deelname aan die projek indien u sou instem. Die data opname sal slegs een periode duur om te verhoed dat leerders belangrike skool werk sal mis.

Sal u kind voordeel trek deur deel te neem aan hierdie navorsing?
U kind se deelname help die navorsingspan om opvoedkundige riglyne op te stel vir die korrekte sittende postuur en die bevordering van goeie rug gesondheid. U kind en toekomstige leerders kan voordeel trek aangesien hierdie riglyne die voorkoms van rug en skouer pyn deur kinders wat rekenaars gebruik ervaar word, kan help voorkom. Dit sal ook help met die voorkoming van langtermyn gewrig- en spierprobleme.

Is daar enige risiko's verbonde aan u kind se deelname aan hierdie navorsing?
Daar is geen gevare verbonde aan die deelname aan hierdie navorsingsprojek nie.

Wie sal toegang hê tot u kind se mediese rekords?
Alle inligting wat ingesamel word in hierdie projek word as konfidensieel beskou en sal sodanig beskerm word. Indien hierdie inligting in 'n tesis of ander publikasie gebruik word sal u kind se identiteit anoniem bly. Slegs die navorser en haar span sal toegang hê tot die inligting. Die rekords sal veilig gestoor word by die Fisioterapie Departement, Stellenbosch Universiteit.

Wat sal gebeur in die onwaarskynlike geval van ’n besering wat mag voorkom as gevolg van my kind se deelname aan hierdie navorsingsprojek?
Die toetsing vind plaas by die Departement van Fisioterapie by Stellenbosch Universiteit. Vervoer word verskaf deur die skool of die Universiteit Stellenbosch. Daar is derde party versekering wat u kind sal dek indien die voertuig in ‘n ongeluk betrokke sou wees.

Sal u of u kind betaal word vir deelname aan die projek en is daar enige koste verbonde aan deelname?
Nee, nie u of u kind sal betaal word vir deelname aan die projek nie. Deelname aan die projek sal u niks kos nie.

Is daar enigiets anders wat u moet weet of doen?
1 U kan Sjan-Mari van Niekerk kontak by tel 071 673 9748 indien u enige vêrdere vrae het of enige probleme ondervind.
2 U kan die Komitee vir Mensnavorsing kontak by 021-938 9207 indien u enige bekommernis of klag het wat nie bevredigend deur u studiedokter hanteer is nie.
3 U sal 'n afskrif van hierdie inligtings- en toestemmingsvorm ontvang vir u eie rekords.

Instemming van minderjarige

Ek (naam van kind/minderjarige) …….....…… is genooi om deel te neem aan bogenoemde navorsingsprojek.

1 Die studiedokter/verpleegster en my ouers het die besonderhede van bogenoemde navorsingsprojek aan my verduidelik en ek verstaan wat hulle aan my gesê het.
2 Ek weet ook dat ek te enige tyd aan die navorsingsprojek kan onttrek indien ek ongelukkig is.
3 Deur my naam hieronder in te vul, onderneem ek om vrywillig aan die navorsingsprojek deel te neem. Ek bevestig ook dat ek nie deur my ouers of studiedokter gedwing is om deel te neem nie.

..... **.....**

Naam van kind Onafhanklike getuie

(Deur kind geskryf te word indien moontlik)

Verklaring deur ouer/wettige voog

Met die ondertekening van hierdie dokument onderneem ek, (*naam van ouer/wettige voog*) …….....…..., om my kind *(naam van kind)* …….....…..., wat ..... jaar oud is, te laat deelneem aan ’n navorsingsprojek getiteld ‘**Die ontwikkeling van 'n ergonomies korrekte stoel vir rekenaar laboratoriums in die Kaapse Metropool**

Ek verklaar dat:

1 Ek hierdie inligtings- en toestemmingsvorm gelees of aan my laat voorlees het en dat dit in ’n taal geskryf is waarin ek vaardig en gemaklik mee is.
2 My kind moet instem om aan die navorsingsprojek deel te neem as hy/sy ouer as 7 jaar is, en dat sy/haar INSTEMMING op hierdie vorm aangeteken sal word.
3 Ek geleentheid gehad het om vrae te stel en dat al my vrae bevredigend beantwoord is.
4 Ek verstaan dat deelname aan hierdie projek **vrywillig** is en dat daar geen druk op my geplaas is om my kind te laat deelneem nie.
5 My kind te enige tyd aan die projek mag onttrek en dat hy/sy nie op enige wyse daardeur benadeel sal word nie.
6 My kind gevra mag word om aan die projek te onttrek voordat dit afgehandel is indien die studiedokter of navorser van oordeel is dat dit in sy/haar beste belang is, of indien my kind nie die ooreengekome studieplan volg nie.

Geteken te (*plek*) **.....**…….. op (*datum*) ……...…… 2011.

..... **.....**

Handtekening van ouer/wettige voog Handtekening van getuie

Verklaring deur navorser

Ek (naam) …… verklaar dat:

1 Ek die inligting in hierdie dokument verduidelik het aan …….....……..
2 Ek hom/haar aangemoedig het om vrae te vra en voldoende tyd gebruik het om dit te beantwoord.
3 Ek tevrede is dat hy/sy al die aspekte van die navorsingsprojek soos hierbo bespreek,

voldoende verstaan.

4 Ek ’n tolk gebruik het/nie ’n tolk gebruik het nie. (*Indien ’n tolk gebruik is, moet die tolk die onderstaande verklaring teken.)*

Geteken te (*plek*) .....…….. op (*datum*) …...……..... 2011.

