

MEASURING THE SITTING POSTURE OF HIGH SCHOOL LEARNERS. A RELIABILITY AND VALIDITY STUDY

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**Thesis presented for the degree of Master in Science in
Physiotherapy at University of Stellenbosch**



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DECLARATION

“I, the undersigned, hereby declare that the work contained in this thesis is my original work and that I have not previously in its entirety or in part submitted it at any university for a degree.”

Signature:..... Date:.....



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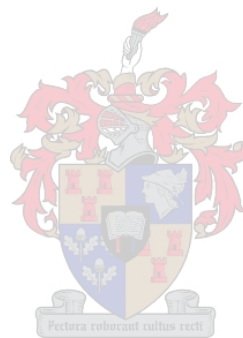


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ABSTRACT

Objective

The objective of this study was to establish the reliability and validity of a Portable Posture Analysis Method (PPAM).

Design

The design for the reliability section was a *repeated measures observational study* and the design for the validity section was a *correlation study*.

Background

The prevalence of spinal pain among high school learners is high (Murphy *et al*, 2002). It is also notable that the prevalence of back pain increases across the teenage years (Grimmer & Williams 2000, Burton *et al* 1996). In South Africa, the preliminary findings of a study conducted by a Physiotherapy masters candidate (Ms L Smith: ethics nr. N05/09/164) indicates that about 74% of high school learners in Cape Town complained of musculoskeletal pain. Posture has been identified by some researchers to be a primary predictor of the development of spinal, particularly upper quadrant pain among computer users (NIOSH 1997, Vieira *et al* 2004). Measurement of posture poses a real challenge to researchers wanting to accurately evaluate posture in research projects. Considering the practical implications in measuring posture, the validity and reliability of posture measurement are often reported to be poor. Many of these methods of indirect assessment of working posture have been reported on in the literature. These measures include; the goniometer, inclinometer, flexible electrogoniometer, flexicurve and photography (Harrison *et al* 2005, Christensen 1999, Nitschke *et al* 1999, Chen & Lee 1997).

Method

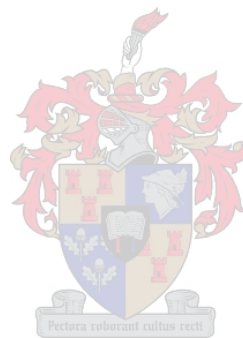
A sample group of 39 learners were recruited from 3 schools. Each learner was asked to complete a modified pain questionnaire before the commencement of the study. Three learners were tested simultaneously at the reliability laboratory, after which they proceeded to the validity laboratory where they were tested individually. Golem retro-reflective markers were placed on the lateral canthus of the eye, the trachus of the ear, spinous process of C7 (Grimmer *et al* 2005), midpoint of the superior border of the manubrium, spinous process of T8 and the lateral epicondyle of the elbow (Szeto *et al* 2002). All markers were placed on the dominant side of the learner. The learners were randomly selected to sit in one of 3 postures; slouched, straight or normal. Five photos, with the flash on, were taken of each learner at the reliability station. After each photo the learner walked at a normal pace for a total distance of four meters, and sat in a similar position as before (Grimmer *et al* 2005). At the validity station, 2 upper body photos and 1 X-ray were taken of each learner, to calculate the cervical angle, sagittal head angle, shoulder protraction/retraction angle, thoracic angle and the arm angle.

Results

Thirteen of the 39 learners (33%) experienced mild pain on the day of testing as well as during a variety of mostly school related activities. Inter-class correlation coefficients (ICC's) were calculated for the reliability and validity of the PPAM as well as for the subsections; posture (slouched, straight and normal), gender and age. The reliability ICC values for the sagittal head angle and the cervical angle was found to be 0.98, for the protraction/retraction angle 0.94, thoracic angle 0.96 and for the arm angle 0.99. For the validity testing the above mentioned angles scored ICC values as follows; 0.91 for the sagittal head angle, 0.93 for the cervical angle, 0.87 for the protraction/retraction angle, 0.91 for the thoracic angle and 0.78 for the arm angle.

Conclusion

The findings of this study illustrate that the PPAM is a valid and reliable method for assessing the sitting posture of learners in front of a desktop computer. This system is portable, inexpensive and easy to use. These results warrant the next phase of testing learners in the school environment and determining the association of posture and pain.



UITTREKSEL

Doel

Die doel van hierdie studie is om die betroubaarheid en geldigheid van die 'Portable Posture Analysis Method (PPAM)' te bepaal.

Studie Ontwerp

Die ontwerp van die geldigheidsafdeling was 'n herhaaldelike meet- en observasiestudie en die ontwerp vir die geldigheidsafdeling was 'n korrelasiestudie.

Agtergrond

Rugpyn is 'n algemene verskynsel onder hoërskool leerlinge (Murphy *et al* 2002). Dit is ook opmerkbaar dat hierdie verskynsel van rugpyn vererger gedurende die tienerjare (Grimmer & Williams 2000, Burton *et al* 1996).

In Suid-Afrika toon voorlopige bevindinge van 'n studie, uitgevoer deur 'n Fisioterapie magisterskandidaat (Me. L Smith: etiek nr. N05/09/164), dat 74% van hoërskool leerlinge aantoon dat hulle muskuloskeletale pyn ervaar. Postuur is geïdentifiseer deur sommige navorsers, as die primêre aanwyser vir die ontwikkeling van rugpyn, in besonder boonste kwadrant onder rekenaarverbruikers (NIOSH 1997, Vieira *et al* 2004). Die meting van postuur is 'n uitdaging vir die navorsers wat postuur akkuraat wil evalueer. Indien die praktiese implikasies van postuur evaluasie in gedagte gehou word, word die geldigheid en herhaalbaarheid van die evaluasie van postuur betwyfel. Daar word na verskeie evaluasies van werkpostuur in die literatuur verwys. Hierdie meet-instrumente sluit die volgende in; goniometer, "inclinometer", die buigbare elektro-goniometer, "flexicurve" en fotografie. (Harrison *et al* 2005, Hinmann *et al* 2003/2004, Lee *et al* 2003, Moffet *et al* 1989, Malmström 2003,

Pringle 2003, Tousignant *et al* 2000 & 2001, Nitschke *et al* 1999, Chen & Lee 1997, Youdas *et al* 1991).

Metodiek

'n Steekproef van 39 leerlinge is uit 3 skole verwerf. Elke leerling is gevra om 'n aangepasde pynvraagstuk in te vul voor die aanvang van die studie. Drie leerlinge is gesamentlik getoets by die herhaalbaarheidslaboratorium, waarna hulle by die geldigheidslaboratorium individueel getoets is. Golem retro-reflektiewe merkers is op die op die laterale hoek van die oog, tragus van die oor, spineuse proses van C7 (Grimmer *et al* 2005), middelpunt van die superior grens van die manubrium, spineuse proses van T8 en die laterale epikondule van die elmboog (Szeto *et al* 2002) geplaas. Al die merkers is aan die dominante kant van die leerling geplaas. Die leerlinge is lukraak in drie postuur groepe verdeel, naamlik; geboë ("*slouched*"), regop en normaal. By die herhaalbaarheidslaboratorium is vyf foto's, met die kamera se flits aan, van elke leerling geneem. Na elke foto het die leerling 'n afstand van 4m teen 'n normale spoed geloop en weer in 'n soortgelyke posisie as voorheen gesit (Grimmer *et al* 2005). Daarna, by die geldigheidslaboratorium, is twee foto's en een X-straal van elke leerling geneem om die sagittale nek hoek, die sagittale kop hoek, skouer protraksie/retraksie hoek, torakale hoek en die arm hoek te bepaal.

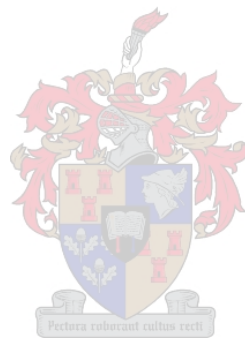
Resultate

Dertien van die 39 leerlinge (33%) het ligte pyn ervaar die dag van toetsing, sowel as gedurende 'n redelike verskeidenheid skoolverwante aktiwiteite. Tussen-klas korrelasie koëffisiënte is bereken vir die geldigheid en herhaalbaarheid van die PPAM, sowel as vir die onderafdelings; postuur, geslag en ouderdom. Die herhaalbaarheids koëffisiënte vir die sagittale kop en nek hoek was 0.98, vir die protraksie/retraksie hoek 0.94, vir die torakale hoek 0.96 en vir die arm hoek 0,99. Vir die geldigheid van die bogenoemde was die koëffisiënte; 0.91 vir die sagittale kop hoek, 0.93 vir die sagittale nek

hoek, 0.87 vir die protraksie/retraksie hoek, 0.91 vir die torakale hoek en 0.78 vir die arm hoek.

Gevolgtrekking

Dié bevindinge wys dat die PPAM 'n geldige en herhaalbare metode is om sittende postuur voor 'n rekenaar te analiseer. Die sisteem is draagbaar, bekostigbaar en maklik om te gebruik. Hierdie resultate veroorloof die volgende fase om leerlinge in die skoolomgewing te toets en die assosiasie tussen pyn en postuur te bepaal.



Chapter 1

INTRODUCTION

The prevalence of spinal pain among high school children is high (Murphy *et al* 2002). It is also notable that the prevalence of back pain increases across the teenage years (Grimmer & Williams 2000, Burton *et al* 1996). The findings of a landmark study indicated that incidence rate for spinal pain in adolescences increases with age, and by the age of 15 years the lifetime prevalence exceeds 50% among British adolescents (Burton *et al* 1996). In South Africa, the preliminary findings of a study conducted by a Physiotherapy masters candidate (Ms L Smith: ethics nr. N05/09/164) indicates that about 73% of high school learners in Cape Town complained of musculoskeletal pain. Considering that back pain at an early age was found to be the most important predictor of chronic spinal pain in adult life, preventative action among adolescents and children are of great value (Korovesis *et al* 2005, Feldmann *et al* 2000).

A number of studies have recently indicated that computer usage may increase development of musculoskeletal pain among adolescents (Trevelyan & Legg 2006, Ming *et al* 2004). A number of aetiological factors including ergonomic workstation design, level of physical activity, body mass index, height, etc. can be attributed to the development of musculoskeletal pain among adolescents. One important factor related to the development of musculoskeletal pain among computer users is the posture of the individual (Szeto *et al* 2005, Szeto *et al* 2002). Posture has been identified by some researchers to be a primary predictor of the development of spinal, particularly upper quadrant pain among computer users (NIOSH 1997). Posture is most commonly defined as biomechanical alignment or position of body segments when performing a specific task (Vieira *et al* 2004). In order to understand the causes and risk factors of musculoskeletal pain development, it is necessary to measure posture.

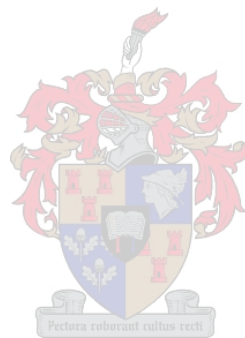
Measurement of posture poses a real challenge to researchers wanting to accurately evaluate posture in research projects. Postural measurements often involve using external bony landmarks of the body to determine the underlying alignment of the spine. Considering the practical implications in measuring posture, the validity and reliability of posture measurement are often reported to be poor (Vieira *et al* 2004, Leskinen *et al* 1997). Practical implications of measurement tools, poorly defined procedures contributing to increase the measurement errors and the inability to compare postural measurement tools to a “Golden Standard” are also reasons for the lack of reliability and validity. X-rays are viewed to be a gold standard postural evaluation method, since it is a valid measure for determining the position of bony landmarks, which can then be used to calculate postural alignment (Harrison *et al* 2005). However, X-ray measurements are very costly, it is also impractical for large samples and the X-ray equipment is not easily transported to different settings.

Many methods of indirect assessment of working posture have been reported on in the literature. These measures include the goniometer, inclinometer, flexible electrogoniometer, flexicurve and photography (Harrison *et al* 2005, Christensen 1999, Nitschke *et al* 1999, Chen & Lee 1997). Nitschke *et al* (1999) tested inter- and intra tester reliability of goniometric and inclinometric measurements of lumbar movement and both instruments were found to be unreliable in determining the posture of the lumbar spine. This can be due to the fact that the landmarks that were used (the sacrum, the mid-axillary line and the level of the lowest rib) could easily differ between the assessors or the same assessor's repeated measure.

The flexible electrogoniometer is also often used as it avoids biomechanical problems related to axis alignment and thereby improves the validity of the measurements (Tesio *et al* 1995). However, Christensen (1999) found that the accuracy of the electrogoniometer in determining spinal posture is not acceptable. The electrogoniometer has also been shown to have poor concurrent validity when compared to cervical X-rays in ascertaining cervical spine posture (Harrison *et al* 2005).

Photography is a more recent method used in research to evaluate spinal posture. Photographic methods of evaluating posture are important in both clinical and research environments due to its simplicity, it is non-invasive and less expensive than radiographs (Chen & Lee 1997). In this study by Chen and Lee (1997), the photographs were compared to lumbar radiographs and it was found that the validity and reliability of photographic techniques depends on the specific procedures, methods, and type of skin markers used.

Further research is required to develop a reliable and valid method to analyse sitting posture, which is portable, practical and affordable for analysing posture in larger study samples than currently reported in the literature.



Chapter 2

SYSTEMATIC REVIEW

This chapter presents a systematic review of the published research into the common measurement tools utilised to evaluate posture. This systematic review serves as background information to illustrate the available information reported in the peer-reviewed literature regarding to reliability and validity of posture measurement equipment.

2.1 Review research question

What is the reliability and validity of the posture measurement tools utilised to asses the postural alignment of the cervical spine, shoulder girdle or upper thoracic spine?

2.2 Objectives

This systematic review will address the following objectives:

- To critically appraise the methodology of the eligible published literature reporting on the reliability and validity of the commonly used posture measurement tools.
- To identify the most commonly tools utilised to evaluate cervical, shoulder girdle and thoracic spine postural alignment.
- To describe the types and degree of measurement reliability reported in the eligible studies.
- To describe the types and degree of validity of the common posture measurement tools.
- To describe the subjects included in the eligible studies.
- To critically appraise the methodology of the eligible studies.

2.2.1 Inclusion Criteria

The inclusion criteria for study selection are described below.

2.2.1.1 Types of studies

- Observational or correlational descriptive study designs
- Studies reporting on the validity and reliability testing of posture measurement tools commonly utilised in published research
- Research reports published in the English language
- Primary research including human subjects
- Research into the reliability or validity of the posture measurement tools when measuring cervical, shoulder girdle or upper thoracic static postural alignment or static angles and not dynamic range of movement
- Eligible research publications from the inception date of each of the selected databases



2.2.1.2 Types of participants

- Studies measuring the posture of healthy subjects without skeletal disease or pathology
- Studies reporting on the reliability and validity of measurement tools in adolescents and adults

2.3 List of definitions

The following definitions describe the terms utilised in this review:

Posture measurement: Posture is defined as the measurement of static alignment of body segments relative to each other and incorporates the measurement of static joint angles.

Cervical: The cervical spine is the area of the vertebral column commonly referred to as the neck (<http://backandneck.about.com>).

Upper thoracic: The thoracic spine is the area of the vertebral column commonly referred to as the mid and upper back. The upper thoracic area is classified as T1- T4 (<http://backandneck.about.com>).

Adolescents: The period between childhood and adulthood that is characterised by biological, psychological and social developmental changes. Adolescence is commonly divided into 3 periods: early (ages 11 to 14), middle (ages 14 to 17) and late (ages 17 to 20) (Kaplin and Sadock, 1991).

Adults: Adulthood is commonly divided into 3 major periods: early (end of adolescence to 40 years), middle adulthood (40 to 65 years) and late adulthood or “old age” (Kaplin and Sadock, 1991).

Concurrent validity: The extent to which the index from one test correlates with that of a non-identical ‘Gold Standard’ (Portney and Watkins 2000).

Intra-tester reliability: When one person measures the same item twice and the measurements are compared (Portney and Watkins 2000).

Inter-tester reliability: When 2 or more persons measure the same item and their measurements are compared (Portney and Watkins 2000).

Measurement tool reliability: To replicate the measurements made by the specific tool and then to evaluate the degree of agreement (Portney and Watkins 2000).

2.4 Methodology

The Cochrane Library and Pubmed were searched to ensure that a review answering the same or similar systematic review question has not been published in the past 5 years. The search results revealed that a similar review has not been published in any of these databases.

2.4.1 Search Strategy

The researcher developed search strategies for each of the following databases since inception:

Pubmed (Since 1950), CINAHL (since 1982), The Cochrane Library (2006 Issue) Science Direct Since (since 1823) and Embase.

The detailed search strategy developed for each database is presented in Appendix A. Pearling was also conducted to identify potential eligible articles from the reference list of eligible articles. A citation search was also done in Pubmed for the authors who have published extensively in the field of posture measurement. The names of the authors were identified from the eligible publications and included Straker L, Chockalingam C, Murphy S, Christensen HW and Nitschke J.

The following key words present a summary of the important elements of the search strategy. The key words included reliability, validity, photography, digital image, photographic evaluation, photographic analysis, goniometer, inclinometer, electrogoniometer, flexicurve, posture and spine.

The researcher and a research assistant conducted all the searches independently using the defined search strategies for each database. The reviewers have also independently identified eligible articles. Discrepancies in study selection were discussed by the two parties and where necessary a third party (study supervisor) was consulted.

2.4.2 Methodological Appraisal

An adapted Crombie Appraisal Tool for review studies (Crombie 1996) (Table 2.1) was utilised to assess each of the nine selected articles. A review of critical appraisal instruments highlighted the lack of a Gold Standard instrument, and encouraged reviewers to construct instruments that were relevant to their own review purpose. It has been common to add criteria to the existing critical appraisal instruments where they do not fully address the review requirements (Katrak *et al* 2004). Questions that were inappropriate for the critical appraisal were excluded. The open ended questions were rephrased in order to allow for scoring. The following questions were omitted from the original (Appendix B) as these questions were not appropriate for a systematic review:

- Was a control group used? Should one have been used?
- How adequate was the follow-up?
- Are the measurements likely to be valid and reliable?
- Was the exposure/intervention accurately measured?
- Were relevant outcome measures ignored?
- Did untoward events occur during the study?
- Did the analysis allow for the passage of time?
- How are null findings interpreted?
- Are important findings overlooked?

The researcher appraised all the eligible publications. A research assistant trained in methodological appraisal evaluated a random sub-sample of 3

publications. Any discrepancies were discussed until consensus was reached and a third party (study supervisor) was consulted when required. Table 2.1 presents a summary of the critical appraisal criteria. The open ended questions were rephrased to allow for a dichotomous answer.

Table 2.1: Crombie Critical Appraisal Tool.

	Question	YES	NO
1	Is it stated exactly who has been studied?		
2	Are the aims clearly stated?		
3	Is the design appropriate to the stated aims?		
4	Was the sample size justified?		
5	Are the statistical measures described?		
6	Do the numbers add up?		
7	Were the basic data adequately described?		
8	Is the meaning of the main findings explained?		
9	Are factors that might have influenced the observed outcome, discussed?		
10	Are important findings overlooked?		
11	Is it stated how the results compare with previous reports?		
12	Are the implications that the study has for your practice explored?		



2.4.3 Evidence Hierarchy

The hierarchical system of evidence as described by Sackett *et al* (2000) was used to determine the level of evidence (Table 2.2). The level of evidence is a reflection of the degree to which bias has been considered within the study design (Sackett *et al* 2000).

Table 2.2: Hierarchy of evidence (Sackett *et al* 2000)

Level 1	Meta-analysis of randomized controlled clinical trials
Level 2a	One randomized controlled clinical trial (RCT)
Level 2b	One non-randomised, or non-controlled, or non-blinded clinical trial
Level 3	Observational studies
Level 4	Pre-post test clinical trials
Level 5	Descriptive studies
Level 6	Anecdotal evidence

2.4.4 Data Extraction

All articles were collated and classified using a MS Excel database with the headings listed below. These headings were used to clarify and describe key elements of each study for comparison purposes. The following key elements were considered essential to describe studies in sufficient detail for analysis.

1. Author
2. Year of publication
3. Country
4. Study design
5. Research questions/ objectives
6. Sample size and size calculation
7. Sample description (age and gender)
8. Measurement tool
9. Statistical analysis
10. Validity findings
11. Reliability findings
12. Clinical implications

2.5 Results

2.5.1 Selection of studies and evidence level

The findings of the search are presented in Figure 2.1. Nine eligible articles were included in the systematic review (Harrison *et al* 2005, Hinmann 2003/2004, Lee *et al* 2003, Malmström *et al* 2003, Pringle 2003, Tousignant *et al* 2000 & 2001, Youdas *et al* 1991, Moffet *et al* 1989). All nine articles were observational of nature and are thus ranked as Level 3 on Sackett's Evidence Hierarchy (Table 2.2).

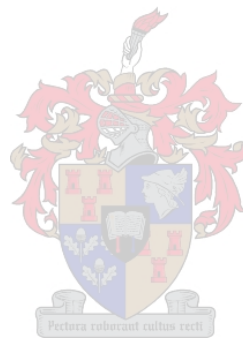
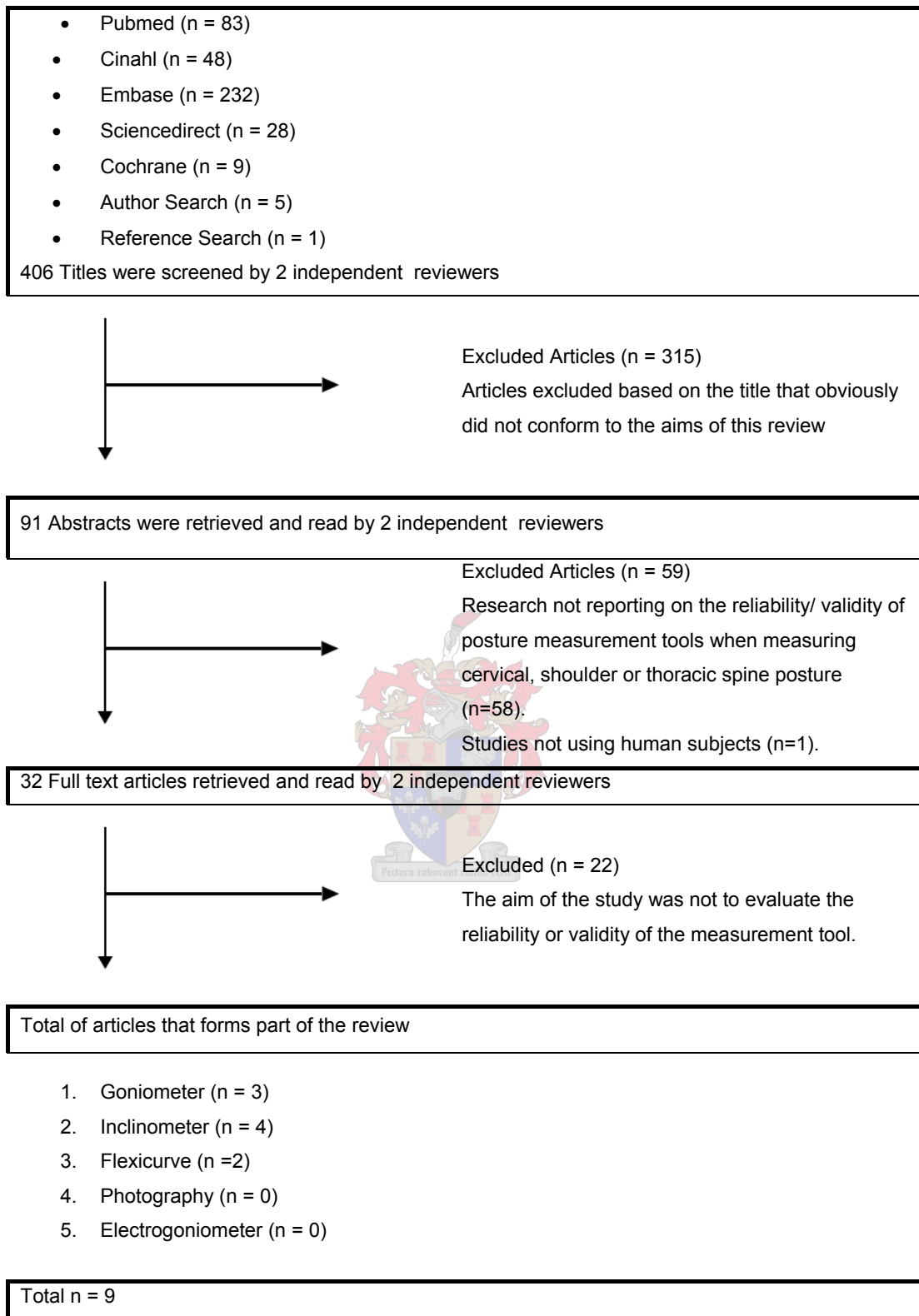


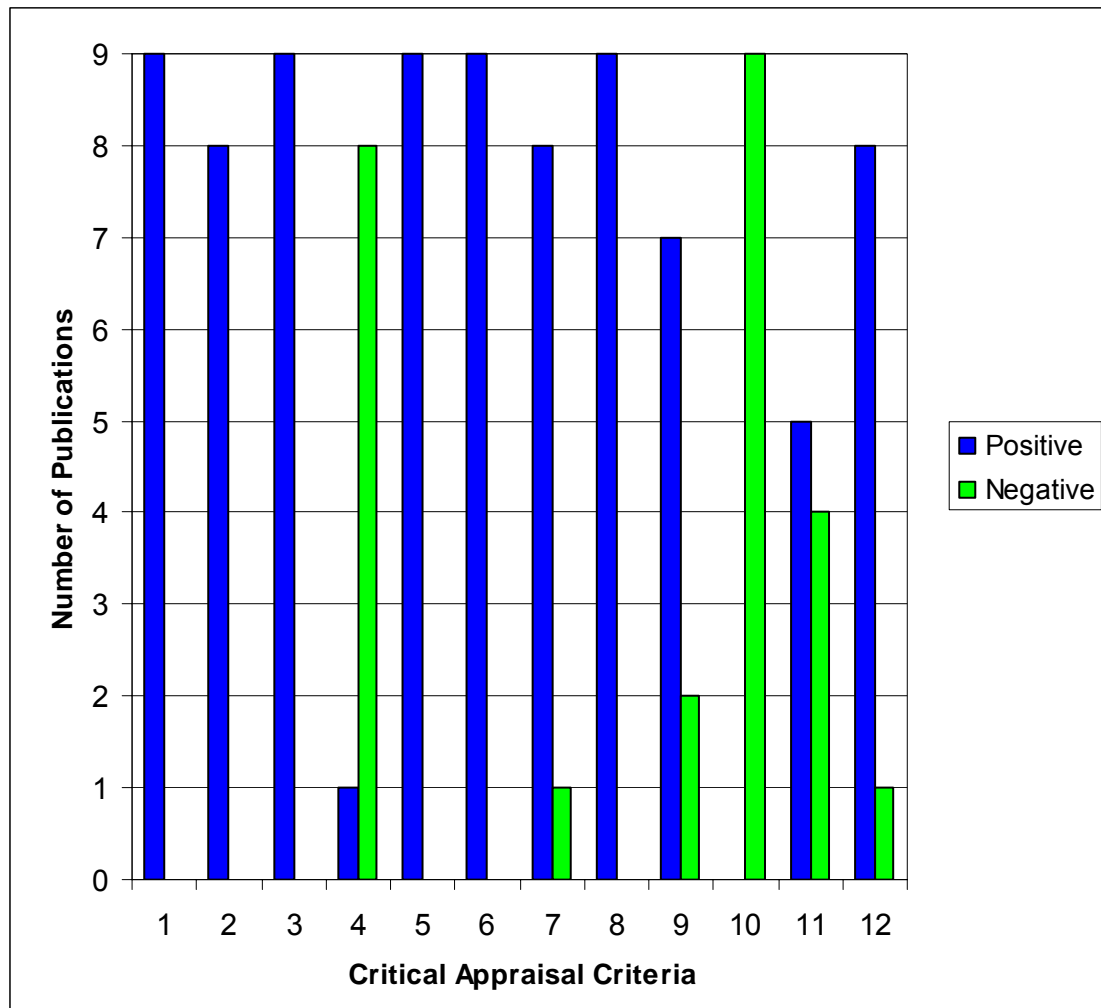
Figure 2.1: Database search method and results.



2.5.2 Methodological Appraisal

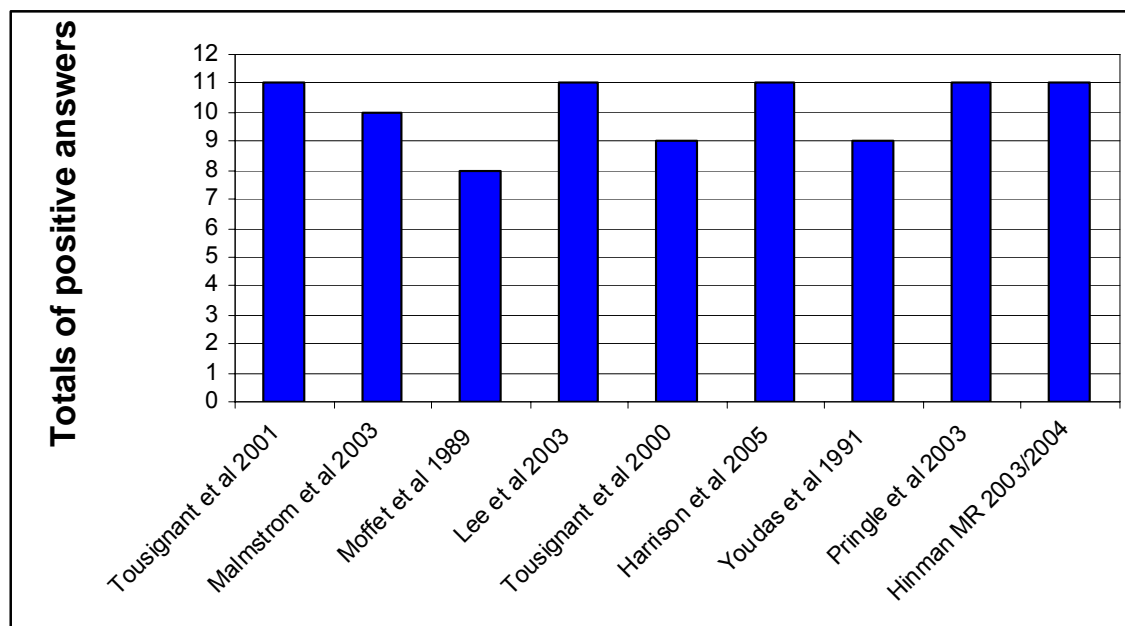
Figure 2.2 shows the answers to each question of the critical appraisal discussed in the Methodology section (Table 2.1). For 5 of the 12 questions all the studies obtained the maximum amount of positive answers, being 9. Question 10 is also regarded as a positive answer seeing that the desired answer to this question is “no”. Question 4, which related to the justification of the sample size, obtained the most negative responses, with only 1 study receiving a positive.

Figure 2.2: Critical Appraisal Questions



The total score of positive answers for each publication to the questions of the critical appraisal is illustrated in Figure 2.3. Five of the 9 articles scored 11 out of 12, with only 1 article scoring a minimum of 8.

Figure 2.3: Critical Appraisal Total.



- **Sample size calculation**

Criterion 4 related to sample size calculation was only fulfilled in one of the studies reviewed (Tousignant *et al* 2001). Tousignant *et al* (2001) compared their sample size of 44 subjects to the sample size of a study conducted by Donner and Eliasziw (1987) who stated that for an 80% power of testing and a 5% of significance a minimum of 34 subjects is necessary.

Sample size calculation is important as a too small sample size decreases the power of the article as well as the external generalisability. It is important that a sample size should be of an adequate size in order for the sample to be representative of the population.

- ***Factors that might have influenced the observed outcome***

All 9 of the reviewed studies obtained a positive answer to question 9. This criterion was related to the factors that might have influenced the outcome of study. All of the studies considered discussed factors such as standard methods of the appropriate design of the studies and standardised methodological procedures.

- ***Description of basic data***

Moffet *et al* (1989) is the only study that scored a negative response to this criterion as the study did not report on the age of the subjects used. Basic data such as sample size, age, gender etc. is important for the reproducibility of a study and allows for comparison with other published research reports.

. 2.5.4 Study Characteristics

In reference to Table 2.4, the sample size ranged from 26 to 96 and age ranged from 17 to 88 years old. Two of the studies only used female subjects while 7 of the studies reviewed included males and females. None of the studies included adolescents or children.

The earliest study was conducted in 1989 and the most recent in 2005. 55% of the studies were conducted in the United States of America and this may be reflective of research activity or publication bias. None of the published studies were conducted in Australia, Europe and Africa.

Table 2.4: Study Characteristics

Author	Yr	Country	Sample Size	Age range	Total males	Total females
Moffet <i>et al</i>	1989	UK	26	Not stated	0	26
Youdas <i>et al</i>	1991	USA	60	21-48	21	39
Tousignant <i>et al</i>	2000	Canada	31	18-45	10	21
Tousignant <i>et al</i>	2001	Canada	44	18-73	25	20
Lee <i>et al</i>	2003	USA	35	18-35	20	15
Malmström <i>et al</i>	2003	Sweden	60	22-58	25	35
Pringle	2003	USA	27	21-41	19	8
Hinmann	2003/ 2004	USA	51	21-51 and 66-88	0	51
Harrison <i>et al</i>	2005	USA	96	Mean age: * Males 17.9 * Females 40.1	36	60

2.5.5 Study Aims

The primary aim for each of the 9 studies is described in Table 2.5. The three measurement tools included in the eligible published research included the goniometer, flexicurve and inclinometer. The inclinometer was included in four of the studies, three studies included the goniometer and two studies included the flexicurve. It is on note that none of the reported studies (see Table 2.5) included photographic measurement tools and procedures.

Five of the nine studies reported on inter and intra-tester reliability (Table 2.5). One of the studies reported inter-tester reliability. The study by Malmström *et al* (2003) is the only study reporting on measurement tool reliability. Concurrent validity was evaluated in 3 of the studies reviewed while only 1 study reported on criterion validity of the measurement tool. Harrison *et al* (2005) and Lee *et al* (2003) determined concurrent validity using X-rays as the gold standard. Harrison *et al* (2005) included 96 adult subjects and Lee *et al* (2003) included 20 adult subjects. The inclusion of only adults may be due to radiation exposure. The relatively small sample by Lee *et al* (2003) may be due to economic costs of health reason related to exposure.

Only one of the studies reviewed reported on subject variability (Malstrom *et al* 2003). This is viewed to be a shortcoming as it is an important element in estimating the standard error of measurement. This element should thus be considered in future studies evaluating reliability of posture measurement tools, particularly considering the individual variability in posture (Christensen *et al* 1998).



Table 2.5: Summary of primary aim of each selected study.

Study	Measurement Tool	Reliability and Validity	Primary Aim
Pringle 2003	Goniometer	Concurrent validity	To compare the tester reliability of the static cervical angle using 4 different goniometers.
Youdas <i>et al</i> 1991	Goniometer	Inter and intra-tester reliability	To determine inter and intra-tester reliability measuring static cervical angle.
Tousignant <i>et al</i> 2000	Goniometer	Concurrent validity	To estimate the concurrent validity of the goniometer with x-rays.
Tousignant <i>et al</i> 2001	Inclinometer	Inter and intra-tester reliability	To determine the inter- and intra-tester reliability of the inclinometer.
Lee <i>et al</i> 2003	Inclinometer	Inter and intra-tester reliability Concurrent validity	To establish the inter- and intra-rater reliability and validity of the inclinometer using thoracic X-rays.
Malmström <i>et al</i> 2003	Inclinometer	Measurement tool reliability Inter and intra-tester reliability Concurrent validity	To estimate the measurement tool reliability, concurrent validity, inter-tester and, intra-tester reliability of the inclinometer. Validity asses using ultrasound.
Moffet <i>et al</i> 1989	Inclinometer	Inter and intra-tester reliability	To determine the inter- and intra-tester reliability of the inclinometer when static cervical angles.
Hinmann 2003/2004	Flexicurve	Inter- tester reliability	To establish the inter-rater reliability of the flexicurve.
Harrison <i>et al</i> 2005	Flexicurve	Concurrent validity	To validate the flexicurve contour measurements of the cervical spine lordosis with cervical X-rays.

2.5.6 Methodological Procedures

Seven (Harrison *et al* 2005, Hinmann 2003/2004, Lee *et al* 2003, Malmstrom *et al* 2003, Pringle 2003, Tousignant 2001, Moffet *et al* 1989) of the 9 studies performed the measurements in standing, and two of the studies reviewed tested the subjects in a seated position (Tousignant *et al* 2000, Youdas *et al* 1991).

A variety of angles were measured in the studies reviewed. The angles that were measured included cervical flexion, extension, side flexion, left and right rotation static angles. Thoracic measurements included thoracic flexion, extension, side flexion and rotation static angles (Tables 2.6-2.8). The studies were primarily conducted to evaluate elements of reliability and validity by measuring the static position after subjects were instructed to position or place their neck or thoracic spine in a specific position of e.g. flexion or extension. The only study reporting on the 'natural' alignment of body segments is the study by Hinmann 2003/4 as the researchers measured the position of lumbar lordosis and lumber kyphosis. There is thus a dearth of literature reporting on the validity and reliability of "natural" postural alignment, despite the fact that posture is a predictor of musculoskeletal dysfunction during sedentary activities such sitting while using a computer.

This review therefore highlights that there is only one published study that provide information on the validity of posture, evaluating procedures while subjects assume their normal or "natural position" or body alignment in standing. Harrison (2005) assessed concurrent validity of the flexicurve compared to X-rays (Table 2.8) when measuring cervical lordosis in standing. There is thus a shortcoming in studies reporting on the validity of "normal" alignment of the cervical spine in sitting. Furthermore there is no published information on the validity of posture measurement tools to assess shoulder girdle position and only one study reported on the validity of the Thoracic spine (Lee *et al* 2003).

Table 2.6: Different methods used to determine the reliability and/or validity of the goniometer.

Author	Instrument	Static angle measured	Study procedure
Tousignant 2000	Goniometer	Cervical flexion and extension position	A lateral cervical X-ray was taken immediately after the measurements were done with the goniometer. Position of subjects: Sitting
Youdas	Goniometer	Cervical flexion, extension and side flexion position	All subjects were tested thrice on one day by three different testers. Position of subjects: Sitting
Pringle	Goniometer	Cervical flexion, extension, side flexion and rotation position	Measurements were done three times with each of the following four devices on the same day: <ul style="list-style-type: none"> • single hinge inclinometer • single bubble carpenter's inclinometer • dual bubble goniometer • Cybex EDI 320 electrical inclinometer Position of subjects: Standing

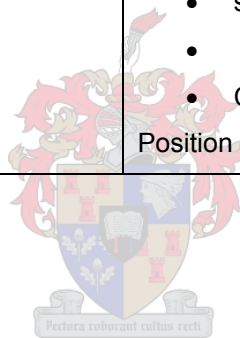


Table 2.7: Different methods used to determine the reliability and/or validity of the inclinometer.

Author	Instrument	Static Angles measured	Method
Lee	Inclinometer	Thoracic flexion, extension and side flexed position	Two raters took single inclinometry measurements on two different days. The same angle was captured on x-rays and compared. Position of subjects: Standing
Tousignant 2001	Inclinometer	Cervical flexion and extension position	Two measurements were taken by two trained testers. Position of subjects: Standing
Malmstrom	Inclinometer	Cervical flexion and extension position	Recordings were made with the following inclinometers: <ul style="list-style-type: none"> • Zebris three- dimensional ultra-sound motion device • Myrin gravity-reference goniometer, simultaneously Position of subjects: Standing
Moffet	Inclinometer	Cervical flexion, extension, right and left side bending and rotation position	Neck angles were measured three times in one hour by the same observer. Neck angles were measured by two observers at the same time. Position of subjects: Standing

Only two studies were found where the reliability and/or validity of the flexicurve was evaluated (Table 2.8).

Table 2.8: Different methods used to determine the reliability and/or validity of the flexicurve.

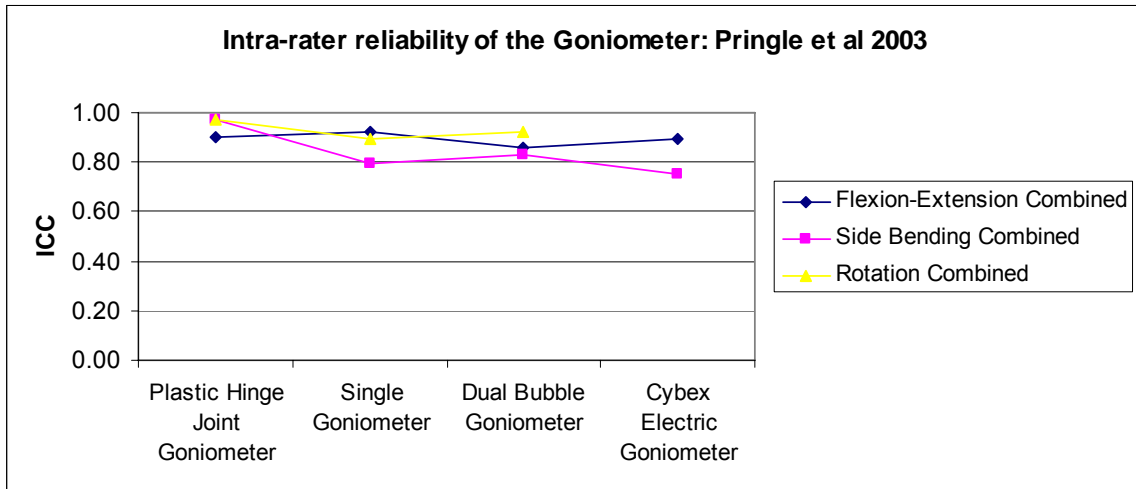
Author	Instrument	Static Angles	Method
Harrison	Flexicurve	Cervical lordosis	The flexicurve skin contour and neutral lateral x-rays were digitized and compared. Position of subjects: Standing
Hinmann	Flexicurve	Thoracic kyphosis and lumbar lordosis.	Three graduate students measured cervical lordosis and thoracic kyphosis in normal standing posture and then in an erect posture. Position of subjects: Standing

2.5.7 Study Findings

2.5.1 Reliability Results

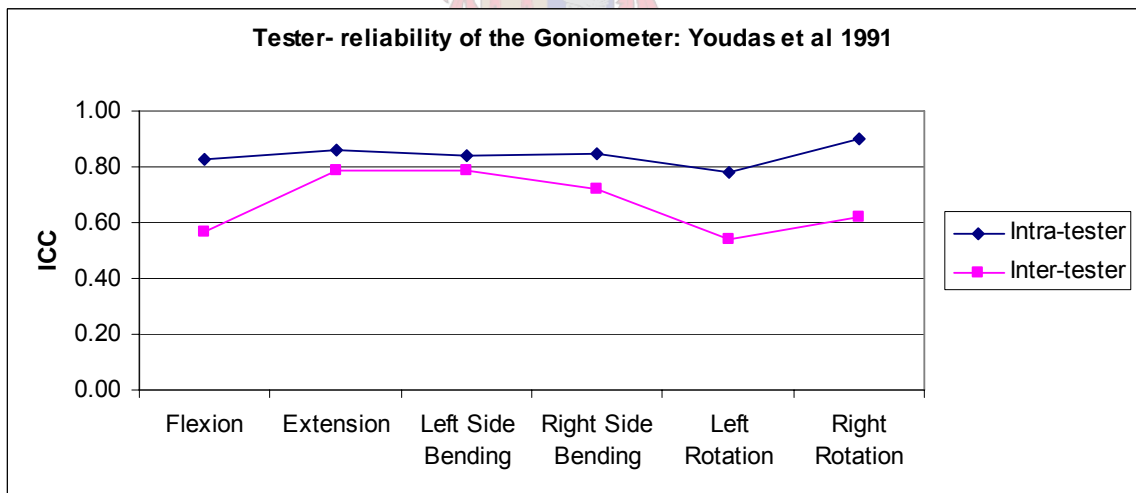
The goniometer was found to be reliable by two different studies (Figure 2.4 and 2.5) (Pringle *et al* 2003, Youdas *et al* 1991). The ICC values for the plastic hinge goniometer ranged between 0.89 for flexion and 0.97 for the side bending position. The single goniometer scored ICC values of between 0.79 for the side bending position and 0.92 for flexion-extension combined. The dual bubble goniometer scored a minimum ICC value of 0.86 for the flexion-extension combination and a maximum of 0.94 for the side bending position. The cybex electric goniometer only assessed the static ROM for flexion-extension combination (0.89) and the side bending position (0.75).

Figure 2.4: Reliability findings for the goniometer



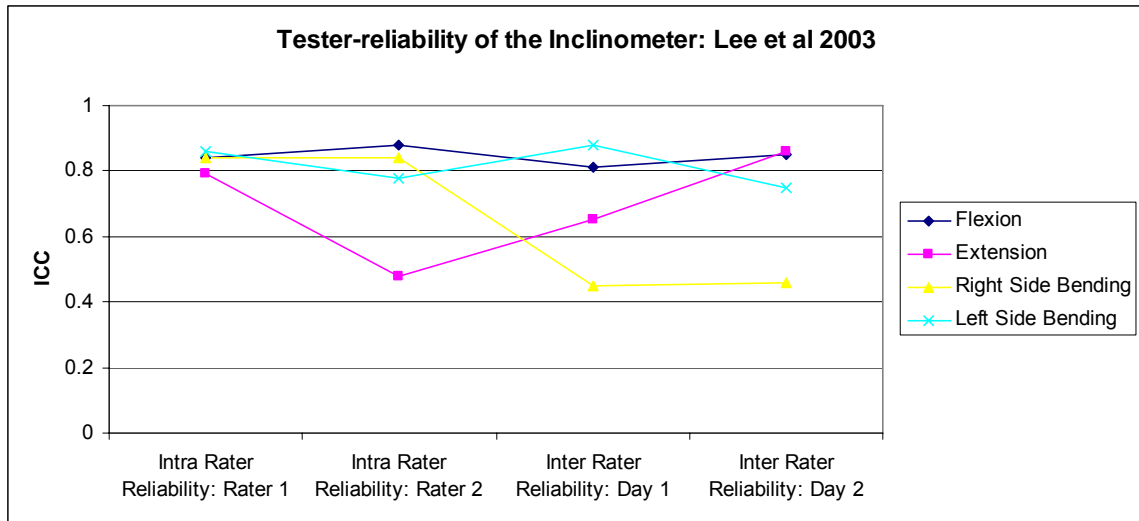
Youdas *et al* (1991) found the goniometer to be reliable with ICC values ranging between 0.78 and 0.90 for the intra-tester reliability and 0.54 and 0.79 for the inter-tester reliability (Figure 2.5).

Figure 2.5: Tester reliability of the goniometer



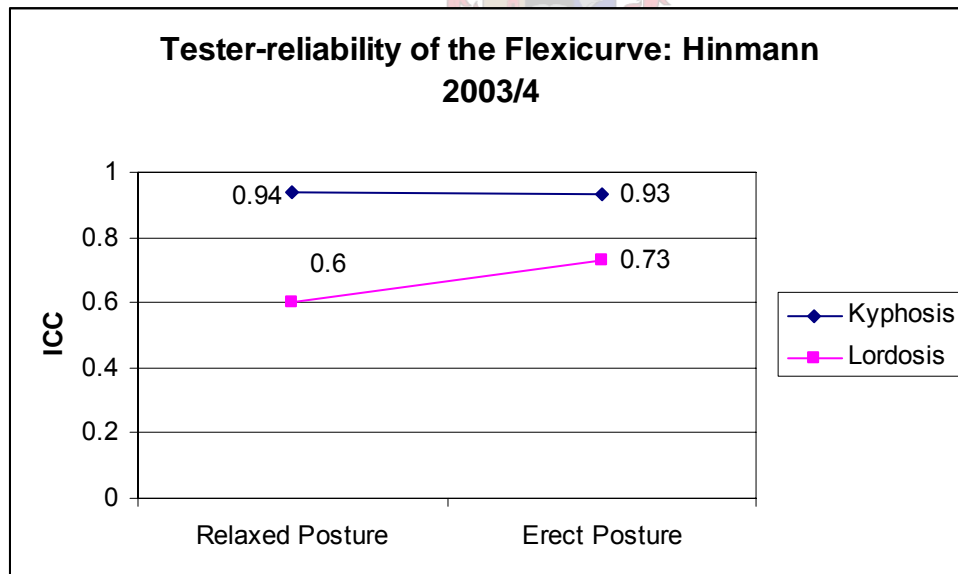
The reliability of the inclinometer was determined by four different studies. The first study found the inclinometer to be reliable (Malmstrom *et al* 2003) with intra- device reliability of 0.90 and intra-tester reliability of 0.92. The second and third found it to have moderate reliability (Figure 2.6) (Tousignant *et al* 2001, Moffet *et al* 1989) and the fourth (Figure 2.6) (Lee *et al* 2003) found it to be completely unreliable.