..... **.....**

Handtekening van navorser Handtekening van getuie

Database	Search	Keywords	Limits	Hits	Exclude by title	Exclude by abstract	Exclude by article	Duplicate	Accept
Biomed Central	1	pain; adolescent or children; posture	2007-2011	57	48	6	2		1 - Briggs
	2	pain; adolescent or children; sitting posture	2007-2011	7	4			3	
	3	neck and/or shoulder pain; adolescent or children; posture	2007-2011	60	51			9	
	4	neck and/or shoulder pain; adolescent or children; sitting posture	2007-2011	9	4			5	
	5	musculoskeletal pain; adolescent or children; posture	2007-2011	12	6			6	
	6	musculoskeletal pain; adolescent or children; sitting posture	2007-2011	7	5			2	
	7	upper limb and or upper extremity pain; adolescent or children; posture	2007-2011	0					
	8	upper limb and or upper extremity pain; adolescent or children; sitting posture	2007-2011	0					
	9	neck and/or shoulder pain; learner and or student; posture	2007-2011	0					
	10	neck and/or shoulder pain; learner and or student; sitting posture	2007-2011	0					
Cinahl	1	pain; adolescent or child; posture	2007-2011; human; English	81	64		5	8	4–Brink 09b, Coleman, Geldhof; Straker 2011
	2	pain; learner or student; posture	2007-2011; human; English	8	8				
	3	neck or shoulder pain; adolescent or child; posture	2007-2011; human; English	36	27			9	
	4	neck or shoulder pain; learner or student; posture	2007-2011; human; English	3	3				
	5	upper extremity pain; adolescent or child; posture	2007-2011; human; English	0					
	6	upper limb pain; adolescent or child; posture	2007-2011; human; English	0					
	7	upper extremity pain; learner or student; posture	2007-2011; human; English	0					
	8	upper limb pain; learner or student; posture	2007-2011; human; English	0					
ProQuest	1	pain; adolescent or child; sitting posture	2007-2011; English	217	216			1	
	2	pain; learner or student; sitting posture	2007-2011; English	125	123			1	

Database	Search	Keywords	Limits	Hits	Exclude by title	Exclude by abstract	Exclude by article	Duplicate	Accept
ProQuest	3	neck or shoulder pain; learner or student; sitting posture	2007-2011; English	26	25			1	
	4	neck or shoulder pain; adolescent or child; sitting posture	2007-2011; English	21	20			1	
	5	upper extremity pain; adolescent or child; sitting posture	2007-2011; English	115	115				
	6	upper limb pain; adolescent or child; sitting posture	2007-2011; English	118	118				
	7	upper extremity pain; learner or student; sitting posture	2007-2011; English	144	144				
	8	upper limb pain; learner or student; sitting posture	2007-2011; English	154	154				
	9	musculoskeletal pain; adolescent or child; posture	2007-2011; English	254	254				
	10	musculoskeletal pain; learner or student; posture	2007-2011; English	27	27				
Pubmed	1	pain[mesh]; child[mesh]; adolescent[mesh]; posture[mesh]	2007-2011; human; English	27	26		1	1	
	2	musculoskeletal pain; child[mesh]; adolescent[mesh]; posture[mesh]	2007-2011; human; English	8	7			1	
	3	neck pain[mesh]; shoulder pain[mesh]; child[mesh]; adolescent[mesh]; posture[mesh]	2007-2011; human; English	1	1				
	4	upper limb pain; child[mesh]; adolescent[mesh]; posture[mesh]	2007-2011; human; English	2	1		1		
	5	upper extremity pain; child[mesh]; adolescent[mesh]; posture[mesh]	2007-2011; human; English	1	1				
	6	pain[mesh]; student[mesh]; posture[mesh]	2007-2011; human; English	17	15			2	
	7	musculoskeletal pain, posture[mesh], student[mesh]	2007-2011; human; English	9	7			2	
	8	upper limb pain, posture[mesh], student[mesh]	2007-2011; human; English	5	3			2	
	9	upper extremity pain, posture[mesh], student[mesh]	2007-2011; human; English	4	3			1	
Science Direct	1	musculoskeletal pain; adolescent or children; sitting posture	2007-2011	284	278		1	1	4-Straker 08, Straker 09, Hellstenius, Brink 09a
	2	musculoskeletal pain; learner and or student; sitting posture	2007-2011	207	206			1	

Database	Search	Keywords	Limits	Hits	Exclude by title	Exclude by abstract	Exclude by article	Duplicate	Accept
Science Direct	3	neck and/or shoulder pain; adolescent or children; sitting posture	2007-2011	340	332	2		6	
	4	upper limb and or upper extremity pain; adolescent or children; sitting posture	2007-2011	150	149			1	
	5	upper limb and or upper extremity pain; student or learner; sitting posture	2007-2011	83	83				
	6	neck and/or shoulder pain; learner and or student; sitting posture	2007-2011	228	227			1	
Scopus	1	musculoskeletal pain; adolescent; posture	1960-2011	145	140	1	2	2	
	2	musculoskeletal pain; children; posture	1960-2011	76	69	1	1	5	
	3	musculoskeletal pain; student; posture	1960-2011	65	60			5	
	4	musculoskeletal pain; learner; posture	1960-2011	0					
	5	upper limb pain; adolescent; posture	1960-2011	15	13			2	
	6	upper limb pain; children; posture	1960-2011	8	5			3	
	7	upper limb pain; student; posture	1960-2011	13	10			3	
	8	upper limb pain; learner; posture	1960-2011	0					
	9	upper extremity pain; adolescent; posture	1960-2011	14	14				
	10	upper extremity pain; children; posture	1960-2011	8	8				
	11	upper extremity pain; student; posture	1960-2011	6	6				
	12	upper extremity pain; learner; posture	1960-2011	0					
	13	neck pain; adolescent; posture	1960-2011	134	126	2		6	
	14	neck pain; children; posture	1960-2011	61	58			3	
	15	neck pain; student; posture	1960-2011	43	39			4	
	16	neck pain; learner; posture	1960-2011	0					
	17	shoulder pain; adolescent; posture	1960-2011	99	92			7	
	18	shoulder pain; children; posture	1960-2011	34	33			1	
	19	shoulder pain; student; posture	1960-2011	37	34			3	
	20	shoulder pain; learner; posture	1960-2011	0					
	21	pain, sitting posture; adolescent	1960-2011	112	105		1	6	
	22	pain; sitting posture; children	1960-2011	63	59			4	
	23	pain; sitting posture; student	1960-2011	38	35			3	
	24	pain; sitting posture; learner	1960-2011	0					