Figure 2.6: Tester reliability of the inclinometer



Hinmann 2003/4 determined the inter-tester reliability of the flexicurve. For the kyphosis in relaxed posture an ICC value of 0.94 was obtained and for the erect posture 0.93. For the lordosis in relaxed posture an ICC of 0.60 was obtained and erect posture 0.73 (Figure 2.7).

Figure 2.7 Tester reliability of the flexicurve



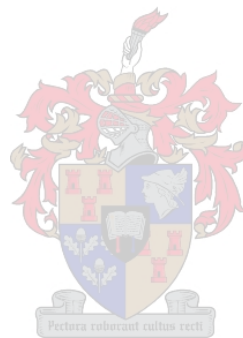
2.5.2 Validity Results

Table 2.10 demonstrates the validity of the inclinometer, goniometer and flexicurve according to the study findings. The inclinometer was found to be valid by one study (Malmstrom *et al* 2003) and invalid by another (Lee *et al*

2003). The goniometer was found to have excellent validity (Tousignant *et al* 2000), whilst the flexicurve was found to be invalid (Harrison *et al* 2005).

Table.2.10: Validity of posture measurement tools

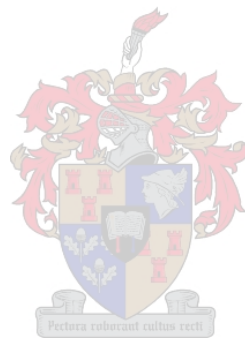
Author	Instrument	Valid
Malmstrom	Inclinometer	- <i>Concurrent validity with ultrasound</i> * ICC>0.93
Lee	Inclinometer	Concurrent validity with x-rays *Left side position : ICC=0.43 * Right side position : ICC=0.44
Tousignant 2000	Goniometer	- <i>Concurrent validity with x-rays</i> * Extension r=0.97; Flexion r=0.98
Harrison	Flexicurve	- <i>Concurrent with x-rays</i> * reliability coefficient < 0.15



2.6 Summary of systematic review findings

- This is the first review to illustrate the reliability and validity of the goniometer, inclinometer, electrogoniometer and photography when assessing upper quadrant posture and position and 9 studies met the inclusion criteria.
- Only 1 of the studies reviewed included subjects younger than 18 years old.
- The studies reviewed complied with most of the methodological criterions. Justification of sample size was not adequately addressed in 8 of the studies reviewed.
- Seven (Harrison *et al* 2005, Hinmann 2003/2004, Lee *et al* 2003, Malmstrom *et al* 2003, Pringle 2003, Tousignant 2001, Moffet *et al* 1989) of the 9 studies performed the measurements in standing, and only two of the studies reviewed tested the subjects in a seated position (Tousignant *et al* 2000, Youdas *et al* 1991). Thus there is a lack of understanding into the reliability and validity of sitting posture measurement.
- The only study reporting on the 'natural' postural alignment of body segments is the study by Hinmann 2003/4 as the researchers measured the position of lumbar lordosis and lumber kyphosis.
- Validity was only addressed by 4 of the studies reviewed and only three of the reviewed studies have validated the measurement tool against x-rays, considered to be the gold standard.
- This review indicated that cervical flexion, extension, rotation and side bending angles have been studied. However there is no published information on the validity of posture measurement tools to assess shoulder girdle position. Only 1 of the studies included the thoracic spine (Lee *et al* 2003). The thoracic spine in particular is frequently affected and therefore reliability should also be aimed at measuring this angle.

- Photography is commonly used to evaluate upper quadrant posture (McEvoy & Grimmer 2005, Szeto *et al* 2002 and 2005). Despite the evaluation of posture in these descriptive studies with Photographic methods, no published study reports on the reliability and validity of upper quadrant posture evaluation was found. This area of research is required especially, considering the simplicity and the non-invasive nature and affordability of photographic methods (Chen & Lee 1997).



Chapter 3

METHODOLOGY

The methodological procedures conducted in order to answer the research questions are presented in this chapter. The sampling method, measurement tools and data processing procedures described in this chapter.

This study forms part of a larger study, “Promotion of spinal health among high school learners.” The comprehensive project encompass an epidemiological study aimed at determining the predictors of spinal dysfunction related to computer usage, this reliability and validity study to evaluate posture while using a computer, a prospective to determine the postural predictors of computer related spinal dysfunction and evaluation of the appropriate interventions to promote spinal pain. Therefore the sampling and methodological processes have specifically been designed to be appropriate for the comprehensive study to promote spinal health.

3.1 Research Question

The research question for this study was “Is a newly developed Portable Posture Analysis Method reliable and valid when assessing the sagittal plane postural alignment of the cervical spine, shoulder girdle and thoracic spine?”

3.2 Objectives

- To develop a photographic, portable sitting posture analysis system.
- To evaluate the sagittal cervical angle, shoulder protraction/retraction angle, sagittal head tilt, thoracic angle and the arm angle in the sagittal plane.
- To assess measurement equipment reliability, this incorporates a degree of subject performance reliability.

- To assess concurrent validity of the posture analysis equipment with a gold standard measure, low dose radiation X-ray system LODOX (LODOX (Pty) Ltd.).

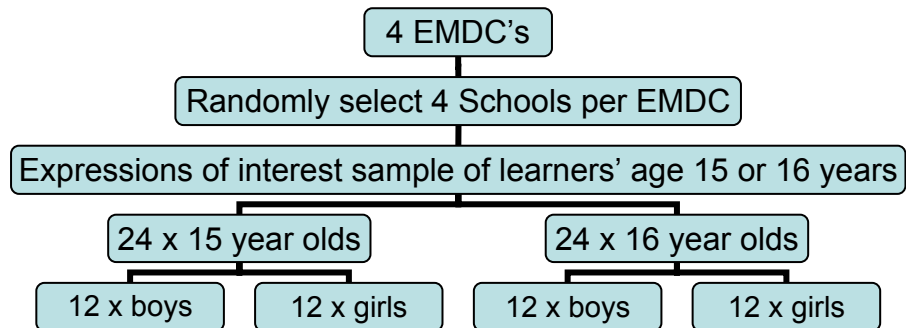
3.3 Study Design

The study comprised of two subsections. The first section incorporated a test retest reliability study and the second section a validity study. The study design for the reliability section was a *repeated measures observational study*. This method to determine reliability testing has been published by McEvoy and Grimmer (2005). A *correlational study* was conducted to determine validity.

3.4 Sampling Method and Size

This sampling method mirrors the sampling methods that have been selected in the epidemiological study in order to foster a network with the participating schools. One school, each from the four EMDC's (Education Management Development Centre) was randomly selected to participate in this study. The four schools were selected from the eight schools initially randomly selected to participate in the included in the epidemiological study.

Figure 3.1: Outline of sampling method.



3.4.1 Sampling

Learners were deemed eligible if they have met the following inclusion criteria:

- High school learners (male and female) who were aged 15 or 16 years old and in Grade 10.
- Learners who were taking Computer Studies or Computyping as a formal subject at school.
- Learners who had no or little musculoskeletal pain (pain should not compromise function) which will inhibit the learner from performing the testing procedures in the testing day.
- Learners for whom parental consent was obtained.

The following exclusion criteria were applied to sample:

- Learners with diagnosed movement disorders as the study was not aimed at analysing the posture of learners with movement disorders.

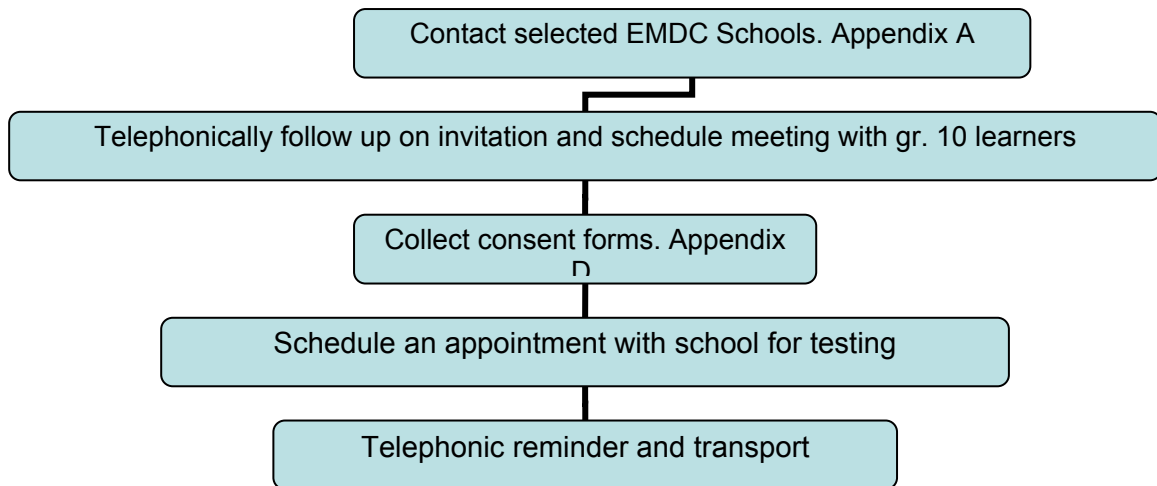
3.5 Learner Recruitment

Subjects were recruited from the four randomly selected schools. The principle researcher sent an invitational letter to each school via fax and e-mail during August 2006. This letter (Appendix C) informed the school principal of the details of this research project, and invited them to form part of the study. The letter was followed up telephonically at which time the school principal was asked for an appropriate date and time to meet with the researcher (Figure 3.2).

3.6 Learner Invitation

A meeting, which was aimed at the Grade 10 learners, was held on the 12th of August 2006 at each of the participating schools. The aim and objectives of the study and what was expected of them, if they participated, was discussed. The eligible learners were also asked about their availability during the testing period, 21 and 23 September 2006, as well as 17 October 2006. The inclusion and exclusion criteria were explained. The principle researcher handed a consent form (Appendix D) to all learners who have indicated willingness to participate in the study. These signed consent forms were collected by the principle researcher, two days later. A convenient date for testing was arranged with the participating learners at each school. An e-mail was sent to the school's principal, a week prior to the chosen date in order to confirm the appointment and to organise transport for the learners to the testing facility at UCT. One of the schools used their own school transport for their learners, the other school were transported with Stellenbosch University transport and a private transport company.

Figure 3.2: Outline of subject recruitment.



3.7 Ethical Consideration

Approval from the Committee for Human Resources at Stellenbosch University (Project number N06/05/092) and the Department of Education (Appendix E) were obtained. The study was conducted according to internationally accepted ethical standards and guidelines.

Written informed consent (Appendix D) was obtained from each learner's parent or legal guardian prior to the execution of the study. A learner had the right to withdraw from the study at any time, by notifying the researcher.

3.8 Pilot study

A pilot study was conducted on the 9th of May 2005. The aim of the pilot study was to ascertain whether the practical procedures were appropriate, standardise the testing procedures, to standardise the testing procedures. The pilot was also conducted to standardise the method of photo digitising

and data processing. The pilot study for repeatability was done at the Engineering Department of the University of Stellenbosch, with the assistance of Dr Schreve. Two convenient subjects participated. The same procedure was used as described in Section 3.11 and the set-up was similar to the set-up described in Section 3.10.3.1. Reflective tape was attached to the tragus, canthus, shoulder and elbow. The software had difficulty in detecting the reflective tape on the tragus and canthus due to the uneven surfaces of these areas. It was thus decided to use the golem retro-reflective markers instead. The pilot data is provided in Appendix F. The measurements of the second subject could not be utilised due to difficulty in detecting the markers positioned on the thoracic spine and therefore the angles could not be calculated.

A second pilot study utilising the LODOX was done on the 22nd of July 2006 at Grootte Schuur Hospital's Radiology Department. The purpose of this study was to standardise the procedures using the LODOX and to determine the appropriate resolution of the LODOX images. Five conveniently selected subjects with an age range of 15-16 years participated in the study. The equipment set-up was done in the manner in Section 3.11.2. The adhesive tape lost its sticky quality when the skin becomes sweaty and therefore rigid plaster was used in the main study that to attach the markers to the learners' skin. Wiping the skin with alcohol before the marker placement also improved the tape's sticking quality and this procedure was thus applied in the main study. The resolution of the X-ray image also required appropriate adjustment in order that the markers and the cervical and thoracic spines were visible. The principal study supervisor also assisted with this pilot study and monitored the processes in order to validate that the data collection procedures will be collected in an appropriate systematic manner. The collaborating engineer was also present to assist in determining the appropriate resolution of the LODOX images for digitising.

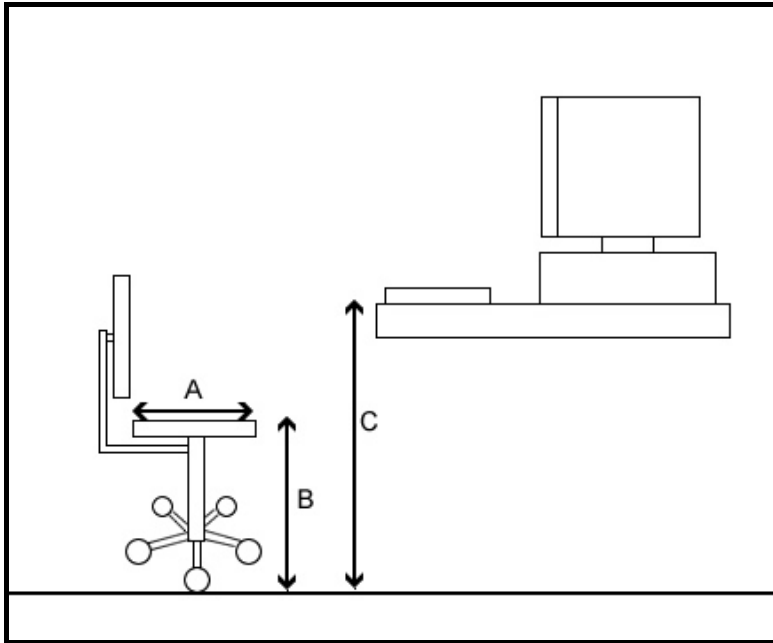
3.9 Study Setting

The main study (reliability and validity) was conducted at the Department of Human Physiology at the University of Cape Town. Verbal permission to use this facility was obtained by the co-supervisor, Prof. K. Vaughan, of the Department of Human Physiology at the University of Cape Town. The workstations consisted of a chair and desk, which are similar to that which the learners are currently using in the school computer laboratories. The information on the specific height and type of the chair and desk which is generally used in schools was obtained from the concurrent workstation evaluation study conducted by Ms. L Smith, (Figure 3.3) a master's candidate in Physiotherapy at the University of Stellenbosch. Ms. Smith evaluated a random sample of all computer laboratories in the Western Cape Metropole (Ethics number: N05/09/164). The chair height was between 380 and 510mm (A), the seat pan depth was between 330 and 430mm (B), the table height was found to be adjustable (C) as seen in Figure 3.4. A chair replicating the mean height (460mm) and a seat pan depth (430mm) was used. Chairs without armrests was utilised in this study, to ensure good marker visibility. This study forms part of a bigger spinal health project.

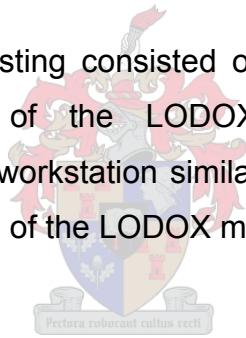
Figure 3.3: Example of a computer laboratory at an EMDC school with typical desks and chairs.



Figure 3.4: Measurements of desks and chairs in school specific environment.



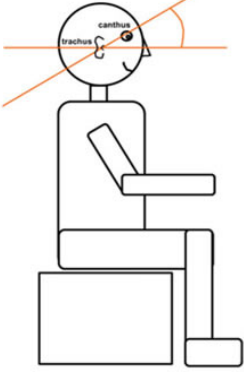
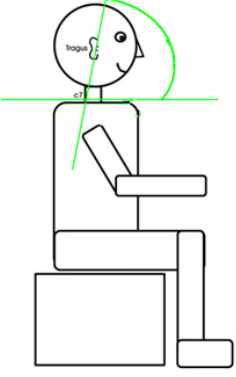
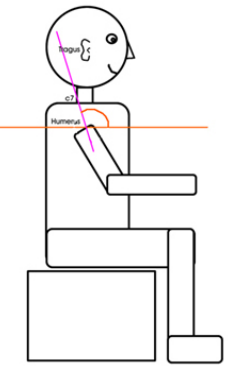
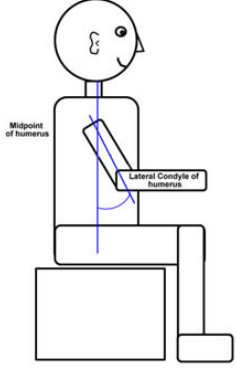
The venue for the validity testing consisted of a laboratory with a LODOX system, which comprised of the LODOX X-ray machine and the accompanying computers. A workstation similar to the one described above, was positioned under the arch of the LODOX machine.

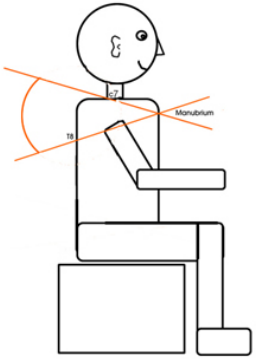


3.10 Instrumentation

The newly developed Portable Posture Analysis Method (PPAM) was used to analyse the sitting posture while working on a desktop computer by measuring the following angles sagittal head angle, cervical angle, protraction/retraction angle, arm angle and the thoracic angle (Figure 3.1).

Table 3.1: Diagrammatic representation of the angles measured in this study.

Angle	Description	Diagram
Sagittal head angle	The line between the lateral canthus of the eye and midpoint of the trachus and the angle of the horizontal line though the middle of the trachus. (Grimmer <i>et al</i> 2005),	
Cervical angle	The line between the midpoint of the trachus and C7 and the angle to the horizontal through C7. (Grimmer <i>et al</i> 2005),	
Protraction/retraction angle	The line between the midpoint of the humerus and C7 and the angle to the horizontal through the midpoint of the humerus. (Szeto <i>et al</i> 2005)	
Arm angle	The line between the midpoint of the humerus and the lateral epicondyle of the elbow and the angle to the vertical line through the midpoint of the humerus. (Szeto <i>et al</i> 2005)	

<p>Thoracic angle</p>	<p>The line between C7 and the manubrium and the angle to the line through T8 and the manubrium. (Szeto <i>et al</i> 2005)</p>	
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3.11 Measurement Tools

3.11.1 Portable Posture Analysis Method (PPAM)

The PPAM consisted of a digital camera (Fujifilm Finepix X5100), Intellect Software (Version 1.1.4), reflective markers and a computer which is Windows 2000 or XP compatible. An example of a learner with the golem retro-reflective markers is illustrated below in Figure 3.5. The markers that required to be positioned away from the body consisted of a retro-reflective marker and wooded stick of 11cm.

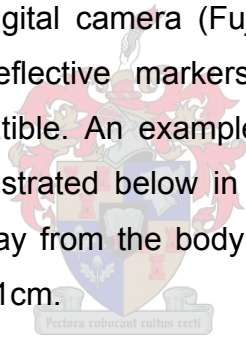


Figure 3.5: Subject with placed golem retro-reflective markers.



3.11.2 LODOX

This locally developed digital radiography device was initially used as a very-low-dose unit for the detection of smuggled diamonds, based on an X-ray security scanner. The designers subsequently investigated the medical application of this machine. The current device was named “LODOX” (derived from “low-dose X-rays”), in reference to the low radiation dose used to obtain images.

The machine makes use of an X-ray tube mounted on one end of a C-arm (figure 3.6). This emits a low-dose collimated fan-beam of X-rays. Fixed to the other end of the C-arm is the X-ray detector unit, comprising scintillator arrays optically linked to charge-coupled devices (CCDs). The detectors have a 60-cm size, and are generally used in combination, providing up to 5,800 elements along the length of the detector arm. Variations of spatial resolution from 1.6 to 4.1 line-pairs per millimetre are possible. They are able to record 14 bits of contrast resolution. The C-arm is able to rotate axially around the patient to any angle up to 90°, permitting horizontal-beam, shoot-through lateral, erect and oblique views. The C-arm travels along the table length at speeds of up to 138 mm/s when emitting radiation. This device is able to rapidly acquire images of part or all of the body; a full body scan requires 13 seconds, with smaller areas requiring proportionately less time (Beningfield *et al* 2003). Beningfield *et al* (2003) found that by averaging the mean conventional dose radiography was 0.573 R (5.73 mGy), while the mean digital dose (LODOX) was 0.033 R (0.33 mGy), 5.9% of the conventional X-ray.

The current consensus is for radiation protection purposes the most appropriate risk model at low doses is one which the risk of radiation-induced cancer and hereditary disease is assumed to increase with increasing radiation dose, with no threshold. Any increment of exposure above natural background levels will produce a linear increment of risk, the so-called linear no threshold (LNT) model (Wall *et al* 2006). Thus, the lower the radiation dose, the lower the risk of developing cancer. Wall *et al* (2006) found that with

a normal X-ray the risk range was found to be minimal (one in a million to one in 10 000) and with the extremely low radiation dose of the LODOX, this range is even lower. Figure 3.6 demonstrates the LODOX system.

Figure 3.6: LODOX X-ray system

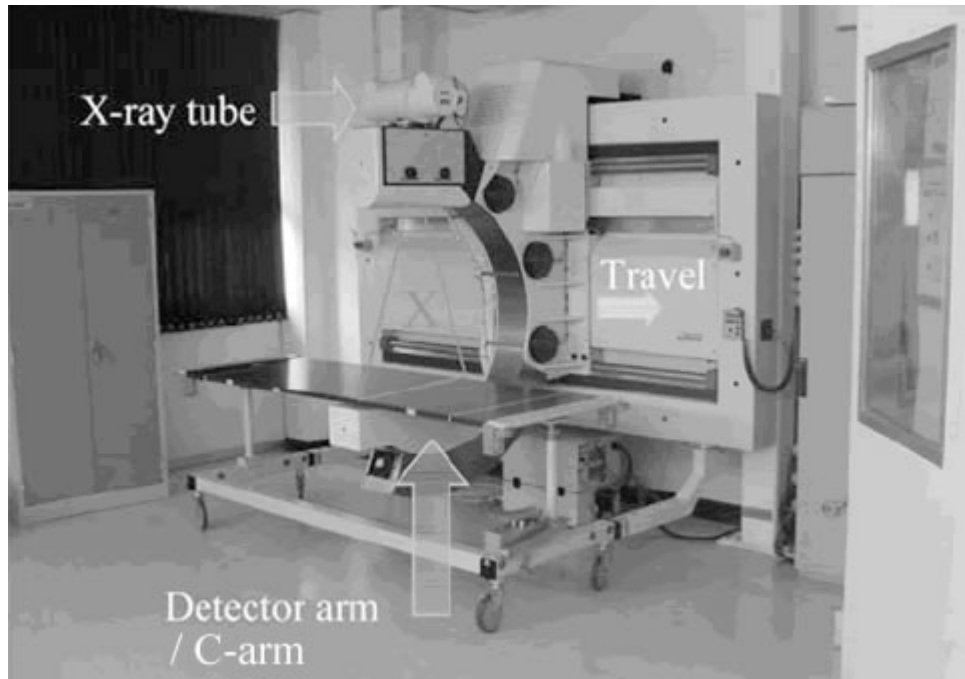


Figure 3.7 demonstrates a LODOX image of a learner with the retro-reflective markers in place.

Figure 3.7: Example of a LODOX image.

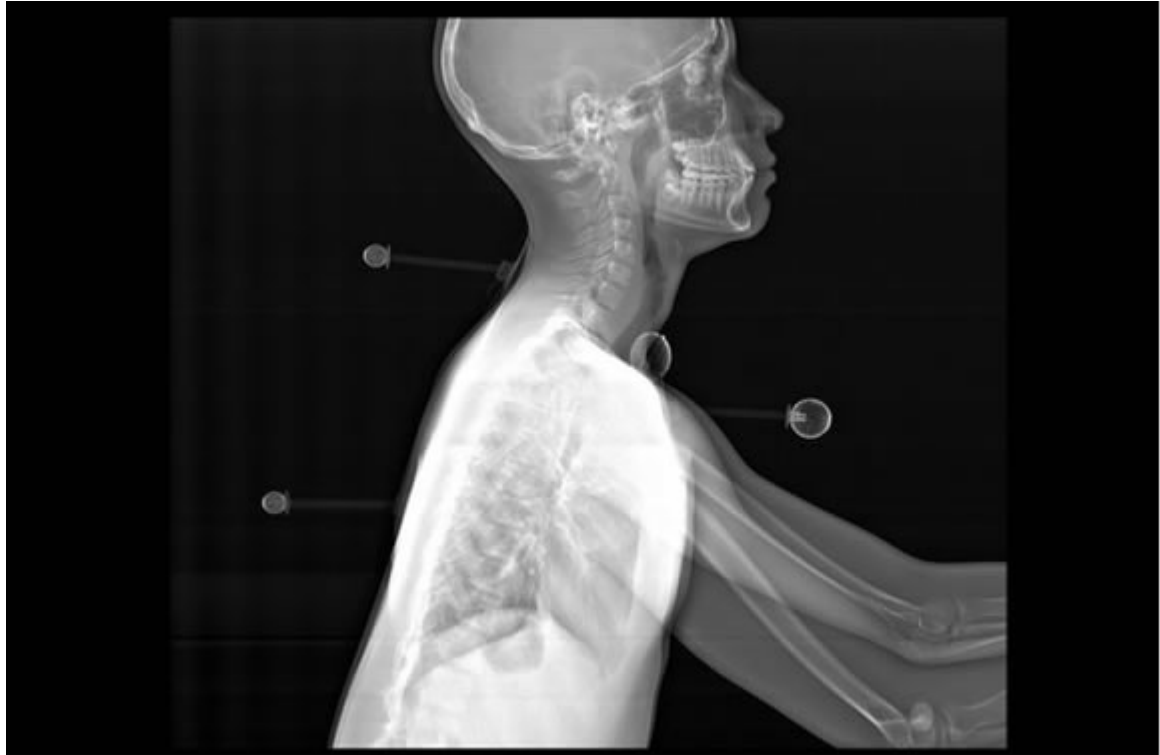


Figure 3.8 illustrates a learner being scanned by the LODOX X-ray machine.

Figure 3.8: Photo of learner being scanned by the LODOX machine.



3.12 Data Collection Procedure

3.12.1 Data Collection Period

Data collection took place on 22nd and 23rd August and 17th October 2006.

3.12.2 Role of each Research Assistant, Radiographer and Engineer

The help of four research assistants was needed to ensure systematic and time efficient data collection. The responsibilities of the principle researcher and the assistants were as follows:

- **Principle researcher** was responsible for the preparation station. She welcomed the learner and handed the sports tops and attach the golem

retro-reflective markers. The principal researcher also administered the pain questionnaire prior to testing. The principal researcher also gave instructions regarding the sitting position of the learners.

- **Assistants number one, two and three:** These assistants were each responsible for checking the position of a learner as well as taking the digital photos of the learners, since three learners were tested at the same time. They then directed the learners to the next testing station where they were met by assistant number four.
- **Assistant number four:** Positioned one learner at a time at the LODOX testing station and took one digital photo just before the X-ray was taken and one photo immediately afterwards. These photos were used for the analysis of validity.
- **Mechanical Engineer:** The engineer acted as a consultant for the development of the PPAM. The engineer also adapted the software to analyse the joint angles.
- **Radiographer:** A radiographer and clinical application specialist in the field of LODOX, was responsible for taking the LODOX X-rays required for the validity study. This radiographer has five years of experience in operating LODOX X-ray system.

3.12.3 Preparation of Laboratory

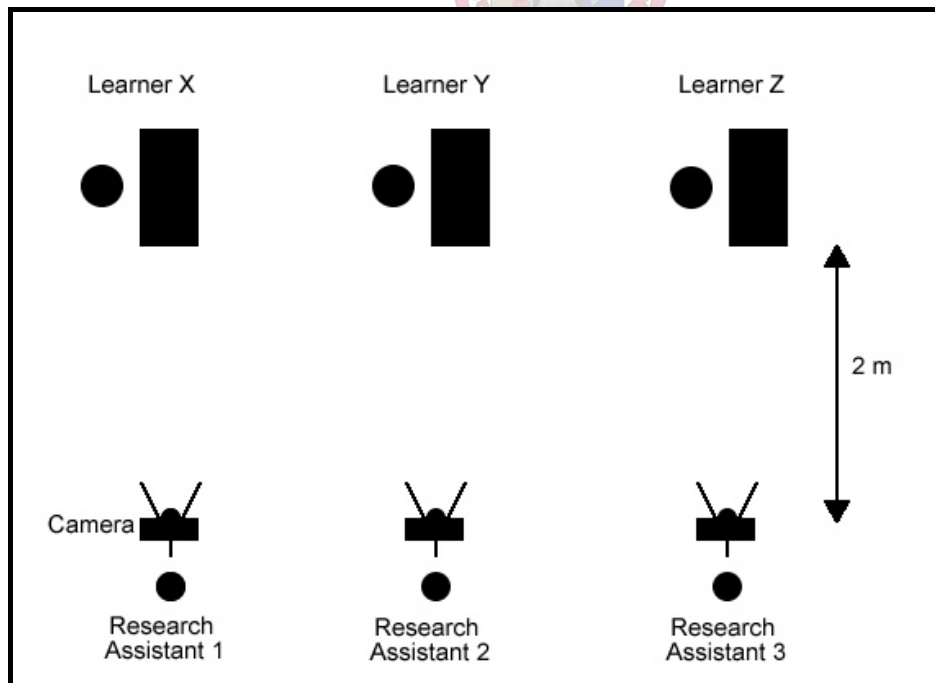
Prior to the arrival of the learners, on the day of trial capture, the principle researcher and the research assistants prepared the laboratory environment for data capture. The preparation involved the set-up of the four workstations for the reliability testing as well as the LODOX system station. An hour before the testing commenced, the procedures of the testing process were explained to the four research assistants. The set-up was performed by the principle

researcher, as described above and five photos were taken as a trial run to assess the camera setting and set-up.

3.12.3.1 Portable Posture Analysis Method camera set-up for repeatability testing.

The principle researcher and the four research assistants positioned the 3 digital cameras in the laboratory. The cameras were positioned in such a manner that all seven of the retro-reflective markers placed on the subject were detectable by one camera. The cameras, mounted on tripods, were placed 2m to the side of the learner testing chair. One camera was used to capture the photos of one learner per set. The photos from 3 learners were conducted at the same time using three cameras (Figure 3.9). The reason for this was to optimise data collection time and standardise the envisaged data collection process in the follow-up study to be conducted at the schools in 2006.

Figure 3.9: A diagrammatic representation of camera placement and laboratory set-up.



3.12.3.2 LODOX with PPAM set-up

A workstation as described in the study setting (Section 3.7) was set up prior to testing. The LODOX was switched on 10 minutes before testing to allow the machine to warm-up. Figure 3.10 illustrates a learner being evaluated by the LODOX and PPAM.

Figure 3.10: A photo of the LODOX and PPAM set-up.



3.13 Trial Capture Procedure

Each learner was asked to complete a modified pain questionnaire to assess whether they had pain on the day of testing, which may hamper their ability to maintain sitting posture for data collection (Appendix G). This questionnaire was developed and validated in a similar representative sample in the parallel conducted study by a masters candidate, Ms L Smith (Ethics number: N05/09/164) before the commencement of the study. Since the questionnaire assessed present pain experience recall bias was not likely to influence the results.

The reliability and validity subsections took place on the same day. The reliability testing was done first, followed by the validity testing. Three learners were tested simultaneously at the reliability laboratory after which they proceeded to the validity laboratory where they were tested individually. The learners who had to wait, before and after testing, were kept entertained by watching a DVD.

3.13.1 Learner Preparation

The learners were greeted on arrival by the principle researcher, who explained the logistical arrangement for the testing. One school at a time were tested, with between 12 to 15 learners. All the learners received a sticker showing a number which was used for identification during digitising process. The sticker was colour coded to indicate the posture which each of the learners must assume for data collection. The posture subgroups included slouched, straight and normal sitting posture. The allocated sitting posture was randomly assigned using a name list of all the participants.

These 3 selected sitting postures were demonstrated by the principle researcher. The reason for the different sitting posture was to ensure that the PPAM is sensitive in measuring angles in extreme ranges of postures as well as normal sitting posture.

Each learner was also handed a sports top to wear for data collection. The principal researcher wiped the appropriate areas of the learners' skin (as described in Section 3.11.2) with alcohol in order to allow good contact between the retro-reflective markers and the skin.

3.13.2 Application of reflective markers

The principle researcher applied the golem retro-reflective markers to the lateral canthus of the eye, the trachus of the ear, spinous process of C7 (Grimmer *et al* 2005), midpoint of the superior border of the manubrium, T8 and the lateral epicondyle of the elbow (Szeto *et al* 2005). All markers were

placed on the dominant side of the subject. If a subject was left side dominant, the workstation was changed towards the opposite direction. However, all the participating subjects were right side dominant.

The markers were not removed during photographs as the objectives for this study was not to assess reliability or marker placement or tester reliability. The primary objective was to assess the equipment reliability, which incorporates a component of subject variability. For an outcome measure to be relevant and clinically meaning, the measurement process(es) must be deemed reliable (Beattie, 2001). According to Portney and Watkins (2000) test- retest reliability measures the degree to which measurement is stable, and incorporates an assessment of the consistency of the subjects' performance.

This methodology was also deemed to be appropriate since it mimics the process that will be utilised in the subsequent project aimed at the evaluation of learners in the school setting (Project number N06/05/093). This will be a once off evaluation of posture and therefore the marker placement is not considered to be a primary consideration.



The design of this study is also not appropriate assessing validity of marker placement. Validity of marker placement will require an appropriate design incorporating e.g. an anatomist to assess marker placement.

3.14 Data Capturing

3.14.1 PPAM: Reliability

The three learners proceeded to the reliability station after marker placement. They were directed to sit at the table with the same colour as the dot on their stickers indicating the posture to be captured. Assistant number one, two and three took a photo of the sticker indicating the identity number of each of the three learners to allow for identification during the digitising process.

The sitting posture was captured while the camera flash was activated in order to ensure visibility of the markers during the digitising process. After each photo the learner was asked by an assistant, to stand up and walk at a normal pace towards the assistant and then back towards the table, for a total distance of four meters, and sat in a similar position as before (Grimmer *et al* 2005). The learners were instructed to maintain a static posture while each photograph was captured. The testing time for the reliability section was 10 minutes for every set of three learners. The three learners then proceeded to the validity station. Figure 3.11 demonstrates the reliability station set-up.

Figure 3.11: A photo of the reliability station set-up.



3.14.2 LODOX: Validity

The learners were tested individually at the validity station. The LODOX took an image of the upper trunk (T8 and up). The digital camera was positioned accordingly to capture the same body area as the LODOX.

Assistant number four asked the learner to assume the same sitting posture as performed for the reliability testing. Two upper trunk images and one X-ray were taken of each learner, to calculate the cervical angle, shoulder

protraction/retraction angle, sagittal head tilt, thoracic angle and the arm angle.

One photo was taken by assistant number one, followed by an X-ray which was captured by the radiologist. A second camera photo was taken immediately after the LODOX X-ray. The learner was asked to maintain a static posture and take a deep breath; this was done in order to avoid a distortion of the X-ray image.

3.15 Digitising process

The C7, T8, and the elbow markers which were easily detectable on the LODOX image after LODOX X-ray was taken. External validation of the marker position was conducted by the principal researcher in order to assess whether the placed were placed on the correct bony landmarks. The positions of the markers were checked before testing to ensure that the marker is still in the correct position. The validity testing period took approximately 10 minutes per learner. The learners returned to the preparation station and continued watching the DVD post completion of the data collection.

A faint watermark of a university crest is visible in the background of the text. The crest features a shield with various symbols, topped with a crown and supported by two figures. Below the shield is a banner with the Latin motto "Pectora roburant cultus recti".

3.16 Data Processing

The photographic data was imported to the laptop via a USB data-transfer cable and Intellect 1.1.4 software (DVT Corporation). This image processing software is normally used with cameras supplied by DVT Corporation. DVT cameras are used in the engineering industry to perform monitoring and inspection tasks with the cameras. DVT cameras were not used in this project and the photos thus had to be imported to the Intellect 1.1.4 software as it is not automatically picked-up as when using the DVT cameras. The images were processed using the emulator function (Figure 3.12) as this function recognises images from the hard disc of the computer instead of the DVT camera.

The principal researcher performed all the digitising of the photographic data in order to calculate the angles described in Table 3.1. The following functions of the Intellect 1.1.4 software were used to digitising process of the photographic data. In this project the following functions were used; detecting and following a marker, circle fitting, constructing lines and measuring angles.

Detecting and following a marker was the most complex function during the digitising process. The user was required to 'teach' the software how to recognise the marker. Once this function is obtained successfully, the search region had to be defined. In the following images, the software automatically detected the marker. The shape of the marker is 'learned' by the software by defining the edges in the image. The user marked a small rectangular area around the marker in order for the software to recognise the edges as sharp transitions, technically termed, gradients, in the grey level. Each shade of grey has a numeric value, which is called the grey level. In the next image, the software calculated all the edges in the search region and then attempted to detect a set of edges that had approximately the same rectangular shape inserted around each marker.

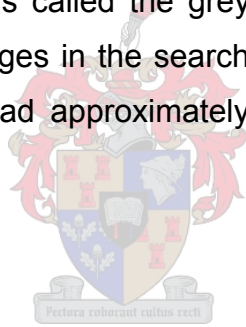
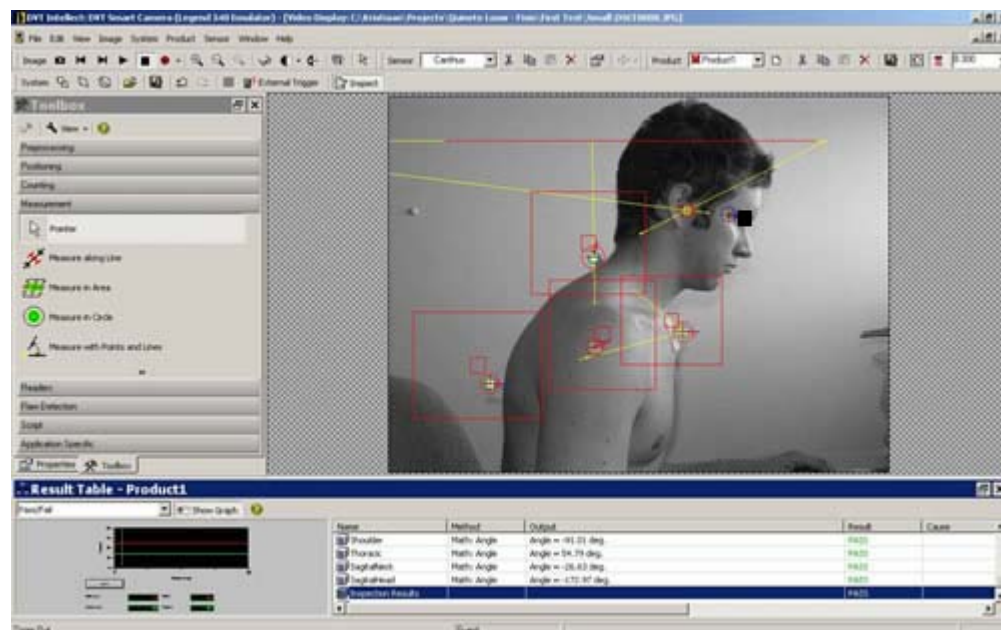


Figure 3.12: Layout of Intellect software with rectangular areas around the markers.



It was important that objects that must be detected in the manner described above before any mathematical angle calculation could be done. In order for the process to be successful, a clear distinguishing contrast between the object and the background was essential. Another success factor was that the marker was required to maintain the same in all the photographic images. This could occur if the marker was partially obscured. The third factor to ensure successful digitising was to prevent presence of shadows behind the marker. In order to minimise the effect of this problem, we have used spherical reflective markers as it was clearly visible on the photographic image provided that the flash of the camera was operating.

Once the marker could be detected by the software, the next step in the photographic digitising process was to calculate the centre of the marker (Figure 3.13). The marker edge was calculated and the Intellect software then automatically fit a circle through the edge points. The centre of the fitted circle also represented the centre of the marker. The circles were then connected with lines by the researcher in order for the angles (described in Table 3.1) to be calculated.

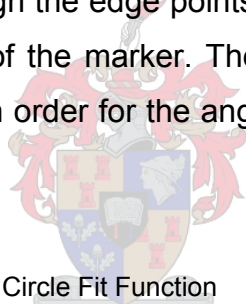
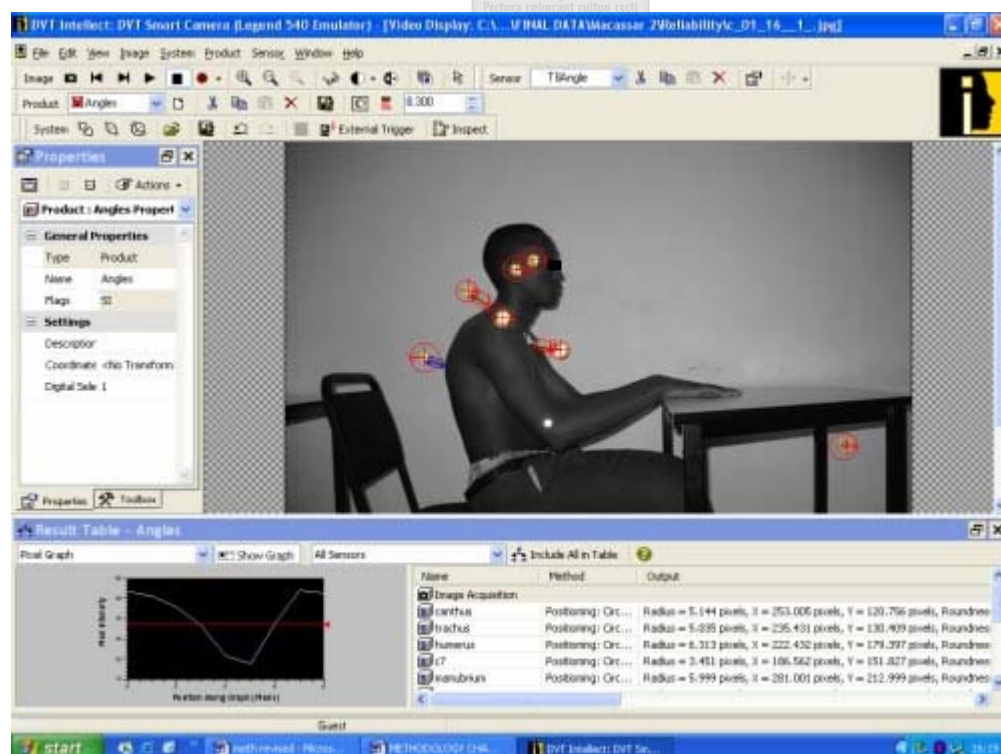
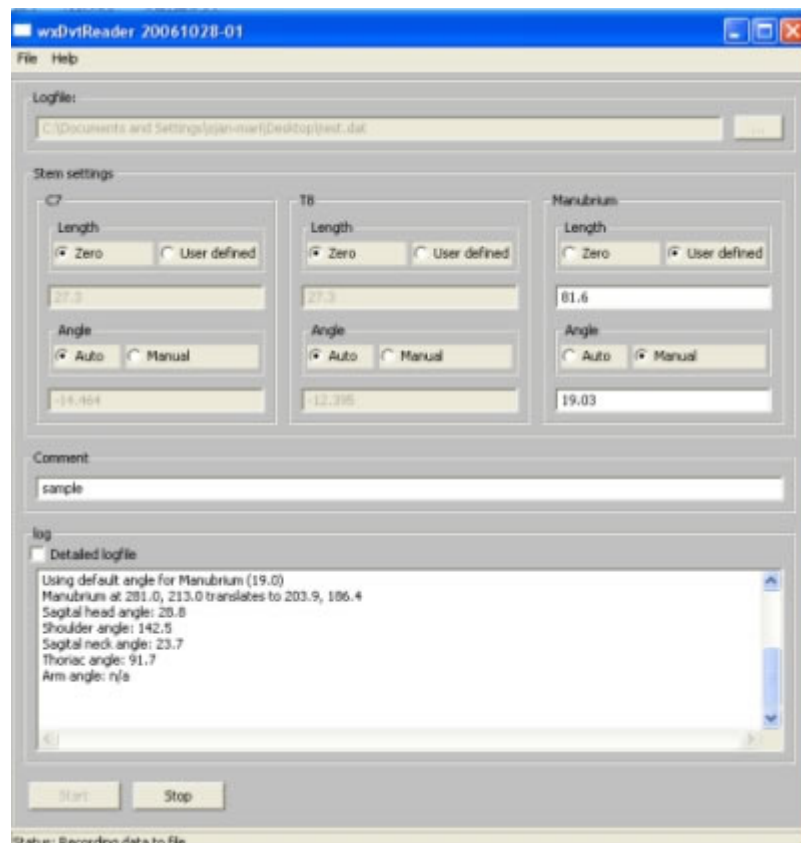


Figure 3.13: DVT Intellect Interface: Circle Fit Function



Provided that the markers could be detected accurately, the calculation of the angles for a series of images could be automated. The system was programmed for the first image of each participant and new software (DVT Reader) was developed to apply the digitising process described above to the full set of photographic images in order to calculate the angles much faster than with the original Intellect 1.1.4 software (Figure 3.14). Dr Kristiaan Schreve, Mechanical Engineer, University of Stellenbosch, a collaborator for this project and a postgraduate engineer, Sven Queisser, developed the new software.

Figure 3.14: DVT Reader Interface.



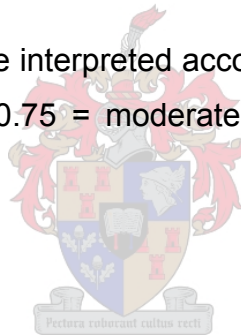
The final phases of the data processing involve the exporting of the DVT generated text file containing the photographic angle data into Microsoft Excel (2002) for statistical analysis.

3.17 Statistical Analysis

Descriptive and inferential statistical tests were conducted. The mean angles for subgroup analysis were determined using Microsoft Excel (2002). Validity and reliability were determined using intra-class correlation coefficients determined around 95% confidence intervals using SPSS Viewer Version 14 software. The intra-class correlation coefficient was considered more appropriate than correlation coefficient as it provides information on agreement and correlation of the data sets.

Validity was also graphically analysed using Bland-Atman plots constructed in SPSS Viewer Version 14 software.

The strength of the ICC's were interpreted according to (Portney and Watkins, 2000) : <0.50 = poor, $0.50 < 0.75$ = moderate, $0.75 < 0.90$ = good, > 0.90 = excellent.



Chapter 4

RESULTS

The aim of this study was to establish the measurement tool reliability and concurrent validity of a Portable Posture Analysis Method (PPAM). This chapter presents the demographic representation of the study sample, the general reliability and the validity of the PPAM as well as the age, gender and posture subgroup findings.

4.1 Sample Demographics

The following flowchart (Figure 4.1) demonstrates the demographic information as well as the sample selection. Two of the schools have cancelled their commitment to participate at a late stage during the data collection phase. The schools were unable to participate due academic activities. Due to the limited number of learners who were able and willing to participate, we were unable to apply stratification, although we have attempted to obtain representation of the two selected age groups as well as both genders.