			YES	NO
Study purpose	1	Was the purpose of the study clearly stated?		
Design	2	Was the study design appropriate?		
Biases	3	Were there sample biases detected in the study?		
	4	Were there measurement biases detected in the study?		
Sample	5	Was the sample size stated?		
	6	Was the sample described in detail?		
	7	Was the sample size justified?		
Outcomes	8	Were the outcomes clearly stated and relevant to the study?		
	9	Was the method of measurement described sufficiently?		
	10	Were the measures reliable?		
	11	Were the measures valid?		
Results	12	Were the results reported in terms of statistical significance?		
	13	Were the analysis methods appropriate?		
	14	Was clinical importance reported?		
Dropouts	15	Were missing data or dropouts reported where appropriate?		
Conclusion and clinical implication	16	Were the conclusions relevant and appropriate given the methods and results of the study?		

Navrae
Enquiries **Dr RS Cornelissen**
IMibuzo
Telefoon
Telephone **(021) 467-2286**
IFoni
Faks
Fax **(021) 425-7445**
IFeksi

Verwysing
Reference **20091016-0028**
ISalathiso

Wes-Kaap Onderwysdepartement

Western Cape Education Department

ISebe leMfundo leNtshona Koloni

Mrs Yolandi Brink
P.O. Box 2101
WINDMEUL
7630

Dear Mrs Y. Brink

RESEARCH PROPOSAL: POSTURE AND PSYCHOSOCIAL FACTORS AS PREDICTIVE FACTORS OF NECK, SHOULDER AND ARM PAIN AMID HIGH SCHOOL STUDENTS USING DESK TOP COMPUTERS.

Your application to conduct the above-mentioned research in schools in the Western Cape has been approved subject to the following conditions:

12. Principals, educators and learners are under no obligation to assist you in your investigation.
13. Principals, educators, learners and schools should not be identifiable in any way from the results of the investigation.
14. You make all the arrangements concerning your investigation.
15. The programmes of Educators are not to be interrupted.
16. The Study is to be conducted from **20th January 2010 to 30th April 2010**.
17. Should you wish to extend the period of your survey, please contact Dr R. Cornelissen at the contact numbers above quoting the reference number.
18. A photocopy of this letter is submitted to the principal where the intended research is to be conducted.
19. Your research will be limited to the list of schools as submitted to the Western Cape Education Department.
20. A brief summary of the content, findings and recommendations is provided to the Director: Research Services.
21. The Department receives a copy of the completed report/dissertation/thesis addressed to:

    The Director: Research Services
    Western Cape Education Department
    Private Bag X9114
    CAPE TOWN
    8000

We wish you success in your research.

Kind regards.

Signed: Ronald S. Cornelissen
for: **ACTING HEAD: EDUCATION**
DATE: 19th October 2009

PARTICIPANT INFORMATION LEAFLET AND CONSENT FORM FOR USE BY PARENTS/LEGAL GUARDIANS

TITLE OF THE RESEARCH PROJECT
Are sitting posture and psychosocial factors risk factors for the development of neck, shoulder and arm pain in grade ten high school students working on desktop computers?

REFERENCE NUMBER: _____
PRINCIPAL INVESTIGATOR: Yolandi Brink
CONTACT NUMBER: 021 8728695
ADDRESS: Stellenbosch University
Tygerberg Campus
Parow

Your child *(or ward, if applicable*) is being invited to take part in a research project. Please take some time to read the information presented here, which will explain the details of this project. Please ask the study investigator any questions about any part of this project that you do not fully understand. It is very important that you are fully satisfied that you clearly understand what this research entails and how your child could be involved. Also, your child's participation is **entirely voluntary** and you are free to decline to participate. If you say no, this will not affect you or your child negatively in any way whatsoever. You are also free to withdraw him/her from the study at any point, even if you do initially agree to let him/her take part.
This study has been approved by the **Committee for Human Research at Stellenbosch University** and will be conducted according to the ethical guidelines and principles of the international Declaration of Helsinki, South African Guidelines for Good Clinical Practice and the Medical Research Council (MRC) Ethical Guidelines for Research.

What is the research project about?
The purpose of this project is to determine if a student's sitting posture in front of a computer might be the cause of neck and/or shoulder pain. This project will also assess psychosocial aspects that might contribute to neck and/or shoulder pain. The results of this project will enable the medical profession to appropriately intervene in order to prevent students from developing computer-related neck and/or shoulder pain.

In February 2010 the grade ten students from all the participating schools will be asked to complete a questionnaire about muscle pain or discomfort. As a result of this questionnaire a sample of students will be chosen to participate in the research project.