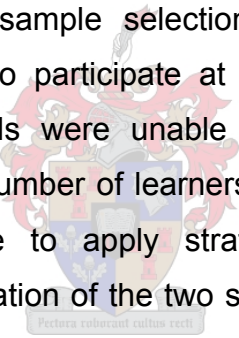
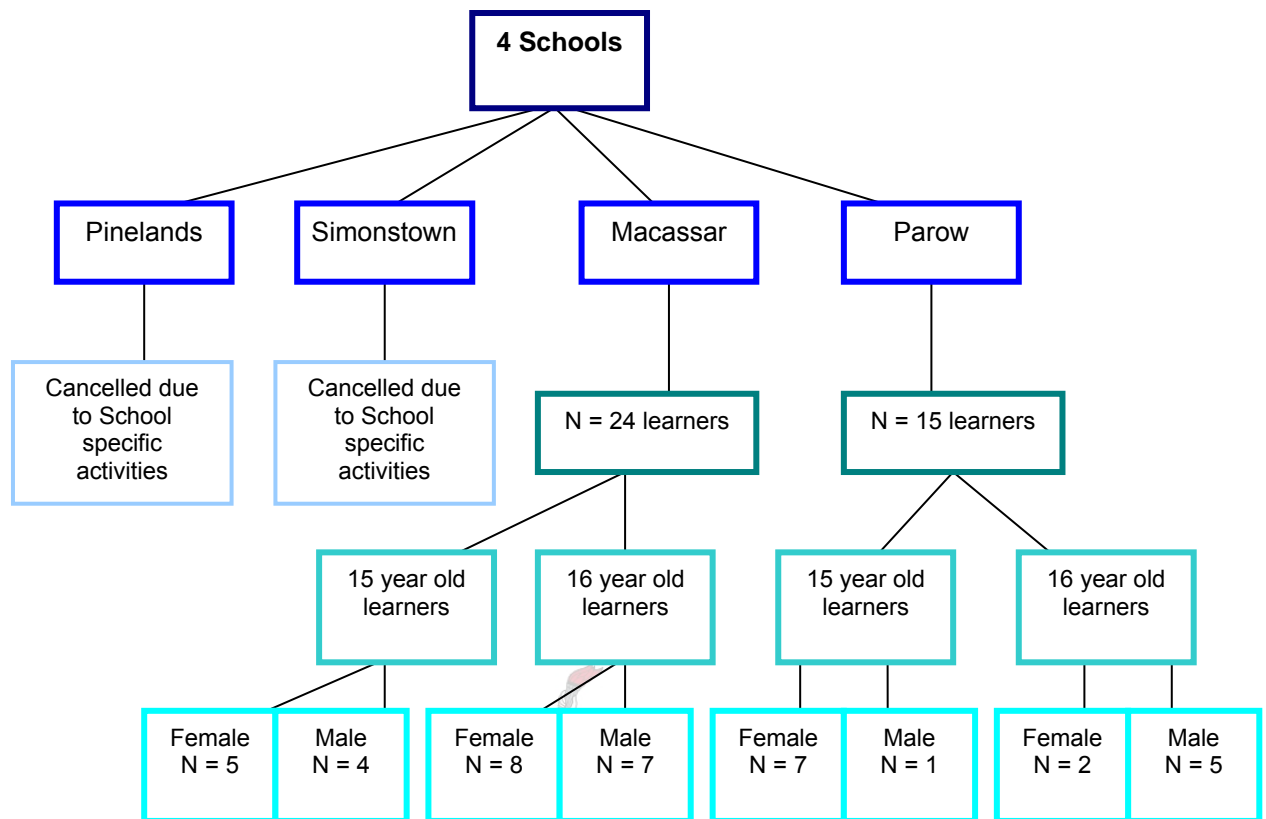


Figure 4.1: Flow chart demonstrating sample demographics.



The sample comprised of 40 learners. The data from one female learner could not be used as she refused to undress her right side, which was her dominant side, due to severe burn scars. The data of 39 learners were thus analysed.

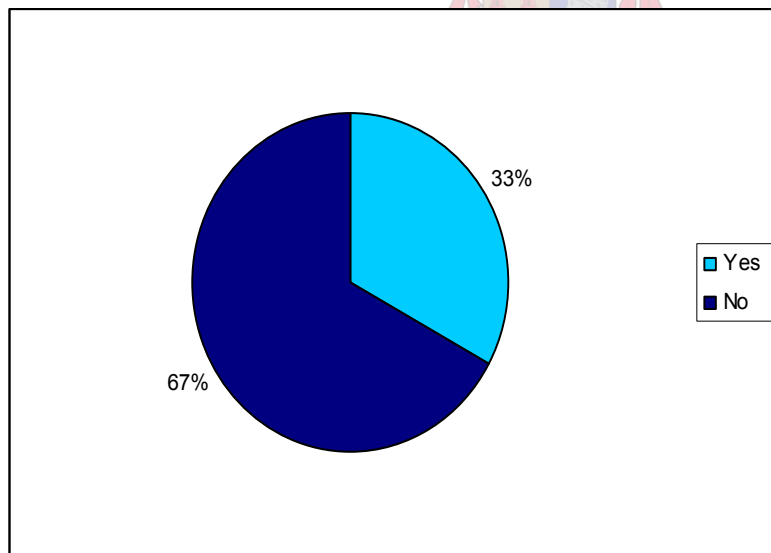
Table 4.1 demonstrates the learners' age, gender and posture, as instructed by the researcher (Chapter 3), as well as the total of each group. A total of 17, 15 year olds and 22, 16 year olds were used. The total sample comprised of 19 males and 20 females.

Table 4.1: The learners' age, gender and posture.

Posture	15 Year olds		16 Year olds		Total
	Male	Female	Male	Female	
Slouched	2	5	4	2	13
Upright	3	2	4	4	13
Normal	2	3	4	4	13
Total	7	10	12	10	39

Figure 4.2 demonstrates the pain prevalence according to the pain questionnaire (Appendix G) that each of the learners was instructed to complete before data capture. This questionnaire served as a screening tool to assess if any of the eligible subjects will be unable to assume the instructed posture collecting the posture data.

Figure 4.2: Pain prevalence on data collection day.



Thirteen of the 39 learners (33%) experienced mild pain on the day of testing as well as during a variety of mostly school related activities. Table 4.2 demonstrates the detail pertaining to the area of pain, during which activity pain was experienced as well as the severity of the pain. Relatively more females than males experienced a mild degree of pain on data collection day.

None of the subjects were excluded on the basis of pain post screening of pain experience.

Table 4.2: Description of pain experience.

Age	Sex	Location of pain	When pain is experienced	Severity
15	F	Upper back	Elsewhere	Mild
15	F	Low back, upper back	School work and computer use at home	Mild
15	F	Right hand	School work at home	Mild
16	F	Left/Right shoulders	Computer use at home	Mild
16	F	Left/Right shoulders	Computer use at home and school	Mild
16	F	Head, lower back, neck	School work at home, computer use at school	Mild
16	F	Upper back, neck, right shoulder	Computer use at school, sports	Mild
16	F	Neck	Computer use at school	Mild
16	F	Low back, neck, upper back	Work at school and at home, sports, elsewhere	Mild
16	M	Neck	Computer use at school	Mild
16	M	Right hand & neck	Computer use at home and school, school work at home	Mild
16	M	Left hand, neck	School work at home, computer use at school and home	Mild
16	M	Low back	Computer use at school	Mild

4.2 Reliability Findings

Table 4.3 shows the mean, the standard deviation and the range for each of the five angles in all three of the postures. The protraction/retraction angle demonstrated the largest degree of SD in all three postures. The sagittal head angle showed the smallest SD in both the 'normal' and 'upright' sitting postures with the thoracic angle showing the smallest SD in the 'slouched' posture.

Table 4.3 The mean, SD and range values of the angles.

Angles	Normal			Upright			Slouch		
	Mean	SD	Range (Degrees)	Mean	SD	Range (Degrees)	Mean	SD	Range (Degrees)
Sagittal Head Angle	20.05	7.84	0 - 34.70	19.99	8.15	0.90 - 34.40	10.28	10.68	(-)15.90 - 34.20
Cervical Angle	47.66	9.75	21.90 - 62.90	52.72	11.18	22.30 - 71.30	21.49	27.57	(-)34.10 - 53.40
Protraction / Retraction Angle	130.21	25.77	65.30 - 178.70	124.76	20.36	76.50 - 159.80	145.68	20.62	103.70 - 208.70
Thoracic Angle	63.25	8.57	49.50 - 89.20	61.37	11.76	40.80 - 97.60	61.46	8.88	39.30 - 78.10
Arm Angle	23.46	12.75	(-)5.00 - 50.30	24.21	12.09	3.30 - 60.90	32.72	10.34	14.50 - 48.80

Table 4.4 presents the inter-class correlations (ICC's) findings for all five of the measured angles namely, the sagittal head angle, cervical angle, protraction/retraction angle, arm angle and the thoracic angle (Chapter 3). The ICC's for reliability were calculated by comparing each of the five photos with each other. All of these angles had an ICC value greater than 0.94. The arm angle had the highest agreement with an ICC value of 0.99. The scatterplots, illustrating the reliability of the sagittal head angle, cervical angle, protraction/retraction angle, arm angle and the thoracic angle, are attached as Appendix H.

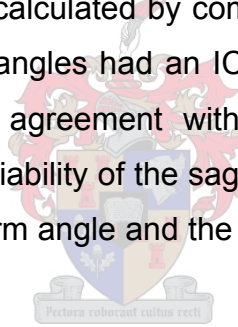
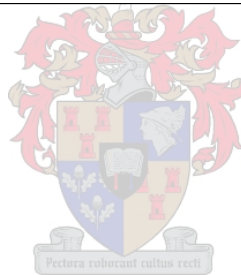
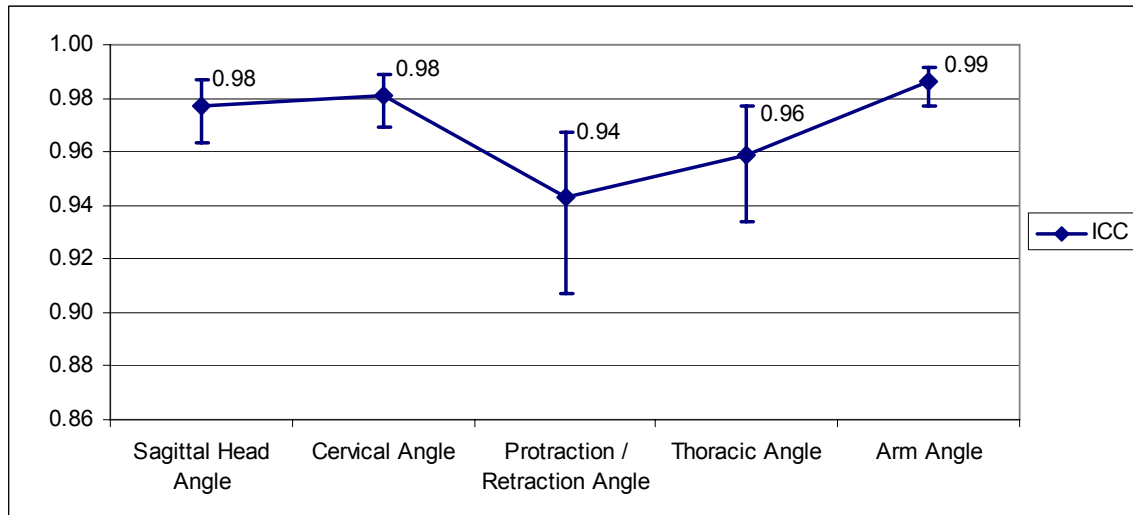


Table 4.4: ICC values for reliability testing.

	ICC Agreement	Lower 95% CI	Upper 95% CI	Lower Difference	Upper Difference
Sagittal Head Angle	0.98	0.96	0.99	0.01	0.01
Cervical Angle	0.98	0.97	0.99	0.01	0.01
Protraction/ Retraction Angle	0.94	0.91	0.97	0.04	0.02
Thoracic Angle	0.96	0.93	0.98	0.02	0.02
Arm Angle	0.99	0.98	0.99	0.01	0.01

Figure 4.3 is the graphic representation of Table 4.4 above. The figure graphically illustrates that the protraction/retraction angle has the lowest ICC and the arm angle the highest.

Figure 4.3: Range plot demonstrating the ICC agreement for reliability.



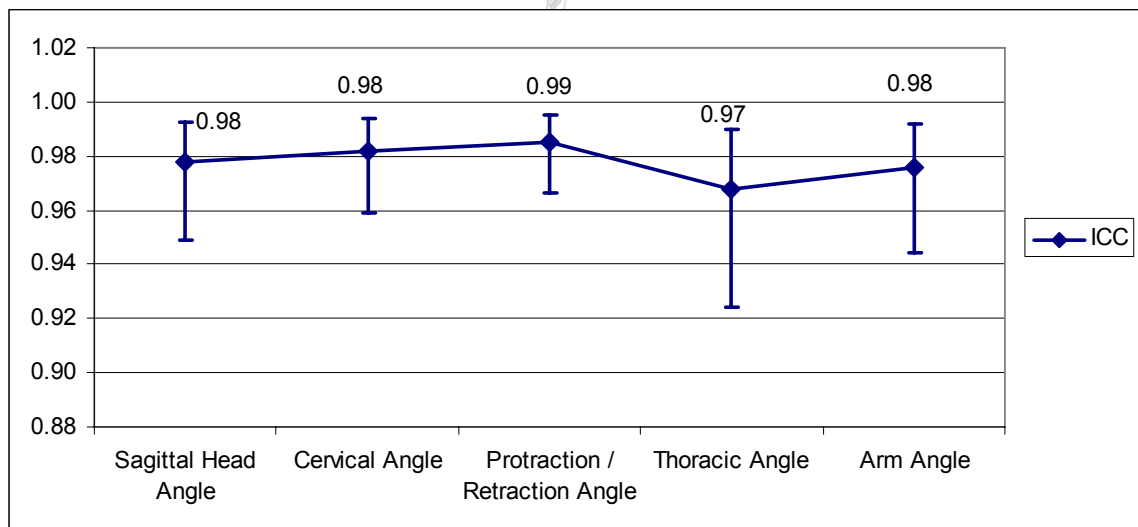
4.2.1 Reliability findings according to sitting posture

ICC values were also analysed according to sitting posture to ascertain variations in measurement tool or subject performance according to the three postures analysed. Subjects were randomly asked to sit in either a 'slouched', 'upright' or 'normal' posture (Chapter 3). Figure 4.4, 4.5 and 4.6 demonstrates the ICC agreement according to posture.

4.2.1.1 Slouched posture

The thoracic angle demonstrated the biggest variability as well as the lowest ICC value of 0.97. The protraction/retraction angle demonstrated the highest ICC value of 0.99 as well as the smallest range of variability.

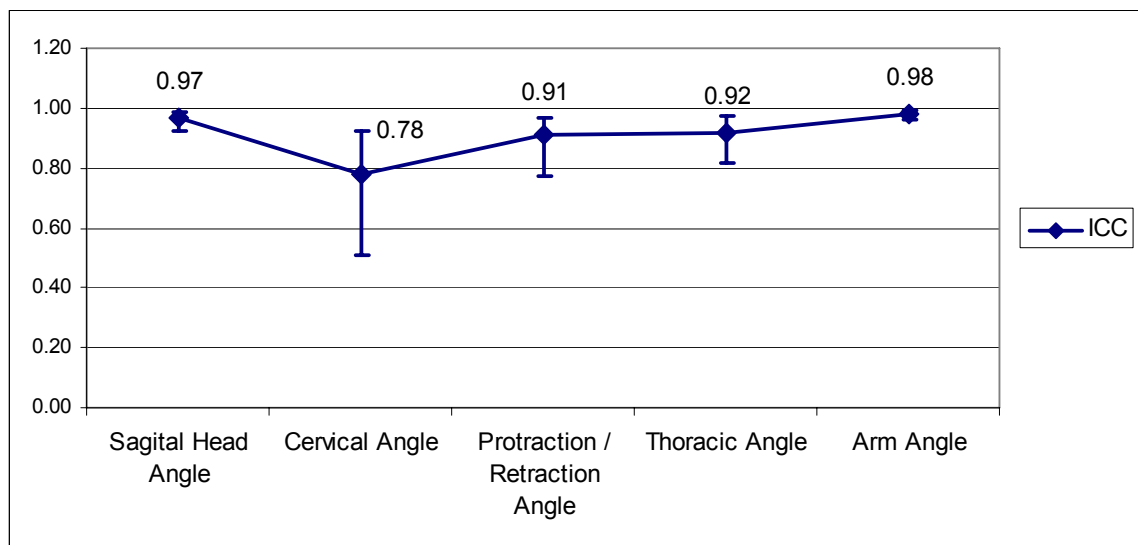
Figure 4.4: Range plot for subsection: posture, slouched.



4.2.1.2 Normal sitting posture

The cervical angle demonstrated the more variability compared to the other angles measured (Figure 4.5). This angle also scored the lowest ICC values of 0.78. The most reliable angle for the normal sitting group was the arm angle with an ICC value of 0.98 and very narrow confidence intervals.

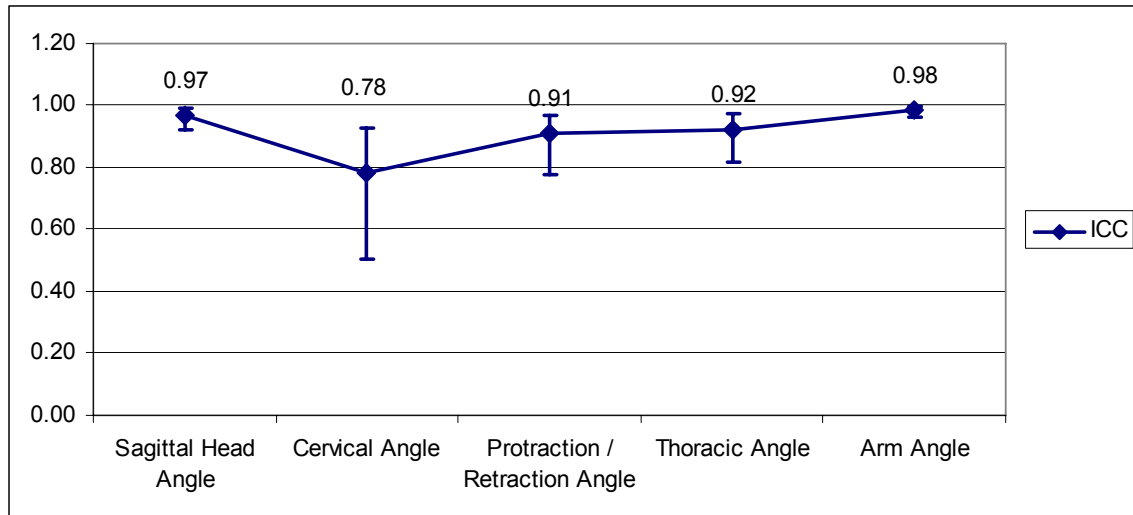
Figure 4.5: Range plot for subsection: posture, normal.



4.2.1.3 Upright sitting posture

All the angles in the upright posture group showed very little variability. These angles also showed to be highly reliable with ICC values ranging between 0.78 and 0.97.

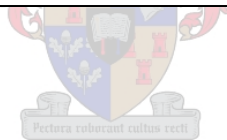
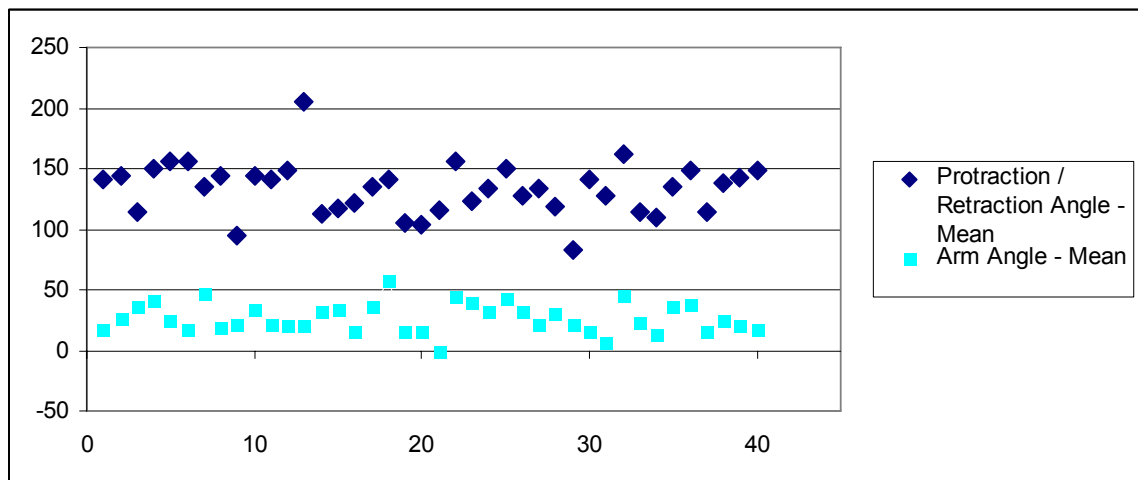
Figure 4.6: Range plot for subsection: posture, upright.



4.2.1.4 Correlation between the arm angle and the protraction/retraction angle

The correlation between arm position and protraction and retraction was determined due to the functional relationship between these two angles. A weak positive correlation of 0.24 was found between the arm angle and the protraction/ retraction angle.

Figure 4.7: Correlation between the arm angle and the protraction/retraction angle.



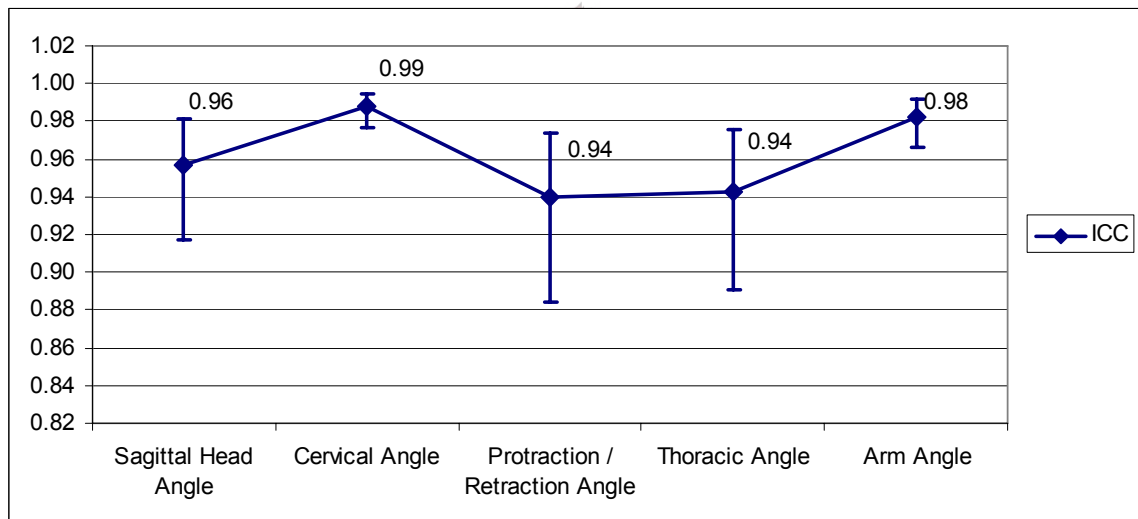
4.2.2 Reliability findings according to gender

Data was also analysed according to gender subgroups. Figure 4.8 and 4.9 illustrates the ICC agreement and the range for the gender subsection. The female group generally scored a lower ICC than the male group, but both groups scored above 0.94.

4.2.2.1 Female group

The female group performed reasonable consistent and the ICC values ranged between 0.94 and 0.99 (Figure 4.8). The 95% confidence intervals also demonstrated good values ranging to about 0.89 to just below 1.

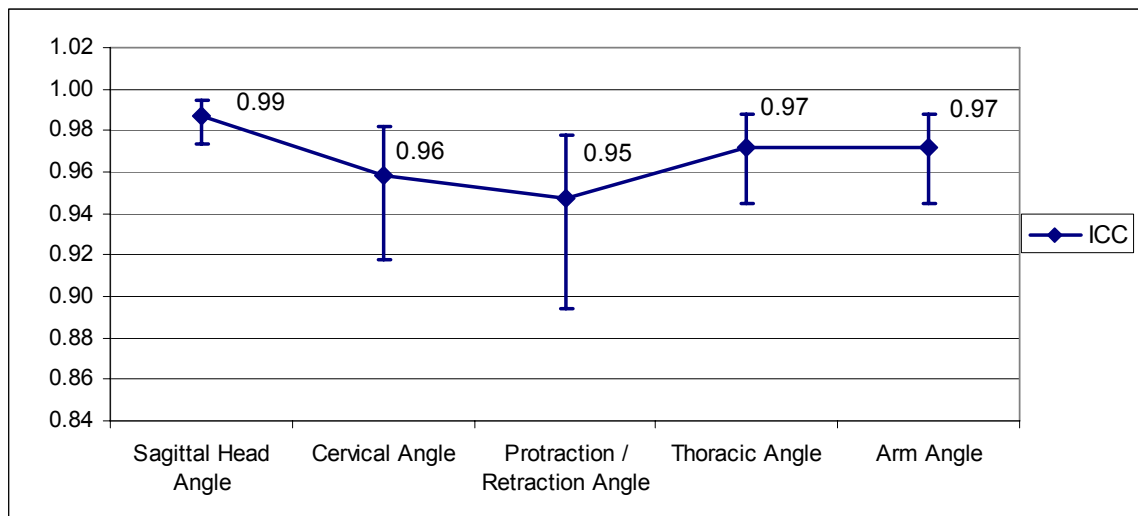
Figure 4.8: Range plot for subsection: Females.



4.2.2.2 Male group

The ICC values of the male group differed slightly from the values calculated from the female group. For example, in that the sagittal head angle for the male group scored a slightly higher ICC, with 0.96 versus 0.99. However, both these values are considered to be excellent correlation (Portney and Watkins 2000).

Figure 4.9: Range plot for subsection: Males.



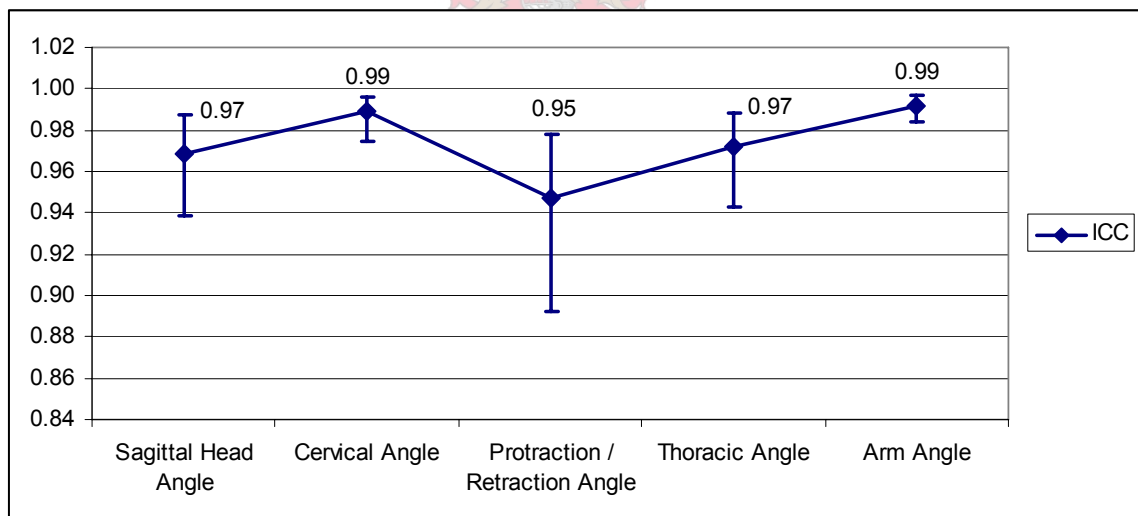
4.2.3 Reliability findings according to age

The data was analysed according to age to ascertain any differences in subject variability between age groups. Figure 4.10 and 4.11 demonstrates a very high ICC agreement and little variance in the range as well as very little difference between the two age groups.

4.2.3.1 Fifteen year old group

The sagittal head angle and the arm angle are considered to be highly reliable with an ICC value of 0.99 surrounded by very narrow confidence intervals. The protraction/retraction angle scored the lowest ICC of 0.95 and demonstrated relatively more variability as illustrated by the confidence intervals.

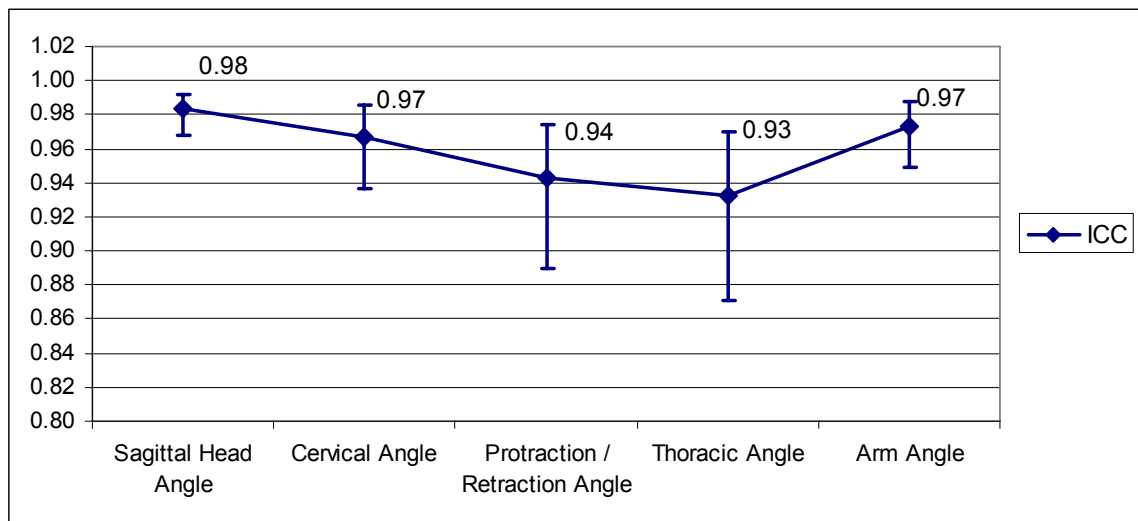
Figure 4.10: Range plot for subsection: Age 15 year old.



4.2.3.2 Sixteen year old group

The thoracic angle scored a slightly lower ICC in the 16 year old group with an ICC value of 0.93 in comparison with the 15 year old group with an ICC value of 0.97. The thoracic angle and the protraction/retraction angle demonstrated relatively more variability, although the lower confidence intervals are still considered to be good (Portney and Watkins 2000).

Figure 4.11: Range plot for subsection: Age 16 year old.

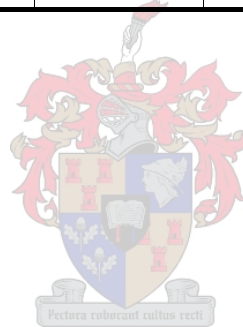


4.3 Validity Results

Table 4.5 demonstrates the ICC values for the validity of the PPAM as measured against the LODOX images. The mean of the angles of the 2 photos taken at the validity station were compared to the angles of the LODOX images, as explained in Chapter 3. The arm angle shows the lowest agreement of ICC (0.78) and the cervical angle the highest with ICC (0.93).

Table 4.5: ICC values for validity

	ICC	95% Lower	95% Upper	Lower Diff	Upper Diff
Sagittal Head Angle	0.91	0.82	0.96	0.09	0.04
Cervical Angle	0.93	0.86	0.96	0.07	0.03
Protraction/retraction Angle	0.87	0.74	0.93	0.13	0.07
Thoracic Angle	0.91	0.60	0.97	0.31	0.06
Arm Angle	0.78	-0.21	0.94	1.00	0.16



4.3.1 Validity results according to sitting posture

Figure 4.12 demonstrates the range plot for the validity of all five of the measured angles. As described in the reliability section and Chapter 3, the learners were randomly selected to sit in one of three positions; slouched, upright or normal. At the validity station they were asked to assume the same position as they did at the reliability station. All the angles illustrated good validity with ICC's of more than 0.87, with only the arm angle scoring an ICC of less than that, ICC = 0.78. The arm angle also demonstrates the largest degree of variation value of all the angles.

Figure 4.12: Range plot for the validity values.

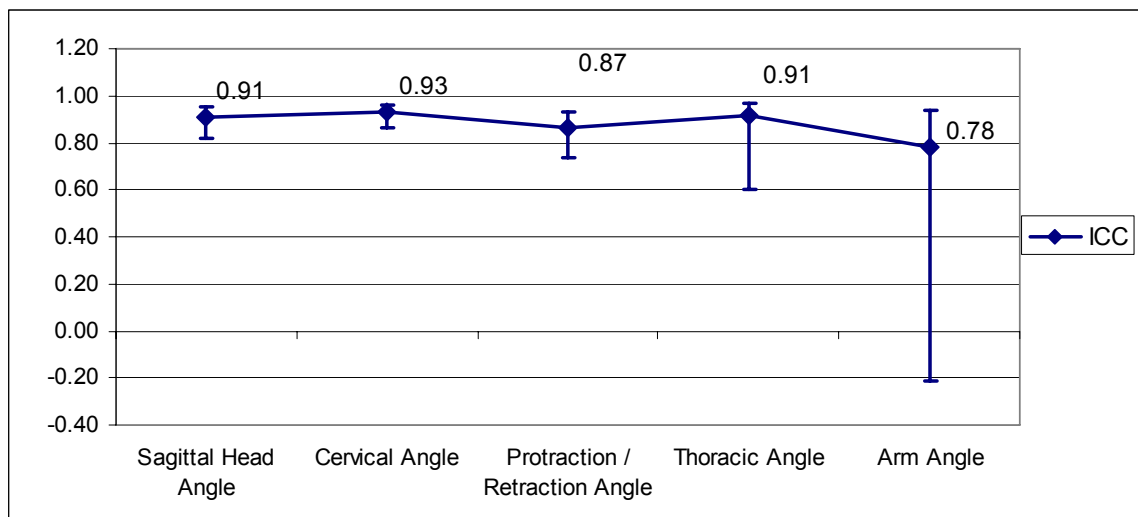
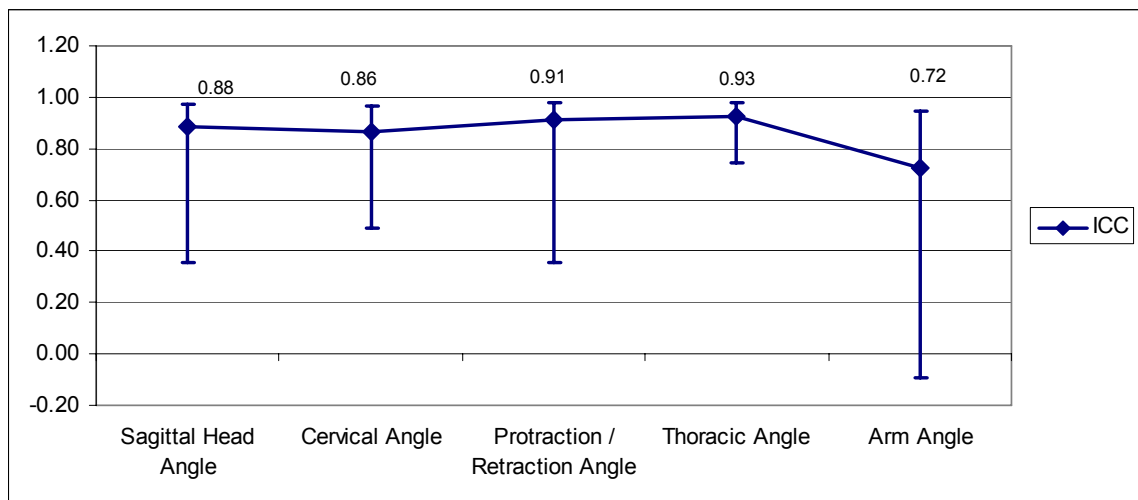


Figure 4.13, 4.14 and 4.15 demonstrates the range plot for the subsection posture. The arm angle demonstrated the largest degree of variability with a range from -0.22 to 0.90, for all three postures. The negative values are an illustration that the elbow was positioned in such a way that the retro-reflective marker was behind the shoulder, thus resulting in a negative value.

4.3.1.1 Slouched sitting posture

The arm angle scored the lowest ICC value of 0.72 as well as the widest confidence intervals. The protraction/retraction angle had the highest ICC values of 0.93, however, the lower confidence interval was considered to be low and thus a degree of variability was evident.

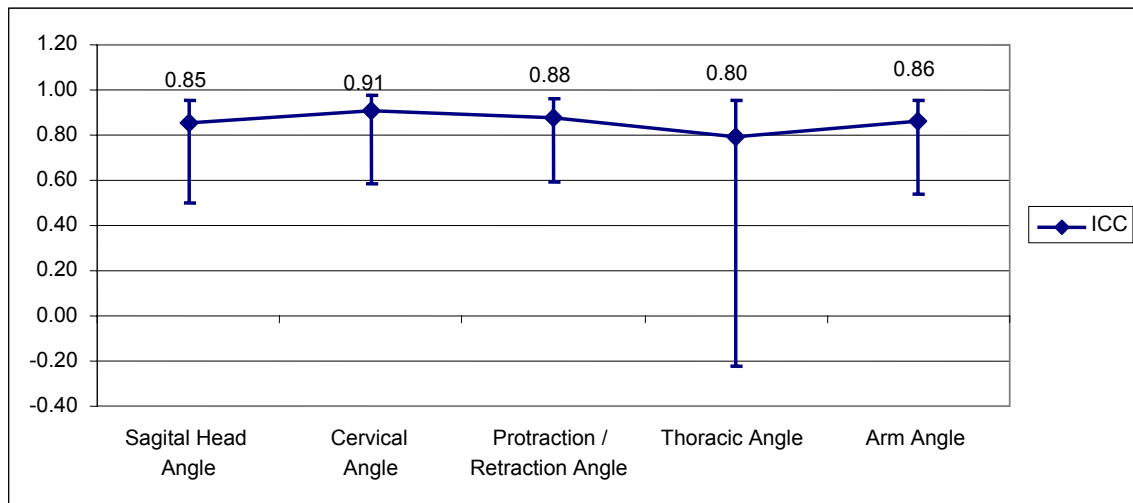
Figure 4.13: Range plot for the subsection: Posture, slouched.



4.3.1.2 Upright posture

The thoracic angle scored the lowest ICC value with 0.80 as well as the largest degree of variability as illustrated by the confidence intervals. The cervical angle scored the highest ICC with a value of 0.91 with moderate correlation and agreement since the lower confidence interval was about 0.6.

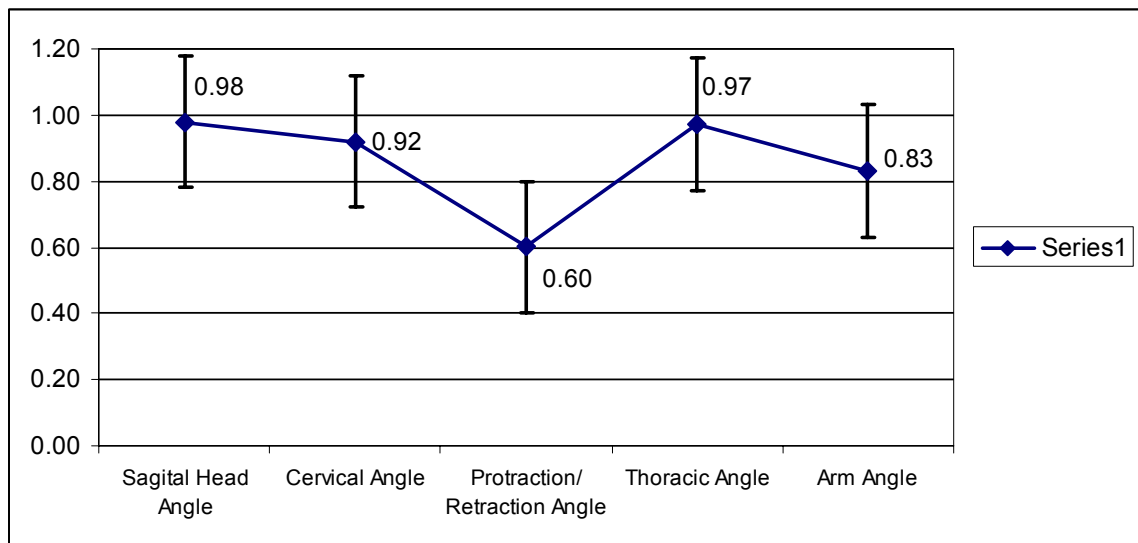
Figure 4.14: Range plot for the subsection: Posture, Upright.



4.3.1.3 Normal sitting posture

The protraction/retraction angle scored a moderate ICC value for the normal posture group, with an ICC value of 0.60. The most valid angle for this posture group was the sagittal head angle with an ICC of 0.98 and good ICC values for the lower and upper confidence intervals. .

Figure 4.15: Range plot for the subsection: Posture, Normal



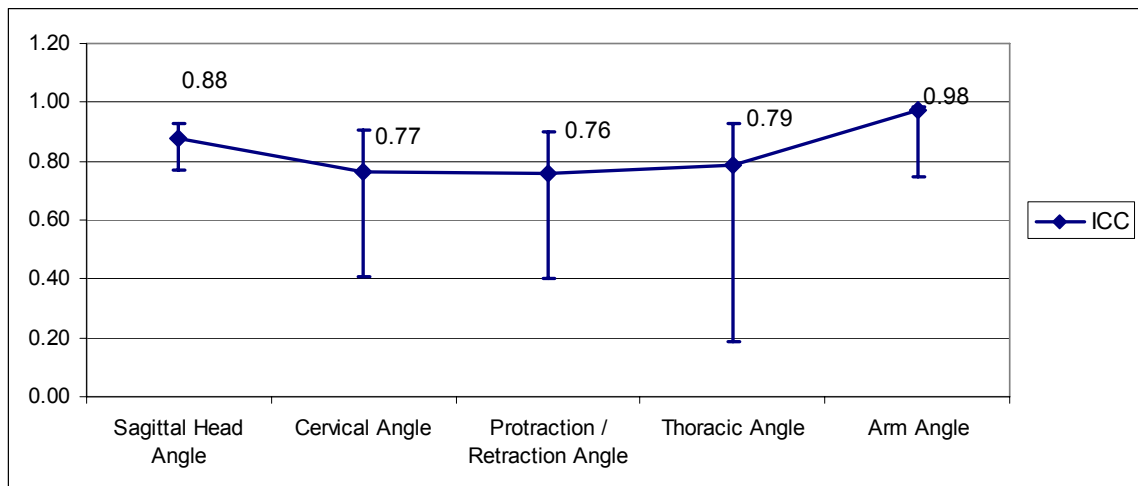
4.3.2 Validity results according to gender

The thoracic angle for both genders demonstrated the largest degree of variability compared to the other angles (Figure 4.16 and 4.17). However, the ICC values were still good for both groups.

4.3.2.1 Female group

Moderate to excellent ICC values were reported for this group. The highest ICC value was for the arm angle. The thoracic angle demonstrated wide variability as noted by the confidence intervals.

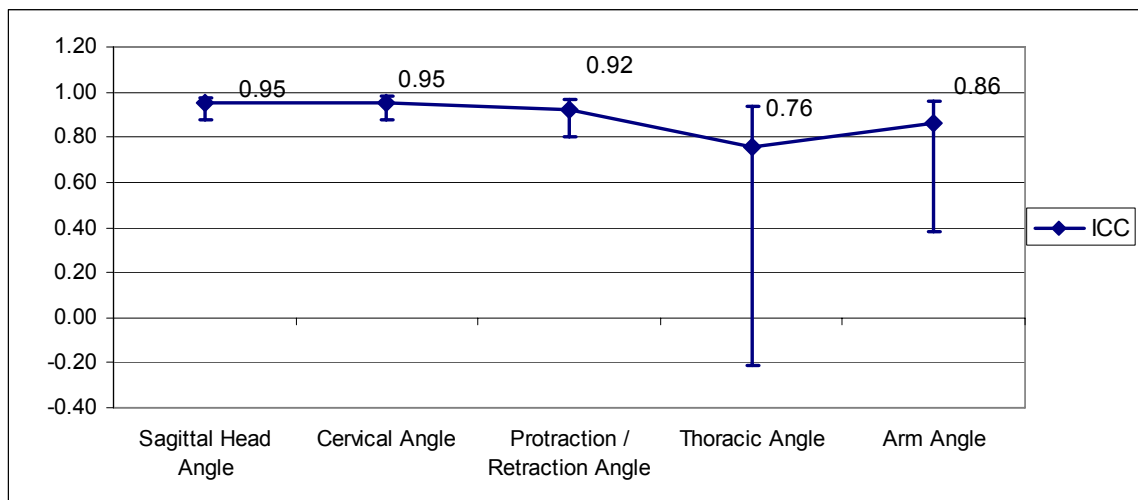
Figure 4.16: Range plot for the subsection: Gender, Female.



4.3.2.2. Male group

Figure 4.17 illustrates that the male group demonstrated less variability than the female group, except for the thoracic angle which was also variable in the male group. The ICC values of all angles, except the arm angle were higher in the male group.

Figure 4.17: Range plot for the subsection: Gender, Male.



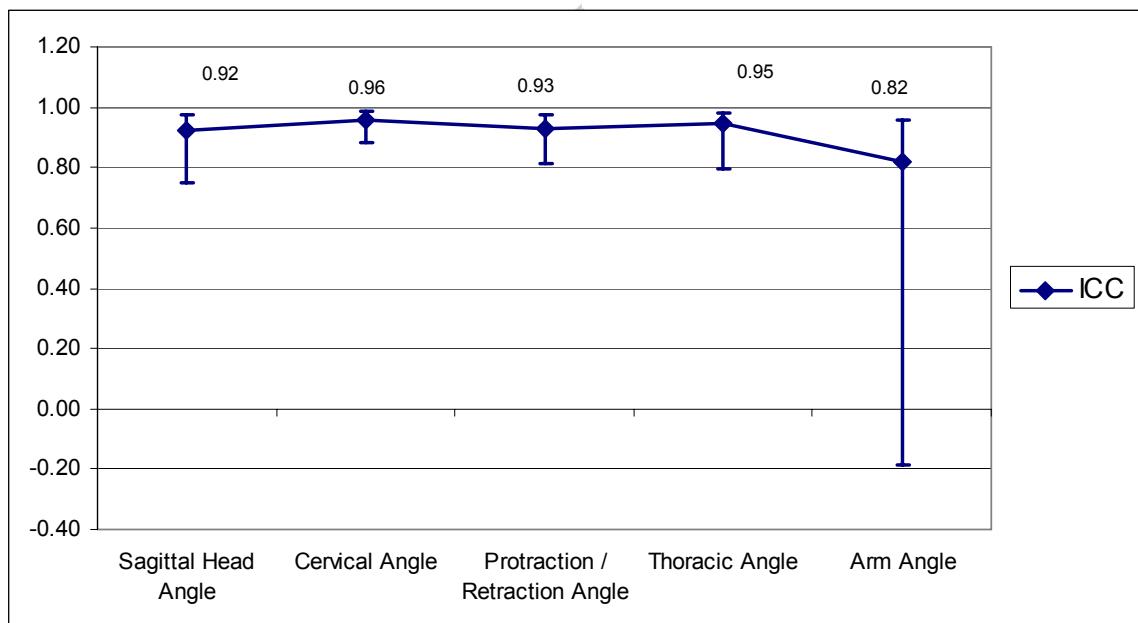
4.3.3 Validity results according to age

Figure 4.18 and 4.19 demonstrates the range plot for the subgroup analysis according to age. The thoracic angle and arm angle for the 15 year and 16 year old groups presented the largest degree of variability.

4.3.3.1 Fifteen year old group

The sagittal head angle, cervical angle and protraction/retraction angle and the thoracic angle demonstrated very little variability. The arm angle showed the lowest ICC value of 0.82 and the largest variability as noted by the confidence intervals.

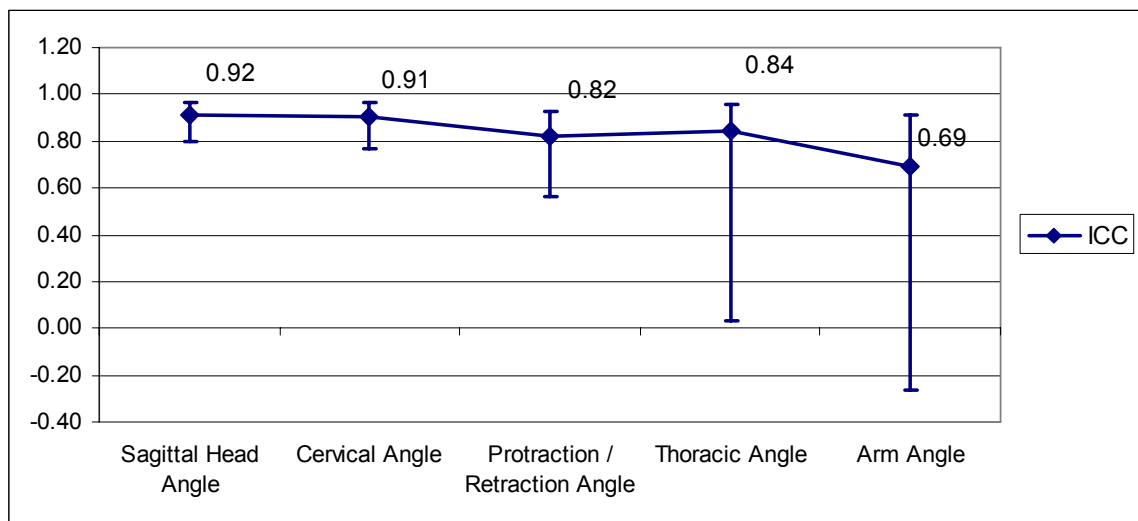
Figure 4.18: Range plot for the subsection: Age, 15 year old.



4.3.3.2 Sixteen year old group

The 16 year old group showed generally more variability than the 15 year old group, except for the sagittal head and cervical angles. The protraction/retraction angle scored a higher ICC value than the 15 year old group. The arm angle scored a lower ICC value than the 15 year old group with 0.69 compared with 0.82 although these values are still considered to be good (Portney and Watkins 2000).

Figure 4.19: Range plot for the subsection: Age, 16 year old.

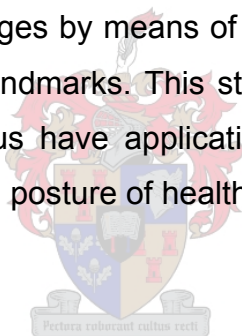


Chapter 5

DISCUSSION

5.1 Introduction

This study presents the finding of the reliability and validity of the newly developed Portable Posture Analysis Method (PPAM) in the measurement of the sitting posture of high school learners aged 15-16 years, in front of a desktop computer. This study is novel since it is the first study reporting on the reliability and validity of photographic methods compared with X-ray images internationally. Based on a review of the literature (Chapter 2) this is the first study reporting on validity and reliability of sitting posture among adolescents. Five angles were electronically calculated from digital photographs and LODOX images by means of retro-reflective markers, which were placed on anatomical landmarks. This standardised posture evaluation method and findings may thus have application to future studies aimed at describing or evaluating sitting posture of healthy adolescents.