In March 2010 the selected students will be asked to complete a computer typing task while researchers take measurements of their sitting posture. The typing will take place in the school's computer room within school hours. The measurements will be taken by means of photographs. The students will be asked to wear a black t-shirt. These t-shirts will be provided by the researcher. Reflective markers will be placed on certain landmarks. The landmarks will include the eye, ear, neck, upper back vertebrae, upper point of the breastbone and the hip. After completing the 10 minute typing task, the students will be ask to complete a questionnaire asking questions about their feelings and how they relate to others.
A questionnaire asking about any neck or shoulder pain symptoms or discomfort will be given to the participating students to complete in July and November 2010. One year later, March 2011, the

researcher will come back to the schools and take repeated measurements of posture, psychosocial factors and pain symptoms as in 2010.

Why has your child been invited to participate?

The schools that are selected all have Computer Application Technology (CAT) as a subject for grade ten students. Only students that take CAT at school can participate in this research project.

Will your child benefit from this project?

Because this is not an invasive study your child will not benefit directly from participating in this project, however if your child participates it makes it possible for the researcher to study the possible contributing factors for muscle pain and can therefore in future treat other students that do suffer from computer-related pain.

Are there any risks involved in your child taking part in this project?

There are no risks for your child participating in this project. The project will be conducted at the school where your child attends and the task that they are required to do is something that they do ever day for CAT.

Who will have access to your child's postural measurements?

The answers from the questionnaires and data from the photographs are confidential and only the researcher has access to the information. Your child will be allocated a number so that he/she remains anonymous. If any of the results are published in a thesis, the child will still remain anonymous.

Will you or your child be paid to take part in this project and are there any costs involved?

You or your child will not be paid to take part in this project and there will be no costs involved for you if your child participates.

Any additional information that you would like to know?

You can contact the Committee for Human Research at 021 9389207 if you have any concerns or complaints that have not been adequately addressed by the study investigator.

Assent of minor

I (*name of child*)…… have been invited to take part in the above research project.

- The study investigator and my parents have explained the details of the study to me and I understand what they have said to me.
- They have also explained that this study will involve: typing for 10 minutes on my school computer while the study researchers take measurements of my sitting position. I will also complete questionnaires asking about my feelings and any muscle pain or discomfort.
- I also know that I am free to withdraw from the study at any time if I am unhappy.
- By writing my name below, I voluntary agree to take part in this research project. I confirm that I have not been forced either by my parents or study investigator to take part.

....

Name of child **Independent witness**

(To be written by the child if possible)

Declaration by parent/legal guardian

By signing below, I *(name of parent/legal guardian)* …….. agree to allow my child (*name of child*) …… who is ……. years old, to take part in a research study entitled: Are sitting posture and psychosocial factors risk factors for the development of neck, shoulder and arm pain in grade ten high school students working on desktop computers?

I declare that:

- I have read or had read to me this information and consent form and that it is written in a language with which I am fluent and comfortable.
- My child is older then 7 years, therefore he/she must agree to take part in the study and his/her ASSENT must be recorded on this form.
- I have had a chance to ask questions and all my questions have been adequately answered.
- I understand that taking part in this study is **voluntary** and I have not been pressurised to let my child take part.
- I may choose to withdraw my child from the study at any time and my child will not be penalised or prejudiced in any way.

Signed at (*place*) .....…..……..... on (*date*) ……...……...2010.

....

Signature of parent/legal guardian **Signature of witness**

Declaration by investigator

I *(name)* ……..…… declare that:

- I explained the information in this document to …….
- I encouraged him/her to contact me and ask questions and took adequate time to answer them.
- I am satisfied that he/she adequately understand all aspects of the research, as discussed above
- I did not use a translator.

Signed at (*place*) .....….....…….. on (*date*) ……...…….. 2010.

....

Signature of investigator Signature of witness

DEELNEMERINLIGTINGSBLAD EN TOESTEMMINGSVORM VIR GEBRUIK DEUR OUERS/WETTIGE VOOGDE

TITEL VAN DIE NAVORSINGSPROJEK:
Are sitting posture and psychosocial factors risk factors for the development of neck, shoulder and arm pain in grade ten high school students working on desktop computers?

VERWYSINGSNOMMER: _____

HOOFNAVORSER: Yolandi Brink
KONTAKNOMMER: 021 8728695
ADRES: Stellenbosch Universiteit
Tygerberg Kampus
Parow

U kind *(of pleegkind, indien van toepassing*) word genooi om deel te neem aan ’n navorsingsprojek. Lees asseblief hierdie inligtingsblad op u tyd deur aangesien die detail van die projek hierin verduidelik word. Indien daar enige deel van die projek is wat u nie ten volle verstaan nie, is u welkom om die navorser daaroor uit te vra. Dit is baie belangrik dat u ten volle moet verstaan wat die navorsing behels en hoe u kind daarby betrokke gaan wees. U kind se deelname is ook **volkome vrywillig** en dit staan u vry om deelname te weier. U kind sal op geen wyse hoegenaamd negatief beïnvloed word indien u sou weier om hom/haar te laat deelneem nie. U mag u kind ook te eniger tyd aan die projek onttrek, selfs al het u ingestem om hom/haar te laat deelneem.
Hierdie studie is deur die **Komitee vir Mensnavorsing van die Universiteit Stellenbosch** goedgekeur en sal uitgevoer word volgens die etiese riglyne en beginsels van die Internasionale Verklaring van Helsinki en die Etiese Riglyne vir Navorsing van die Mediese Navorsingsraad (MNR).

Wat behels die navorsingsprojek?