5.2 Duration of testing

The testing for each learner in this study was completed within a period of 20-30 minutes. A similar time period, 40 to 60 minutes, of data collection was conducted to evaluate standing posture in children under the age of 12 years old McEvoy & Grimmer (2005). A pilot study was conducted prior to the main study's data collection in order to standardise the data collection procedures and ensure that all procedures can be conducted within the minimum time period. When conducting postural evaluation, it is critical to ensure that data collection proceed within the shortest possible time frame in order to minimize the effects of fatigue on sitting posture. Fatigue of postural muscles has an effect on postural control and consequently this may affect the body segments (Morris 2006, Schieppati *et al* 2003). For instance, it has been demonstrated that postural control of the head and cervical spine is reduced after 15

minutes of sustained sitting posture (Gosselin 2004). The subjects in this sample were instructed to stand up and walk after capturing each photograph and this process took about two minutes. It is thus unlikely that fatigue bias influenced the findings of this study. Therefore since subjects were not expected to sit for 15 minutes sustained, it is unlikely that muscle fatigue could have influenced their postural alignment. Therefore the most likely reason for differences in subject position could be attributed to natural variability in subject responses to the test retest situation (Woollacott and Shumway-Cook 1990). This time period applied for data collection in this study therefore appears to be appropriate in reducing the effects of fatigue as good reliability findings were obtained for all the angles measured.

5.3 The reliability of the posture measurements

Five photos of each of the 39 learners were taken to evaluate the reliability of the PPAM in measuring the sitting posture of learners simulating using a desktop computer. This was done by comparing the cervical and sagittal head angles, the protraction/retraction angle, the arm angle and the thoracic angle of each learner. Good agreement was found for all the angles with ICC's ranging from 0.94 to 0.99, which illustrates the PPAM to be highly reliable. According to Portney and Watkins (2000) correlation co-efficient values above 0.75 generally indicate good reliability and reliabilities of 0.90 or higher are excellent and can be recommended for diagnostic tests. Considering the high reliability findings the PPAM may also be useful in classification of common postural syndromes such as poking-chin posture and forward-head-posture. These postural syndromes have been associated with the development of musculoskeletal pain (Szeto 2002 and 2005). The usefulness of the PPAM may thus apply to clinical as well as the research environment. However the sampling method of this study was compromised by the fact that two of the randomly selected schools were unable to participate, thereby reducing the generalisability of the study findings. Further development and evaluation of the posture measurement tool should incorporate larger samples of adolescents presenting with a range of spinal postures representing the

common postural deviations. This may then enhance the clinical application of the tool.

5.3.1 Cervical Angle

The five angles measured to assess posture in this study (Chapter 3) were adapted from studies done by McEvoy & Grimmer (2005) and Szeto *et al* (2002). The neck angle is commonly affected by computer usage and therefore is an important angle in posture evaluation (Szeto *et al* 2002). The cervical angle across this study sample group ranged between 0 and 34.7 degrees for the “normal posture” group. For the “slouched posture” group the range was between -22.7 to 53.4 and the “up-right posture” group ranged between 22.3 and 71.3 degrees. The negative values can be explained by the fact that those angles were close to zero. The cervical angle was measured between the horizontal and a line defined by the trachus and C7 markers. The positive direction when measuring an angle is left, this means you start at the horizontal and turn left by some degrees till you end at the line defined by the trachus and canthus markers. When you apply this to a line that is not directed upwards but downwards you have to turn the horizontal line by almost 360 degrees to end up at the line defined by the trachus and C7 markers.

The cervical angle was most variable in the group of students who assumed the “up-right posture”. An up-right posture is not naturally assumed by adolescents (www.crosscom.com.sg). Therefore, it is usually less economical for individuals to assume the upright posture as it requires more muscle activity and neuromuscular control (www.acmandal.com). Learners could thus have been more inclined to deviate from their baseline alignment of upright sitting posture. The intra-class correlation coefficient is also more sensitive in ascertaining the degree of subject variability than measurement tool reliability (Stratford and Goldsmith 1997). Therefore the variability noticed may thus be attributed to variability in subject performance.

This explanation can also be illustrated by two of the subjects in his sample (Chapter 4) who showed an obvious change in head position between photos and consequent relatively large changes in cervical angle as well (Appendix H). The values of the cervical angles demonstrated by these two subjects could be the reason for the large variability in the overall correlation values of the cervical angle. Although the variability of the cervical angle is large, the angle still had an ICC of 0.98 for reliability, which indicates a high agreement (Pringle 2003, Tousignant *et al* 2001, Tousignant *et al* 2000). The cervical angle was also found to be valid with an ICC value of 0.93.

The large variation between the reliability ICC values of the males (0.95) and that of the females (0.77) can be explained by inevitable intra-subject variability. It may be explained by the fact that pain may increase variability of performance (Anderson *et al* 2006). A reliability study among chronic rotator cuff patients demonstrated that the painful side's performance was more variable (Anderson *et al* 2006). Relatively more females than males experienced mild pain on the day of testing. Few reliability and validity studies have been conducted on subjects with pain and most reliability and validity studies incorporated healthy or pain free subjects. It is notable that none of the reliability and validity studies reviewed in Chapter 2 were excluded on the basis that the studies included subjects with musculoskeletal pain. Therefore the search strategy results presented in Chapter 2 further augments that most studies included healthy or patients without musculoskeletal pain. Further research into the effect of pain on subject and measurement reliability and validity could provide further insight into this observation. It is however notable that ICC values for both gender groups are still considered to be good (Portney and Watkins, 2000).

The results of the cervical angle are difficult to compare with other studies as similar studies did not measure the angles in the same postures and used different age groups than this study (Chapter 2). A study conducted by McEvoy & Grimmer (2005) aimed at assessing the variability of children's standing posture tested the neck angle, gaze angle and arm angle. Two studies conducted by Szeto *et al* (2002 and 2005) were aimed at comparing

the sitting posture of symptomatic and asymptomatic office workers by measuring the head angle, neck angle and thoracic angle and can thus not be directly compared with this study's findings. The findings of the study by Szeto *et al* (2002 and 2005) could not be compared to this study due to differences in angle calculation and data analytical procedures.

The cervical angle is the measure of the forward head position, which is a useful clinical indicator of mid/lower cervical spine dysfunction (McEvoy & Grimmer 2005). A relatively lower value may indicate a more normal head posture (McEvoy & Grimmer 2005). From an anatomic perspective, the cervical erector spinae provide an extensor moment to balance the flexion moment created from the forward head posture (Chaffin 1999, Keshner *et al* 1989). The upper trapezius muscle is a long lever muscle designed more for scapular elevation rather than head-neck position (Johnson *et al* 1994, Keshner *et al* 1989). Szeto *et al* (2005) suggests that high amplitudes of upper trapezius activity coupled with reduced cervical erector spinae activity controlling the neck extensor moment, may result in a greater compressive pressure on the cervical spine. Bogduk (1995) also found that both the altered muscle recruitment patterns and the altered kinematics are likely to result in compressive loading in the cervical spine, affecting muscles, articular structures such as; zygapophyseal joints, connective tissue and neural tissue, which are all peripheral generators of referred pain.

In a study done by Szeto *et al* (2005), it was found that symptomatic persons have increased forward neck flexion and head tilt angles in comparison to asymptomatic participants. It has also been reported that a difference of about 5 degrees in the neck flexion angle can have a considerable impact on the neck extensor moment and the muscle force required from the neck extensors to support the weight of the head (Straker *et al* 1997). Szeto *et al* (2005) also found that the asymptomatic group had significantly higher upper trapezius muscle activity coupled with lower activity in the cervical erector spinae muscles. A posture measurement tool should thus be able to detect postural abnormalities that can lead to abnormal stress on the body, in order to successfully understand aetiology factors, thereby preventing musculoskeletal

dysfunction. The PPAM, provided that it is tested on similar populations, may be useful in identifying postures of the neck angle that may lead to the development of pain and thereby be useful in evaluating preventative strategies (Szeto *et al* 2005, Gajdosik 1987).

5.3.2 Sagittal Head Angle

The sagittal head angle is commonly influenced by the workstation design when using visual display units such as computers (Jaschinski *et al* 1998). The height of the desk may influence the head angle due to changes in gaze angle (visual angle) in order to interact with the VDU. The downward gaze position (between horizontal and -16 degrees) is considered more comfortable for both the innervational and anatomical factors of the eyes (Jaschinski *et al* 1998, Quaranta *et al* 1994).

The sagittal head angle illustrated to be reliable and valid (ICC values of 0.91 and 0.98 respectively). This angle indicates the position of the head relative to the neck (McEvoy & Grimmer 2005). McEvoy & Grimmer (2005) also states that a relative decrease in the sagittal head angle is considered as a “poking-chin” posture and may also be as a result of stresses on the upper cervical spine as discussed in the cervical angle section above (5.3.1). In addition Szeto *et al* (2002) reported that the “poking-chin” posture, similar to the “forward head” posture, was also more common among the symptomatic subjects when they concentrated on viewing the computer display. Reliable and valid measurement of this angle may thus have clinical value.

The sagittal head angle ranged between 0 and 34.70 degrees for the “normal posture” group, and -15.90 to 34.20 degrees for the “slouched posture” group. For the “up-right posture” group, the angles varied between 0.90 to 34.40 degrees. The negative angle can be explained as discussed in Section 5.3.1. with the sagittal measured between the horizontal and a line defined by the trachus and canthus markers.

5.3.3 Shoulder Protraction/retraction Angle

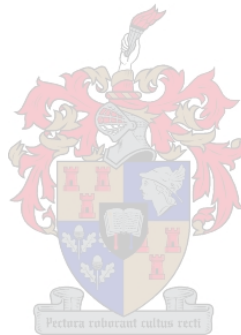
The protraction/retraction angle was measured based on the method used by Szeto *et al* (2002). Szeto *et al* (2002) measured this angle as the displacement of the acromion along the x-axis with reference to the C7 marker in terms of centimetres anterior to C7. Protraction/retraction angle of the shoulder is commonly implicated in the development of shoulder syndromes. Shoulder or subacromial impingement syndrome is the most common work related overuse shoulder syndrome associated with computer use (Bullock *et al* 2005). Several factors such as posture, muscle force, range of motion, and scapular dysfunction are commonly believed to contribute to shoulder impingement (McClure *et al* 2006). Shoulder protraction combined with an increased thoracic angle leads to a downwardly rotated, anteriorly tilted, and protracted scapula. This ultimately leads to increased compression in the subacromial space, resulting in subacromial impingement syndrome (Lewis *et al* 2005, Kebaetse *et al* 1999).

Shoulder protraction/retraction is also related to the postural control muscles of the shoulder girdle and thoracic spine. The muscles that serve to stabilize the scapula include levator scapulae, rhomboids major and minor, serratus anterior, and trapezii. The glenohumeral rotators include the muscles of the rotator cuff: the supraspinatus, infraspinatus, teres minor, and subscapularis (Kibler 1998, Kamkar *et al* 1993, Jobe and Pink 1993, Pink and Jobe 1991, DiVeta *et al* 1990). The role and function of these muscles are often investigated by researchers evaluating postural control (Kibler 1998, Bak and Faunl 1997, Bigliani *et al* 1997, Kamkar *et al* 1993, Jobe and Pink 1993, Moseley *et al* 1992, Pink and Jobe 1991, DiVeta *et al* 1990). The biomechanical research of both Jobe and Pink (1993) and Bak and Faunl (1997) demonstrated that if weakness or fatigue of any of the aforementioned structures occurs, scapulohumeral rhythm is disrupted and secondary impingement ensues (Bak and Faunl 1997, Kamkar *et al* 1993). Most of the overuse injuries that occur around the shoulder girdle are due to alterations in the function of scapular-stabilizing muscles (Moseley *et al* 1992). It is thus

imperative to measure the protraction/retraction angle reliably and valid, as an increased protraction angle might instigate shoulder impingement syndrome.

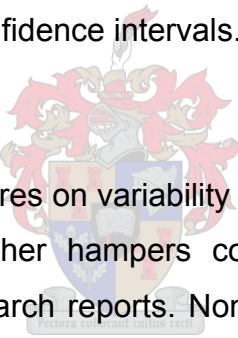
In this study the protraction/retraction angles were defined as the line between the midpoint of the humerus head and C7 and the angle to the horizontal through the midpoint of the humerus. The ranges for the protraction/retraction angle for the “normal posture” group are 65.30 to 178.70, and for the “slouched posture” group 103.70 to 208.70. For the “up-right posture” group it ranged between 76.50 and 159.80. These angle values indicate that relatively larger values are associated with the slouched posture. This finding is not unexpected since a slouched posture involves upper thoracic flexion and scapulae protraction and elevation (Szeto *et al* 2002). This finding illustrating the normal biomechanical and functional interplay between the thoracic and protraction angles may be an affirmation of the validity findings presented in Chapter 4.

5.3.4 Thoracic Angle



The thoracic angle was measured as described by Szeto *et al* (2002), as the angle between the line through C7 and the superior notch of the manubrium and the line through T8 and the superior notch of the manubrium. The need for objective range of motion values distinguishing normal and asymmetric ranges and posture is needed in the thoracic region and unfortunately few measures for this area are reported in the literature (Lee *et al* 2003). The ICC values for the thoracic angle as measured by PPAM were considered to be good (Chapter 4). Reliability and validity measures of the thoracic spine are important to allow clinicians to quantify movement in this region and may assist in evaluating the response to intervention and the selection of treatment techniques (Nitschke *et al* 1999).

The ranges for the thoracic angle varied between 49.50 and 89.20 degrees for the “normal posture” group, 39.30 to 78.10 degrees for the “slouched posture” group and for the “up-right posture” group the angles varied between 40.80 and 97.60 degrees. In the upright posture wide confidence intervals around the ICC value for the validity study was found (Figure 4.14). This angle is not often measured in posture evaluation studies (Chapter 2) and therefore it is difficult to compare the findings of this study to similar reports. A relatively small group of 13 learners were included each of the subgroup postures and therefore postural changes of even a single learner can deviates could have influenced the width of the confidence intervals. The camera photos were captured just before and just after the LODOX scanning and this lapse in time of about 2-3 seconds could have been sufficient for subtle alteration in postural alignment. This methodology and equipment used did not allow the photo to be taken at exactly the same time as the LODOX image and this may account for the variation in confidence intervals.



The lack of reporting of measures on variability such as confidence intervals is an additional factor that further hampers comparison the thoracic angle variability with published research reports. None of the validity and reliability studies reviewed in Chapter 2 provided confidence intervals as a measure of variability. In addition to providing measures of variability, future studies should also consider to calculate the standard error of measurement. The standard error of measurement quantifies error in the same units as the original measurement (Stratford and Goldsmith 1997). Therefore as the standard error of measurement will provide more insight into whether the variation is due to subject or measurement tool variability (Stratford and Goldsmith 1997).

It has been found that the forward head posture is associated with an increased thoracic kyphosis, and an altered position of the scapula, which in turns leads to increased compression of the subacromial space (Lewis *et al* 2005). In the literature no articles could be found where the above mentioned angles were measured in the three different postures as described in this

study. Szeto *et al* (2002) used the same methods to measure the thoracic angle as was done in this study, but Szeto *et al* (2002) did not measure this angle in the three different postures as was done in this study. Therefore this is the first study reporting on the validity and reliability of the thoracic angle measured in the slouched, upright and normal posture.

5.3.5 Arm Angle

The arm angle indicates the position of the arm relative to the body (Chapter 3). This angle has not been reported on in the current published literature, but was deemed to be an important angle, which may confound the values of the shoulder protraction/retraction angles. Shoulder protraction/retraction may be biomechanically affected by the position of the arm in glenohumeral flexion and extension. This functional link occurs because of the structural linkage of multiple ligaments and muscles crossing the shoulder girdle complex (Norkin and Levangie 2005). Arm angle for thus measured to control for confounding effects in shoulder protraction/retraction angle reliability values.

The study findings indicated that a correlation of 0.24 was found between the arm angle and the protraction/retraction angle (Appendix H). This indicated that a relatively low level of relationship between the protraction/retraction angle and the arm angle was observed in this study. This finding was thus contrary to what was expected by the researcher. These findings can however be explained as the learners were instructed to keep their trunks in a certain position while being tested without instruction to position their arms in a certain manner. It may also be related to the fact that the chair position was maintained at the same distance from the desk throughout the data collection period, the learners were thus not able to position the chair further from the desk which might have caused them to stretch forward with their hands to reach the desk and thus increase the shoulder protraction angle.

The negative values that were obtained for this angle showed that the elbow was posterior to the shoulder, which means that the hands were positioned

close to the body while placed on the table in front of the learner. The arm angle showed the biggest ranges of all the angles with ranges between 3.30 and 44.90 degrees for the “normal posture” group, 12.30 to 48.80 degrees for the “slouched posture” group and 8.30 to 60.9 degrees for the “up-right posture” group. As this angle has the largest range of motion in comparison to the other angles, the large differences in the range were expected; because learners were not asked to always position their hands in the same position and this obviously influenced the variability noted of the arm angle.

5.4 Age considerations when measuring posture

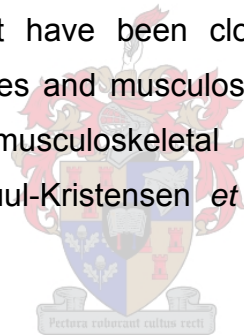
A cohort of researchers reported that age may influence posture (Siivola *et al* 2004, Vikat *et al* 2000, Niemi *et al* 1997). In this study only 15 and 16 year old learners were used to obtain posture measurements. Little variability between the ICC's of these two groups was found. These two age groups are very similar as they are in the same phase of motor development, (Woollacott & Shumway-Cook 1990). Therefore it was not surprising to find no difference in the reliability and validity of posture measurements within these two age groups.

McEvoy and Grimmer (2005) investigated the repeatability of measuring standing posture in children aged 5-12 years. It was found that age had a significant influence on repeated testing. It needs to be taken into account that although age had no significant influence on reliability in this study, only two age groups were used, thus age might influence the reliability of posture measurement when bigger age groups are tested. Age must thus be considered as a confounder in future reliability and validity studies.

5.5 Gender considerations when measuring posture

Grimmer *et al* (2005) concluded in a study into the reliability of upright posture measurements in primary school children that gender had no effect on the mean test difference for any angle. In this study, three more female learners were used than males. It might have had an influence on the results as the groups were not similar in compilation. Despite this both groups had ICC's in the very high range, >0.95 . In the published literature no studies could be found where it was reported that gender plays a role in seated posture of adolescents.

It was however found that 33% of the learners reported to have mild pain on the day of testing and that 69% of these learners were female (Chapter 4). This falls in line with a recent study by Gillespie (2006), Rhee (2005), Siivola *et al* (2004), who found that adolescent females tend to experience more pain than their male counterparts. It was found that the pubertal status of girls and the timing of puberty onset have been closely associated with various symptoms, such as headaches and musculoskeletal pain (Rhee 2005). The increased prevalence of musculoskeletal dysfunction among females continues into adulthood (Juul-Kristensen *et al* 2004, Szeto & Lee 2002, Evans & Patterson 2000).



5.6 Published literature regarding reliability and validity of posture measuring tools

Photography is commonly used to evaluate upper quadrant posture (McEvoy & Grimmer 2005, Szeto *et al* 2002 and 2005). Despite the evaluation of posture in these descriptive studies using photographic methods, no published study reports on the reliability and validity of upper quadrant posture evaluation. This area of research is required especially considering the simplicity and the non-invasive nature and affordability of photographic methods (Chen & Lee 1997).

In the literature more emphasis has been placed on the evaluation of reliability and very little on validity (Sim *et al* 1993). This might be due to the difficulty in obtaining ethical approval for comparing measurements of the different posture tools to that of the “golden standard”, namely X-rays. Normal X-rays pose a threat to so called healthy learners, because of the high levels of radiation (Wall *et al* 2006). The low dose radiation system (LODOX system) made it possible for to evaluate the validity of this photographic postural method.

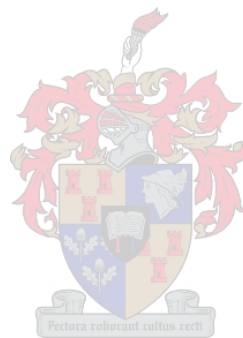
5.7 Clinical Implications of the PPAM in treatment

Reliability is related to stability, consistency, lack of random error and validity deals with accuracy, correctness, and the absence of systematic error, as well as the ability to make inferences (Sim *et al* 1993). In the clinical setting as well as in the research environment it is of utmost importance to have a reliable measurement tool, thus insuring that every measurement made will be consistent with the following measurements.

In a concurrent study conducted by a Physiotherapy masters candidate (Ms L Smith: ethics number N05/09/164) it was found that 74% of the high school learners in her study reported to have pain. She also found a strong correlation between computer use and pain. Headaches, lower back pain and neck pain was most prevalent. Grimmer *et al* (2006) and Siivola *et al* (2004) also found a correlation between headache, cervical and thoracic spine dysfunction and spinal posture. It is thus important to be able to measure the sitting posture of learners in their school environment.

Szeto *et al* (2002 and 2005) found that symptomatic office workers have significantly different sitting postures compared to asymptomatic office workers, due to different neck muscle recruitment patterns. Thus evaluation of office workers is equally important as the evaluation of high school learners in front of a desktop computer as they assume the same postures.

A reliable tool implies that difference in measurement reflects a true difference in the subject's performance. It further implies that the observed difference is not due to measurement error. It is therefore important that further studies should also look into tester reliability to provide insight into all aspects of reliability. Clinically it is important to know whether a patient is showing true progression or regression in relation to posture. De Bruin *et al* (1998) states that a measurement tool cannot be used for diagnostic purposes if it was found to be reliable, but not valid. Hence, according to the findings of this study the PPAM if tested on larger samples and different populations, it could be of value in clinical practice.



Chapter 6

CONCLUSION

This thesis reports on the reliability and validity of the newly developed Portable Posture Analysis Method (PPAM). The prevalence of spinal pain among high school learners is high as it was reported that 40% to 60% of learners suffer from spinal pain (Murphy *et al* 2002). This is the first study reporting on both the reliability and validity of three different postures in adolescents. Posture has been identified by some researchers to be a primary predictor of the development of spinal, particularly upper quadrant pain among computer users (NIOSH 1997, Vieira *et al* 1994). The prevalence of back pain increases across the teenage years and it is thus important to develop a valid and reliable posture measurement tool in adolescents (Grimmer & Williams 2000, Burton *et al* 1996).

Studies have been conducted to determine the reliability and validity of posture measurement tools including the goniometer, inclinometer, flexible electrogoniometer and flexicurve (Harrison *et al* 2005, Hinmann 2003/4, Lee *et al* 2003, Malmström *et al* 2003, Pringle 2003, Tousignant *et al* 2000 & 2001, Youdas *et al* 1991, Moffet *et al* 1989). The review findings presented in Chapter 2 also highlights the limitations of the published reliability and validity studies. Published studies have primarily included adults and there is thus little information on the reliability and validity of posture measurement tools on other age groups. The publications reviewed in Chapter 2 also highlights that only four studies have been conducted to establish the validity of upper quadrant position or posture.

This project determined the reliability of the PPAM by comparing 5 photos of healthy adolescent learners assuming a slouched, normal or upright seated posture, while simulating using a desktop computer. To determine the validity, 2 digital photos were compared to a low dose X-ray image. Clinically acceptable inter-class correlations were found for both the reliability and validity sections of the study for most angles. Further research into the

understanding of the variability observed in the thoracic angle in the validity study should explore how postural sway in adolescents influence sitting posture. The time-frame in which postural sway occurs and the degree of change should particularly be investigated in future studies.

These findings show that the PPAM may be a valid and reliable method for assessing the sitting posture of healthy learners while using a desktop computer. This system is portable, inexpensive and easy to use. These results warrant the next phase of testing learners in the school environment and determining the association of posture and pain.