Die doel van die projek is om te bepaal of ‘n leerder se sitpostuur voor ‘n rekenaar moontlik die oorsaak van nek en/of skouer pyn kan wees. Die projek gaan ook psigososiale faktore ondersoek wat moonlik ‘n bydraende rol kan speel tot die onwikkeling van nek en/of skouer pyn. Die resultate van hierdie projek sal dit vir die mediese professie moontlik maak om leerders met rekenaarverwante nek en/of skouer pyn meer toepaslik te hanteer.

In Februarie 2010 gaan die graag tien leerders van al die deelnemende hoërskole gevra word om ‘n vraelys te voltooi. Hierdie vraelys gaan vrae stel in verband met pyn of ongemak. Volgens hierdie vraelys gaan sekere leerders gekies word om deel te neem aan die projek.

In Maart 2010 gaan die gekose leerders gevra word om 10 minute op ‘n rekenaar te tik terwyl metings van hul sitpostuur deur navorsers geneem word. Hierdie metings sal geneem word in die skool se rekenaarlokaal tydens skoolure. Die metings word gedoen dmv foto’s. Die leerders sal gevra word om ‘n swart t-hemp, wat deur die navorser voorsien word, te dra. Reflekterende merkers sal op sekere areas geplaas word. Hierdie areas sluit in die oog, oor, nek- en rugwerwels, boonste deel van die borsbeen en die heup. Na afloop van die postuurmetings gaan die leerders ‘n vraelys invul wat vrae stel oor hul gevoelens en hoe hul met ander leerders oor die weg kom.

‘n Vraelys wat vrae stel oor enige nek en/of skouer pyn of ongemak sal aan die leerders gegee word om in te vul in Julie en November 2010. March 2011, the researcher will come back to the schools

and take repeated measurements of posture, psychosocial factors and pain symptoms as in 2010. Een jaar later, Maart 2011, sal die navorser teruggaan na al die skole en herhaalde metings, soos in 2010, van postuur, psigososiale faktore en pyn simptome neem.

Waarom is u kind genooi om deel te neem?

Die skole wat genader word om deel te neem bied almal rekenaartoepaslikheidstegnologie as vak aan. Slegs leerders wat rekenaartoepaslikheidstegnologie as vak het, mag deelneem.

Sal u kind voordeel trek deur deel te neem aan hierdie projek?

U kind sal nie direk voordeel trek by hierdie projek nie, maar deur deel te neem sal dit vir die navorser moontlik maak om faktore, wat bydra tot die ontwikkeling van pyn, te kan bestudeer en in die toekoms ander leerders met rekenaarverwante pyn te hanteer.

Is daar enige risiko's verbonde aan u kind se deelname aan die projek?

Daar is geen risiko's verbonde aan u kind se deelname nie. Hierdie projek word by die skool waar u kind skoolgaan uitgevoer en van u kind word verwag om voor die skoolrekenaar te sit en tik en dit word reeds daagliks gedoen.

Wie sal toegang hê tot u kind se vraelys antwoorde en postuurmetings?

Die antwoorde van die vraelyste en die data van die foto's is vertroulik en slegs die navorser het toegang daartoe. U kind sal 'n nommer gegee word sodat u kind anoniem bly. As enige van die resultate van die projek gepubliseer word in 'n tesis, sal u kind steeds anoniem bly.

Sal u of u kind betaal word vir deelname aan die projek en is daar enige koste verbonde aan deelname?

Nee, u of u kind sal nie betaal word vir deelname aan die projek nie. Deelname aan die projek sal u niks kos nie.

Enige addisionele inligting wat u wil weet?

U kan die Komitee vir Mensnavorsing kontak by 021 9389207 indien u enige bekommernis of klagte het wat nie bevredigend deur die navorser hanteer is nie.

Instemming van minderjarige

Ek (*naam van minderjarige*) ……..... is genooi om deel te neem aan bogenoemde navorsingsprojek.

- Die navorser en my ouers het die besonderhede van bogenoemde navorsingsprojek aan my verduidelik en ek verstaan wat hulle aan my gesê het.
- Hulle het ook aan my verduidelik dat die projek die volgende insluit: 10 minute te tik op my skoolrekenaar terwyl die navorsers metings van my sitpostuur neem. Ek sal ook vraelyste volooi wat vrae stel oor my gevoelens en hoe ek met ander oor die weg kom en enige nek/skouer pyn of ongemak.
- Ek weet ook dat ek te eniger tyd aan die navorsingsprojek kan onttrek indien ek ongelukkig is.
- Deur my naam hieronder in te vul, onderneem ek om **vrywillig** aan die navorsingsprojek deel te neem. Ek bevestig dat ek nie deur my ouers of die navorser gedwing is om deel te neem nie.

....

Naam van kind **Onafhanklike getuie**

(*Deur kind geskryf indien moontlik*)

Verklaring deur ouer/wettige voog

Met die ondertekening van hierdie dokument onderneem ek, (*naam van ouer/wettige voog*) …….....…., om my kind *(naam van kind)* …….....…., wat ..... jaar oud is, te laat deelneem aan 'n navorsingsprojek getiteld: Are sitting posture and psychosocial factors risk factors for the development of neck, shoulder and arm pain in grade ten high school students working on desktop computers?

Ek verklaar dat:

- Ek hierdie inligtings- en toestemmingsvorm gelees het of aan my laat voorlees het en dat dit in 'n taal geskryf is waarin ek vaardig en gemaklik mee is.
- My kind moet instem om aan die navorsingsprojek deel te neem omdat hy/sy ouer as 7 jaar is, en dat sy/haar INSTEMMING op hierdie vorm aangeteken sal word.
- Ek geleentheid gehad het om vrae te stel en dat al my vrae bevredigend beantwoord is.
- Ek verstaan dat deelname aan hierdie projek **vrywillig** is en dat daar geen druk op my geplaas is om my kind te laat deelneem nie.
- My kind te eniger tyd aan die projek mag onttrek en dat hy/sy nie op enige wyse daardeur benadeel sal word nie.

Geteken te (*plek*) .....…….. op (*datum*) ……...……..... 2010.

....

Handtekening van ouer/wettige voog Handtekening van getuie

Verklaring deur navorser

Ek (*naam*) ……..... verklaar dat:

- Ek die inligting in hierdie dokument verduidelik het aan …….....……..
- Ek hom/haar aangemoedig het om vrae te vra en voldoende tyd gebruik het om dit te beantwoord.
- Ek tevrede is dat hy/sy al die aspekte van die navorsingsprojek soos hierbo bespreek, voldoende verstaan.
- Ek het nie 'n tolk gebruik het nie.

Geteken te (*plek*) .....…….. op (*datum*) ……...……..... 2010.

....

Handtekening van navorser Handtekening van getuie

INCWADANA YOLWAZI ELUNGISELWE UMTHATHI-NXAXHEBA KUNYE NEPHEPHA-MVUME YOMZALI OKANYE UMGCINI WOMNTWANA NGOKUSEMTHETHWENI

ISIHLOKO SEPROJEKTHI YOPHANDO:
Ingaba iimeko zokuhlala ezitulweni neziyichaphazelayo ingqondo kunye nentlalo zibabeka emngciphekweni na abafundi bezikolo zamabanga aphakamileyo abakwigreyidi yeshumi ekubeni banganeengxaki zokuba buhlungu kweentamo, kwamagxa kunye neengalo zabo xa elowo esebenzisa iikhompyutha ajongene ngqo nayo edesikeni?

INOMBOLO SALATHISO:	_____
UMPHANDI OYINTLOKO:	Yolandi Brink
INOMBOLO YOMNXEBA:	021 8728695
IDILESI:	I-Yunivesithi yaseStellenbosch Tygerberg Campus Parow

Umntwana wakho (*okanye umntwana ophantsi kwegunya lomnye umntu ongengomzali wakhe ngokomthetho kaRhulumente, ukuba kuyenzeka)* uyacelwa ukuba athabathe inxaxheba kuphando olwenziwayo noluyiprojekthi. Nceda uzinike ithuba lokuba ufunde ulwazi olubhalwe apha, lona luza kunika iinkcukacha ngale projekthi. Nceda ubuze umphandi oyintloko nayiphi na imibuzo ongaba akuyiqondi ngokupheleleyo ngale projekthi. Kubalulekile ukuba uthi kanti waneliseke ngokupheleleyo ekuqondeni ukuba olu phando luphathelene nantoni na nokuba umntwana wakho angabandakanyeka njani. Kananjalo, ukubandakanyeka komntwana wakho **kusekuthandeni kwakhe** kwaye uvumelekile ukuba ungamrhoxisa kolu phando. Ukuba wena uyala ukuba athabathe inxaxheba, eso sigqibo asisayi kumchaphazela ngendlela egwenxa umntwana wakho. Uvumelekile ukuba ungayirhoxisa inxaxheba yakhe kolu phando nangaliphi na ixesha, nangona ubusele uyinikile imvume yokwenza njalo ngaphambili.
Olu phando lunikwe imvume **yiKomiti yoPhando ngentlalo yoMntu kwiYunivesithi yaseStellenbosch** kwaye luza kuqhutywa ngokwesiKhokelo seMikhwa eseSikweni noMthetho-siseko wesiBhengezo saseHelsinki, isiKhokelo senKqubo yoNyango esikuMgangatho oPhezulu saseMzantsi Afrika kunye nesiKhokelo seMikhwa eseSikweni seBhunga loPhando ngamaChiza (BLC).

<u>Ingantoni le projekthi yophando?</u>
Injongo yale prowujekhthi kukufikelela kwizigqibo zokuba indlela ahleli ngayo umfundi esitulweni ngeli xesha ajonge ikhompyutha esedesikeni phambi kwakhe ingangunobangela na weentlungu ezisentanyeni nezikuwo amagxa / okanye ezisemagxeni akhe. Le prowujekhthi kwakhona iza kuqikelela iimeko ezichaphazela intlalo kunye nengqondo ezisenokubanalo igalelo kwiintlungu zentamo / okanye zamagxa omfundi. Iziphumo zale prowujekhthi ziza kuzivumela iingcali kwicala lezonyango ukuba zilamle ngokufanelekileyo ukuze kukhuselwe abafundi ekuzenzeni mandundu iintlungu ezisezintanyeni / okanye ezisemagxeni abo.
NgoFebhuwari wonyaka ka-2010 abafundi abakwigreyidi yeshumi abasezikolweni ezithatha inxaxheba baza kucelwa ukuba elowo makafake iinkcukacha eziphelelelyo kwiphepha lemibuzo alinikiweyo malunga neentlungu zezihlunu zabo kunye / okanye ngokungonwabi. Ngenxa yeli phepha lemibuzo, kuza kukhethwa iqela elithile labafundi ukuba malithathe inxaxheba kule prowujekhthi yophando.

NgoMatshi ka-2010 aba bafundi banyuliweyo baza kucelwa ukuba mabawenze ngokupheleleyo umsebenzi wokuchwetheza besebenzisa iikhompyutha, ngelo xesha abaphandi bakuba bexakekile bethatha imilinganiselo ngendlela umfundi ngamnye ahleli ngayo esitulweni esiphambi kwekhompyutha ayisebenzisayo esetafileni. Ukuchwetheza kuza kwenzelwa esikolweni egumbini elineekhompyutha, kanye ngeeyure zokuba sesikolweni. Imilinganiselo iza kuthathwa ngeefoto. Umfundi ngamnye uza kucelwa ukuba makanxibe i-t-shirt emnyama azakube eyinikwa ngumphandi. Imiqondiso ebonisa imeko nganye iza kukrwelwa njengeempawu kwiindawo ezithile ezisemhlabeni phantsi. Ezo mpawu zisemhlabeni ziza kuquka iliso, indlebe, intamo, amathambo omqolo phakathi kwamagxa, umntla wethambo lesifuba kunye namahleza okanye nenyonga. Akuba umfundi ewugqibile umsebenzi wokuchwetheza kangangemizuzu eli-10, uza kucelwa ukuba abhale iinkcukacha ezipheleleyo ephepheni lemibuzo. Uza kubuzwa imibuzo emalunga novakalelo lwakhe kunye nendlela anxibelelana ngayo nabanye abafundi.

Iphepha lemibuzo eliphandayo malunga nemiqondiso yeentlungu ezisentanyeni okanye ezisemagxeni okanye ngokungonwabi liza kunikwa umfundi ngamnye othatha inxaxheba ukuze abhale iinkcukacha ezipheleleyo ngoJulayo nangoNovemba wonyaka ka-2010. Kwakugqitha ixesha elingangonyaka, ngoMatshi ka-2011, umphandi uza kubuyela ezikolweni athathe imilinganiselo yendlela yokuhlala ephindiweyo yomfundi ngamnye, abhale imiqondiso okanye iimpawu ezichaphazela intlalo kunye nengqondo abhale neempawu zeentlungu njengoko bekwenziwe ngonyaka ka-2010.

Yintoni isizathu sokuba umntwana wakho acelwe ukuba athabathe inxaxheba?

Zonke izikolo ezikhethelwe olu phando zinezifundo zekhompyutha ezingesiso isinyanzelo nathi umfundi wegreyidi yeshumi azithathe ukuba uthandile. Ngabantwana abenza izifundo zekhompyutha nabasekwinqanaba lesikolo kuphela abanokuthabatha inxaxheba kule projekthi yophando.

Ingaba uza kuzuza umntwana wakho kule projekthi?

Ngenxa yokuba esi ayisosifundo siphazamisayo, umntwana wakho alukho uncedo oluthe ngqo aza kulufumana ngokuthatha kwakhe inxaxheba kule prowujekhthi, nangona kunjalo, xa umntwana wakho ethatha inxaxheba, umphandi uza kukwazi ukufundisisa ngeemeko ezinegalelo kwiintlungu ezikuzo izihlunu, lilonke kwixa elizayo lo mphandi angabanyanga nabanye abafundi abaxhalabiswa ziintlungu ezinxulumene nokusetyenziswa kwekhompyutha.

Ingaba bukhona ubungozi obukhoyo xa umntwana wakho ethatha inxaxheba kule projekthi?

Akukho bungozi bukhoyo ngokuthatha inxaxheba komntwana wakho kule projekthi. Le prowujekhthi iza kubanjelwa esikolweni afunda kuso umntwana wakho, lo msebenzi kufuneka bewenzile ngulowo bawenza yonke imihla kwinkqubo eyi-CAT

Ngubani oza kufikelela kuthelekiso olwenziweyo lomntwana wakho?

Iimpendulo ezikumaphepha emibuzo neenkcukacha ezikumafoto ziyimfihlelo kwaye ngabaphandi kuphela abaza kufikelela kwezi nkcukacha. Umntwana wakho uza kunikwa inombolo ukuze ahlale engaziwa. Ukuba kukho iziphumo eziza kupapashwa kwithisisi, umntwana wakho uza kuhlala engaziwa.

Ingaba umntwana wakho uza kuhlawulwa ngokuthabatha kwakhe inxaxheba kolu phando, yaye ingaba zikho na iindleko?

Wena nomntwana wakho anizi kuhlawulwa ngokuzibandakanya kwenu kule projekthi kwaye akukho ntlawulo uza kuyifumana ukuba umntwana wakho uthabatha inxaxheba.

Olunye ulwazi olongezelekileyo onokuthanda ukubanalo?

Ungaqhagamshelana neKomiti yoPhando ngentlalo yoLuntu kule nombolo 021 938 9207 ukuba kukho into ekuxhalabisayo okanye izikhalazo ezingakhange zabe umphandi oyintloko uziphendule kakuhle.

Imvume yomntwana

Mna (igama lomntwana) …… ndiceliwe ukuba ndithabathe inxaxheba kuphando oluyiprojekthi nolungentla apha.

- Umphandi oyintloko kunye nabazali bam bandicacisele ngeenkcukacha zolu phando kwaye ndiyayiqonda yonke into abayithethileyo kum.
- Bakwacacisile ukuba esi sifundo siza kubandakanya: ukuchwetheza kangangemizuzu eli-10 kwikhompyutha yesikolo sam ngeli xesha abaphandi besi sifundo bathatha imilinganiselo yendlela endihleli ngayo esitulweni. Kwakhona ndiza kubhala iinkcukacha ezipheleleyo kumaphepha emibuzo afuna ulwazi ngovakalelo nangeentlungu zezihlunu zam okanye ngokungonwabi kwam.
- Ndiyazi ukuba ndinalo ilungelo lokurhoxa kwezi zifundo nagaliphi na ixesha ukuba ndiziva ndingonwabanga.
- Ngokubhala igama lam ngezantsi, ndiyavuma ukuthabatha inxaxheba ngokuzikhethela kwam. Ndiyangqina ukuba abazali bam okanye umphandi oyintloko akhange andinyanzele ukuba ndithabathe inxaxheba.

....

Igama lomntwana **Ingqina elizimeleyo**

(Kufuneka libhalwe ngumntwana ukuba kuyenzeka)

Isibhengezo esenziwa ngumzali okanye umgcini womntwana ngokusemthethweni

Ngokusayina ngezantsi, Mna *(igama lomzali okanye umgcini womntwana ngokusemthethweni)* …….. ndiyavuma ukuba ndikhululele umntwana (igama lomntwana) …… oneminyaka e- ……..... ubudala, ukuba athabathe inxaxheba kuphando olusihloko sithi: **Ingaba iimeko zokuhlala ezitulweni neziyichaphazelayo ingqondo kunye nentlalo zibabeka emngciphekweni na abafundi bezikolo zamabanga aphakamileyo abakwigreyidi yeshumi ekubeni banganeengxaki zokuba buhlungu kweentamo, kwamagxa kunye neengalo zabo xa elowo esebenzisa iikhompyutha ajongene ngqo nayo edesikeni?**

Ndibhengezisa ukuba:

- Ndilufundile okanye ndalufunda ulwazi ngolu phando kunye nephepha-mvume kwaye zibhalwe ngolwimi endilwazi ngendlela etyibilikayo.
- Umntwana wam ungaphezulu kwiminyaka esixhenxe, ngoko ke kufuneka enze imvume ngokwakhe malunga nokuthabatha inxaxheba kwaye imvume yakhe kufuneka ishicilelwe kweli phepha.

- Ndaye ndalifumana ithuba lokuphosa imibuzo kwaye yonke imibuzo yam yaphenduleka ngendlela eyanelisayo.
- Ndiyayiqonda into yokuba ukuthabatha inxaxheba kolu phando **kusentandweni yomntu** kwaye andikhange ndinyanzelwe ukuba ndikhululele umntwana wam ukuba azibandakanye nolu phando.
- Ndingamrhoxisa umntwana wam kolu phando nangaliphi na ixesha kwaye akasayi kufumana sohlwayo okanye adlelwe indlala nangaluphi na uhlobo.

Isayinwe e- (*indawo*) .....……. ngomhla (usuku) ……...…. 2010.

....

Isandla somzali okanye umgcini womntwana ngokusemthethweni Isandla sengqina

Isibhengezo somphandi oyintloko

Mna (*igama)* ……..…… ndibhengezisa ukuba:

- Ndiyenzile ingcaciso ngolwazi olu kolu xwebhu ku…….
- Ndimkhuthazile ukuba aqhagamshelane nam, abuze imibuzo kwaye ndizinike ithuba elaneleyo ndiyiphendula.
- Ndanelisekile kukuba wazi ngokwaneyo ngayo yonke imiba yophando, njengokuba kuchaziwe ngentla apha.
- Ndilusebenzisile okanye andikhange ndilusebenzise uncedo lomguquli wolwimi.

Isayinwe (indawo) .....…..…. ngomhla (usuku) ……...……..…….. 2010.

....

Isandla somphandi Isandla sengqina

You don’t need to wait for tomorrow to be happy and enjoy your life. You don’t even need to be richer or more powerful to enjoy life. LIFE is at this moment, enjoy it fully.

As some great men have said; “My riches consist not in the extent of my possessions, but in the fewness of my wants.”

Live now, you only have this one Life to live!

The mean, SD, maximum and minimum values for the nine postural angles (n = 153)

	Mean	SD	Maximum	Minimum
Head flexion (°)	77.10	7.5	95.23	50.60
Neck flexion (°)	63.65	7.6	86.23	42.46
Cranio-cervical angle (°)	164.11	7.2	178.73	145.45
Cervico-thoracic angle (°)	152.70	6.5	171.75	133.09
Trunk flexion (°)	-9.41	8.8	16.19	-29.35
Head lateral bending (°)	0.15	5.2	20.57	-10.26
Neck lateral bending (°)	-6.04	17.5	37.81	-57.13
Head rotation (°)	-1.26	8.0	26.81	-23.63
Thoracic trunk rotation (°)	-3.15	6.1	19.84	-23.38

Years of exposure, duration per session and frequency per week of computer use school and elsewhere at one year follow up (n=153)

At school			Elsewhere		
Years of exposure					
	Frequency (n)	**Percentage (%)**		**Frequency (n)**	**Percentage (%)**
< 1 yr	9	5.9	**< 1 yr**	23	15.0
2 yrs	92	60.1	**2-3 yrs**	44	28.8
3 yrs	20	13.1	**4 yrs**	13	8.5
> = 4 yrs	32	20.9	**> = 5 yrs**	73	47.7
Duration per session					
	Frequency (n)	**Percentage (%)**		**Frequency (n)**	**Percentage (%)**
<30 minutes	5	3.3	**<30 minutes**	29	19.0
About 45 minutes	121	79.6	**1 h**	57	37.3
1 h	18	11.8	**2-3 h**	50	32.7
1 ½ h	5	3.3	**>=4 h**	15	9.8
2/+ h	3	1.9			
Frequency per week					
	Frequency (n)	**Percentage (%)**		**Frequency (n)**	**Percentage (%)**
Once or less	6	4.0	**Once or less**	17	11.1
Twice	3	2.0	**Twice**	22	14.4
Three times	15	9.9	**Three times**	17	11.1
Four times	34	22.4	**Four times**	26	17.0
Five times	94	61.8	**Five times**	71	46.4