6.1 The limitations of the study are as follows:

1. The planned sample size was 48 learners, but due to the availability of schools and learners on the days of testing the sample size was reduced to 39 learners. The withdrawal of two schools from the study compromised the external validity of the findings and therefore the generalisability of the study findings.
2. The researcher experienced difficulty in detecting the wooden sticks on which the markers for C7, T8 and the manubrium is placed, with the intellect 1.1.4 software. The researcher recommends that these wooden sticks be covered in retro-reflective material. This will ensure easier detection of the angle against which the marker is positioned on the body on the X-ray image and thereby the digitising process will be optimised.
3. The researcher also proposes that learners should keep their hands on actual keyboards for the duration of testing as this might decrease the large variance in the arm angle range that was found in this study. This variance was not evident from the limited pilot data since it was impossible to digitise most of the pilot study photos due to data capture problems.

4. The researcher was not able to conduct the validation study with the LODOX in the computer workstations at school as the LODOX is not portable. However a simulated workstation was created in the laboratory.

6.2 Recommendations for future studies are:

1. PPAM procedures must be validated in the school setting.
2. This study forms part of a bigger project aimed at promoting spinal health. The PPAM can be useful establishing the relationship between posture and pain by measuring the sitting posture in prospective studies.
3. The PPAM can also assist researchers in the design of ergonomically correct workstations for learners, in measuring their postures while sitting at the different prototype workstations. Future reliability and validity studies could thus involve different populations such as office workers, painful syndromes, etc.
4. The PPAM, when tested in larger samples, may enable the researchers to have an objective method of measuring the learners sitting posture, as well as an objective comparison with follow-up measurement. It may thus be useful as an objective outcome measure in intervention and preventative studies.
5. The reliability and validity of the PPAM must also be evaluated in other age groups as this study only included 15-16 year old learners.
6. Further research should also include larger randomised samples as this may provide a more robust method of evaluating this photographic postural method.

REFERENCES

1. Anderson VD, Bialocerkowski AE, Bennell KL. Test-retest reliability of glenohumeral internal and external rotation strength in chronic rotator cuff pathology. *Physical Therapy in Sport* 7. 2006. 115-121.
2. Bak K and Faunl P (1997): Clinicial findings in competitive swimmers with shoulder pain. *American Journal of Sports Medicine*, 70:470-476.
3. Beattie P (2001): Measurement of health outcomes in clinical setting: application to physiotherapy. *Physiotherapy theory and Practice*, 17, 173-185.
4. Beningfield S, Potgieter H, Nicol A, Van As S, Bowie G, Hering E and Latti E (2003): Report on a new type of trauma full-body digital X-ray machine. *Emergency Radiology*, 10: 23-29.
5. Bigliani LU, Codd TP, Connor PM and Levine WN (1997): Shoulder motion and laxity in the professional baseball player. *American Journal of Sports Medicine*, 25:609-613.
6. Bogduk N (1995): The anatomical basis for spinal pain syndromes. *Journal of Manipulative and Physiological Therapeutics*, 18 (9): 603-605.
7. Bullock, MP, Foster NE and Wright CC (2005): Shoulder impingement: the effect of sitting posture on shoulder pain and range of motion. *Manual Therapy*, 10(1): 28-37.
8. Burton AK, Clarke RD. McClune TD and Tillotson KM (1999): The natural history of low back pain in adolescents. *SPINE*, 21 (20): 2323-2328.

9. Chaffin DB, Andersson GB and Martin BJ. *Occupational Biomechanics*. 1999. 3rd edition. New York: Wiley.
10. Chen Y-L and Lee Y-H (1997): A non-invasive protocol for the determination of lumbo-sacral vertebral angle. *Clinical Biomechanics*, 12 (3): 185-189.
11. Christensen HW (1999): Precision and accuracy of an electrogoniometer. *Journal of Manipulative Physiological Therapy*, 22 (1): 10-14.
12. Christensen HW and Nilsson N (1998): Natural variation of cervical range of motion: a one way repeated measurement design. *Journal of Manipulative Physiological Therapy*, 21: 383-7
13. Crombie I 1996: The pocket guide to Critical Appraisal: A handbook for Health care Professionals, BMJ Publishing Group, London.
14. De Bruin ED, Rozendal RH and Stussi E (1998): Reliability of phase velocity measurements of tibial bone. *Physical Therapy*, 78:1166-1174.
15. DiVeta J, Walker ML and Skibinski B (1990): Relationship between performance of selected scapular muscles and scapular abduction in standing subjects. *Physical Therapy*, 70:470-476.
16. Ergonomic Workstations. <http://www.crosscom.com.sg/workstns.html> [Accessed November 20, 2006].
17. Evans, O. & Patterson, K. 2000. Predictors of neck and shoulder pain in non-secretarial computer users. *International Journal of Industrial Ergonomics*, 26:357-365

18. Feldman DE, Shrier I, Rossignol M and Abenheim L (2002): Risk factors for the development of neck and upper limb pain in adolescents. *SPINE*, 27 (5): 523-528.
19. Gaidosik R (1987): Clinical measurement of range of motion: review of goniometry emphasizing reliability and validity. *Physical Therapy*, 67:1867-1872.
20. Gillespie RM (2006): CAKE (Computer and Kids' Ergonomics) The Musculoskeletal Impact of Computer and Electronic Game Use on Children and Adolescents. [Http://www.education.umn.edu/kls/ecee/research.html](http://www.education.umn.edu/kls/ecee/research.html) [Accessed 20 November 2006]
21. Gosselin G, Rassoulain H and Brown I (2004): Effects of neck extensor muscles fatigue on balance. *Clinical Biomechanics*, 19(5): 473-479.
22. Grimmer K and Williams M (2000): Gender-age environmental associates of adolescent low back pain. *Applied Ergonomics*, 31 (4): 343-360.
23. Grimmer K, Nyland L and Milanese S (2006): Repeated measures of recent headache, neck and upper back pain in Australian adolescents. *Cephalalgia*, 26(7):843-851.
24. Grimmer KA, Williams MT and Gill TK (1999): The associations between adolescent head-on-neck posture, backpack weight, and anthropometric features. *SPINE*, 24 (21): 2262-2267.
25. Harrison D E, Haas JW, Cailliet R, Harrison DD, Holland B. and Janik TJ (2005): Concurrent validity of the flexicurve instrument measurements: Sagittal skin contour of the cervical spine compared with lateral cervical radiographic measurements. *Journal of Manipulative and Physiological Therapeutics*, 28 (8): 597-603.

26. Hinmann M (2003/2004): Interrater reliability of flexicurve postural measures among novice users. *Journal of Back and Musculoskeletal Rehabilitation*, 33-36.
27. Jaschinski W, Heuer H and Kylian H (1998): Preferred position of visual displays relative to the eyes: a field study of visual strain and individual differences. *Ergonomics*, 41(7): 1034-1049.
28. Jobe FW and Pink M (1993): Classification and treatment of shoulder dysfunction in the overhead athlete. *Journal of Orthopedic Sports Physio Therapy*, 18:427-432.
29. Johnson G, Bogduk N, Nowizke A and House D (1994): Anatomy and actions of the trapezius muscle. *Clinical Biomechanics*, 9:44-50.
30. Juul-Kristensen, B., Sogaard, K., Stroyer, J. & Jensen, C. 2004. Computer users' risk factors for developing shoulder, elbow and back symptoms. *Scandinavian Journal of Work Environmental Health*, 30(5):390-398
31. Kamkar A, Irrgang JJ and Whitney SL (1993): Nonoperative management of secondary shoulder impingement syndrome. *Journal of Orthopedic Sports Physio Therapy*, 17:212-224.
32. Kaplin HI and Sadock BJ (1991). Synopsis of Psychiatry: *Behavioural Science/ Clinical Psychiatry*. Williams and Wilkins.
33. Katrak P, Bialocerkowski AE, Massy-Westropp N, Kumar S and Grimmer KA (2004): A systematic review of the content of critical appraisal tools. *BMC Med Res Methodol*, 4:22

34. Kebaetse M, McClure P and Pratt NA (1999): Thoracic position effect on shoulder range of motion, strength, and three-dimensional scapular kinematics. *Arch Phys Med Rehabil*, 80(8): 945-950.
35. Keshner EA, Campbell D, Katz RT and Peterson BW (1989): Neck muscle activation patterns in humans during isometric head stabilization. *Experimental Brain Research*, 75:335-344.
36. Kibler WB (1998): The role of the scapula in athletic shoulder function. *American Journal of Sports Medicine*, 26:325-337.
37. Korovesis P, Koureas G, Zacharatos S and Papazisis Z (2005): Backpacks, Back Pain, Sagittal Spinal Curves and Trunk Alignment in Adolescents. *SPINE*, 30 (2): 247-255.
38. Lee CN, Robbins, DP, Roberts HJ, Feda JT, Bryan JM, Masullo L and Flynn TW (2003): Reliability and Validity of Single Inclinometer Measurements for Thoracic Spine Range of Motion. *Physiotherapy Canada*, 55(2): 73-78.
39. Leskinen T, Hall C, Rauas S, Ulin S, Tonnes M, Viikari-Juntura E and Takala EP (1997): Validation of portable ergonomic observation (PEO) method using opto electronic and video recordings. *Applied Ergonomics*, April 28 (2): 75-83.
40. Lewis JS, Wright C and Green A (2005): Subacromial impingement syndrome: the effect of changing posture on shoulder range of movement. *Journal of Orthopedic Sports Physio Therapy*, 35(2): 72-87.
41. Malmström, E, Karlberg, M, Melander, A Magnusson, M (2003): Zebris versus Myrin: A comparative study between a three-dimensional ultrasound movement analysis and an inclinometer/compass method. *SPINE*, 28(21):E433-E440.

42. Mandal, AC: Balanced sitting posture on forward sloping seat. <http://www.acmandal.com> [Accessed November 20, 2006]
43. McClure PW, Michener LA and Karduna AR (2006): Shoulder function and 3-dimensional scapular kinematics in people with and without shoulder impingement syndrome. *Physical Therapy*, 86(8):1075-1090.
44. McEvoy MP and Grimmer K (2005): Reliability of upright posture measurements in primary school children. *BMC Musculoskeletal disorders*, 6:35.
45. Ming Z, Närhi M and Siivola J (2004): Neck and shoulder pain related to computer use. *Pathophysiology*, 11 (2004): 51-56.
46. Moffet JAK, Hughes I and Griffiths P (1989): Measurement of cervical spine movements using a simple inclinometer. *Physiotherapy*, 76(6):309-312.
47. Morris SL and Allison GT (2006): Effects of abdominal muscle fatigue on anticipatory postural adjustments associated with arm raising. *Gait & Posture*, 24(3): 342-348.
48. Moseley JB Jr, Jobe FW, Pink M, Perry J and Tibone JE (1992): EMG analysis of the upper extremity in pitching. *Journal of Shoulder and Elbow Surgery*, 20:128-134.
49. Murphy S, Buckle P and 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 (2002): 365-370.
50. National Institute for Occupational Safety and Health (NIOSH). *Musculoskeletal disorders and work place factors*. Cincinnati, OH: US

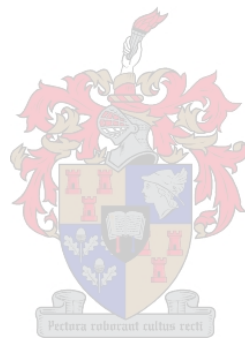
Department of Health and Human Services, 1997. Retrieved March 27, 2006, from:<http://ergonomics.uq.edu.au/download/pdf/97-141.pdf>

51. Niemi SM, Levoska S, Rekola KE and Keinanen-Kiukaanniemi SM (1997): Neck and shoulder symptoms of high school students and associated psychosocial factors. *Journal of Adolescent Health*, 20(3): 238-242.
52. Nitschke J, Nattrass CL, Disler PB, Chou MJ and Ooi KT (1999): Reliability of the American Medical Associations Model for measuring spinal range of motion: It's implication for whole-person impairment rating. *SPINE*, 24 (3): 262-268.
53. Norkin CC and Levangie PK. *Joint structure and function a comprehensive analysis*. 2005. Philadelphia PA: FA Davis Co.
54. Pink M and Jobe FW (1991): Shoulder injuries in athletes. *Journal of Orthopedic Sports Physical Therapy*, 18:427-432.
55. Portney LG and Watkins MP (2000). *Foundations of Clinical Research: Applications to Practice*. Prentice-Hall, Inc.: Upper Saddle River, NY.
56. Pringle RK (2003): Intra-instrument reliability of 4 goniometers. *Journal of Chiropractic Medicine*, 3(2): 91-95.
57. Quaranta LFM, Molle F, Scavino G and Dickmann A (1994): Identification of the preferential gaze position through elevation visual fatigue in a selected group of VDU operators. A preliminary study. *Doc Ophthalmol*, 87(2): 189-197.
58. Rhee H (2005): Relationships between physical symptoms and pubertal development. *Journal of Pediatric Health Care*, 19(2):95-103.

59. Sackett D, Richardson, Rosenberg W, Haynes R 2000: Evidence Based Medicine, Oxford Churchill Livingstone, UK
60. Schieppatti M, Nardone A and Schmid M (2003): Neck muscle fatigue affects postural control in man. *Neuroscience*, 121(3): 665.
61. Siivola SM, Levoska S, Latvala K, Hoskio E, Vanharanta H and Keinanen-Kiukaanniemi S (2004): Predictive factors for neck and shoulder pain: a longitudinal study in young adults. *SPINE*, 29(15):1662-1669.
62. Sim J, Arnell P, Campbell SK, Payton OD and Goldsmith CH (1993): Measurement validity in physical therapy research. *Physical Therapy*, 73(2):102-116.
63. Stratford PW and Goldsmith CH. Use of the standard error as a reliability index of interest: An applied example using elbow flexor strength data. *Physical therapy* Jul 1997 (77) 7.
64. Straker L, Jones KJ and Miller J (1997): A comparison of the postures assumed when using laptop computers and desktop computers. *Applied Ergonomics*, 28(4):263-268.
65. Szeto GPY, Straker L and Raine S (2002): A field comparison of neck and shoulder postures in symptomatic and asymptomatic office workers. *Applied Ergonomics*, 33 (2002): 75-84.
66. Szeto GPY, Straker LM and O'Sullivan PB (2005): A comparison of symptomatic and asymptomatic office workers performing monotonous keyboard work – 2: Neck and shoulder kinematics. *Manual Therapy*, 10 (2005): 281-291.

67. Szeto, G.P. & Lee, R. 2002. An ergonomic evaluation comparing desktop, notebook and subnotebook computers. *Archives of Physical Medicine Rehabilitation*, 83:527-532.
68. Tesio L, Monzani M, Gatti R and Franchignoni F (1995): Flexible Electrogoniometer: Kinesiological advantages with respect to potentiometric goniometers. *Clinical Biomechanics*, 10 (5): 275-277.
69. Tousignant M, Boucher N, Bourbonnais J, Gravelle T, Quesnel M and Brosseau L (2001): Intratester and intertester reliability of the Cybex electronic digital inclinometer (EDI-320) for measurement of active neck flexion and extension in healthy subjects. *Manual Therapy*, 6(4):235-241.
70. Tousignant M, Laurent de Bellefeuille, O'Donoghue S and Grahovac S (2000): Criterion Validity of the Cervical Range of Motion (CROM) Goniometer for Cervical Flexion and Extension. *SPINE*, 25(3): 324-330.
71. Trevelyan FC and Legg SJ (2006): Back pain in school children – Where to from here? *Applied Ergonomics*, 37 (2002): 45-54.
72. Vieira ER and Kumar S (2004): Working Postures: A Literature Review. *Journal of Occupational Rehabilitation*, 14 (2) 143-159.
73. Vikat A, Rimpela M, Salminen JJ, Rimpela A, Savolainen A, Virtanen SM (2000): Neck or shoulder pain and low back pain in Finnish adolescents. *Scandinavian Journal of Public Health*, 28(3):164-73.
74. Woollacott MH and Shumway-Cook A (1990): Changes in posture control across the life span – a systems approach. *Physical Therapy*, 70(12): 799-807.

75. Youdas JW, Carey JR and Garrett TR (1991): Reliability of measurements of cervical spine range of motion – Comparison of three methods. *Physical Therapy*, 71(2): 98-106.



APPENDICES

Appendix A: Systematic review table

Keywords	Pubmed	Cinahl	Science Direct	Cochrane	Embase	Author and Reference Search
* Reliability AND Goniometer AND Spine	25	2	6	1	33	
* Validity AND Goniometer AND Spine	11	6	3	4	23	
* Reliability AND Inclinator AND Spine	24	18	5	2	35	
* Validity AND Inclinator AND Spine	14	11	0	1	30	
* Reliability AND Flexicurve AND Spine	4	4	1	0	18	
* Validity AND Flexicurve AND Spine	1	1	1	0	10	
* Reliability AND Electrogoniometer AND Spine	4	3	3	1	48	
* Validity AND Electrogoniometer AND Spine	0	2	0	0	35	
* Photography AND Posture AND Analysis	0	1	9	0	0	
Straker <i>et al</i> 2002 and 2004, Chockalingam <i>et al</i> 2003, Murphy <i>et al</i> 2004, Christensen 1999, Nitschke <i>et al</i> 1999						6

Appendix B: The Crombie Scale

The complete list for the appraisal of cohort studies

<i>Questions</i>
The essential questions
1. Who exactly has been studied?
2. Was a control group used? Should one have been used?
3. How adequate was the follow-up?
<i>The detailed questions</i>
Design
4. Are the aims clearly stated?
5. Is the design appropriate to the stated aims?
6. Was the sample size justified?
7. Are the measurements likely to be valid and reliable?
8. Was the exposure/intervention accurately measured?
9. Were relevant outcome measures ignored?
10. Are the statistical methods described?
Conduct
11. Did untoward events occur during the study?
Analysis
12. Did the analysis allow for the passage of time?
13. Do the numbers add up?
14. Were the basic data adequately described?
15. Was the statistical significance assessed?
Interpretation
16. What do the main findings mean?
17. What else might influence the observed outcome?
18. How are null findings interpreted?
19. Are important findings overlooked?
20. How do the results compare with previous reports?
21. What implications does the study have for your practice?

Appendix C: Letter of invitation

To Whom It May Concern:

Re: Research project in conjunction with the Physiotherapy Department of the University of Stellenbosch.

With this letter I would like to invite your school to participate in a research project which forms part of a Masters Degree thesis in physiotherapy. Ethical approval has been obtained from the Ethics Board of the University of Stellenbosch (ethics number N06/05/092). This project aims at developing a method of assessing the way learners sit when they use a desktop computer. A recent study done in South Africa showed that 74% of high school learners suffer from pain when they use a desktop computer.

Learners aged 15 or 16 years, in grade 10 and who do Computer Studies as a subject, will be used. Markers will be placed on them and digital photos and a very low dose radiation X-ray will be taken. Certain angles will be calculated by using specialized software. The results will then indicate whether the newly developed method is a suitable way of measuring posture.

A talk aimed at the grade 10 learners will be held at your school, explaining the aim and the logistics of the project. Six learners per age group will be randomly selected; they will then receive a consent form which must be completed by a parent or legal guardian. Testing will take place on 22-23 August and 17 October 2006.

Please contact me should you require any further information with regard to this project. I will contact you in due course to enquire as to your participation.

Thank you

Sjan-Mari van Niekerk (B.Sc Physiotherapy)
Main researcher
083 715 6268

Prof Quinette Louw
Supervisor
021 9389301

Prof Kit Vaughn
Co-Supervisor
021 4066238

Appendix D: Consent Form

PARTICIPANT INFORMATION LEAFLET AND CONSENT FORM FOR USE BY PARENTS/LEGAL GUARDIANS

TITLE OF THE RESEARCH PROJECT:

Measuring the sitting posture of high school learners. A reliability and validity study

REFERENCE NUMBER:

PRINCIPAL INVESTIGATOR: Sjan-Mari van Niekerk

ADDRESS: 72 Jonkershoek Road, Stellenbosch, 7600.

CONTACT NUMBER: 083 715 6268

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 or doctor 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 project is to develop a tool that can be used to analyse the way high school learners sit when they use a desktop computer. In a previous study it was found that 74% of high school learners experience pain while using a desktop computer. One reason for this might be the way the learners sit while they use the computer. To determine this it is necessary to have a reliable and valid tool to analyse the sitting posture of high school learners.

Each learner will be tested twice on the same day. Seven non-invasive skin markers will be placed on him/her. With the first test, five digital photos will be taken of the learner while he/she sits in front of a desktop computer. With the second test a very low dose X-ray will be taken of the learner together with a series of digital photos. The learner will once again sit in front of a desktop computer while he/she is being tested for the second time.

Why has your child been invited to participate?

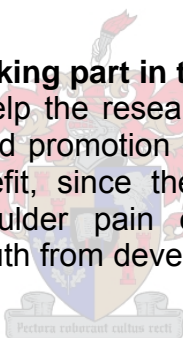
The 15 or 16 year old learners who have Computer Studies or Computyping as a school subject will be invited to participate in the study. Your child has been randomly selected from all the learners who showed an interest to participate in this project.

What will your responsibilities be?

You will be responsible for ensuring that your child is on time at the school on a Saturday morning when data collection will be conducted. Data collection will be conducted on a Saturday to avoid learners from missing any 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 learners 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?

The low dose X-ray machine poses very little risk for radiation to your child since research studies have shown that the low dose X-ray machine's radiation is 95% less than a usual X-ray. The lower the dose of radiation the lower the risks. This machine is now routinely used at Red Cross children's hospital to screen for injuries in children.

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 and video footage 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 of Human Physiology at UCT. 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, but your/your child's transport and meal costs will be covered for each study visit. There will be no costs involved for you if your child does take part.

Is there anything else that you should know or do?

- You can contact..... at tel..... if you have any further queries or encounter any problems.
- 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.
- 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
(To be written by the child if possible)

Independent witness

Declaration by parent/legal guardian

By signing below, I (*name of parent/legal guardian*)

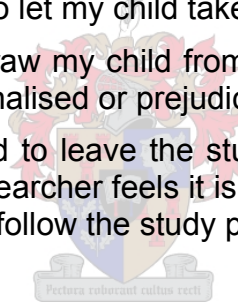
..... agree to allow my child (name of child)

..... who is years old, to take part in a

research study entitled (*insert title of study*)

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*)
..... 2006.

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 (if a translator is used, then the translator must sign the declaration below).

Signed at (place) on (date)
 2006.

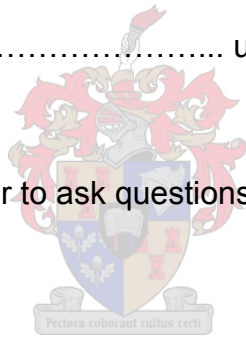
Signature of investigator

Signature of witness

DECLARATION BY TRANSLATOR

I (name) declare that:

2. I assisted the investigator (name)
 to explain the information in this document to (name of parent/legal guardian) using the language medium of Afrikaans/Xhosa.
3. We encouraged him/her to ask questions and took adequate time to answer them.
4. I conveyed a factually correct version of what was related to me.
5. I am satisfied that the parent/legal guardian fully understands the content of this informed consent document and has had all his/her questions satisfactorily answered.



Signed at (place) on (date)
 2006.

Signature of translator

Signature of witness

DEELNEMERINLIGTINGSBLAD EN -TOESTEMMINGSVORM VIR GEBRUIK DEUR OUERS/WETTIGE VOOGDE

TITEL VAN DIE NAVORSINGSPROJEK:

Meting van hoërskool leerders se sittende postuur. 'n Betroubaarheid- en geldigheidstudie.

VERWYSINGSNOMMER:

HOOFNAVORSER: Sjan-Mari van Niekerk (B.Sc. Fisioterapie)

ADRES: Jonkershoekweg 72, Stellenbosch, 7600.

KONTAKNOMMER: 083 715 6268

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 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 daarvoor 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 eniger 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 hierdie studie is om 'n metode te ontwikkel om die sittende postuur van hoërskool leerlinge te analiseer terwyl hulle 'n persoonlike rekenaar gebruik. In 'n vorige studie is gevind dat 74% van hoërskool leerders pyn ervaar terwyl hulle persoonlike rekenaars gebruik. Een rede hiervoor is moontlik die manier waarop hulle sit terwyl hulle die rekenaar gebruik. Dit is egter essensieel om 'n betroubare en geldige metode te ontwikkel om die sittende postuur van leerders te analiseer.

Waarom is u kind genooi om deel te neem?

Die 15 en 16 jarige leerders wie rekenaarvaardigheid of “Computyping” as skool vak neem is uitgenooi vir deelname aan die studie. U kind is lukraak gekies uit al die leerders wat belangstelling getoon het vir deelname in die projek.

Wat sal u verantwoordelikhede wees?

U sal verantwoordelik wees om u kind tydig by die skool te besorg op die Saterdag oggend wanneer die data opname sal plaasvind. Die data opname sal op 'n Saterdag plaasvind om te verhoed dat leerders enige 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 spier probleme.

Is daar enige risiko's verbonde aan u kind se deelname aan hierdie navorsing?

Die lae dosis x-straal masjien het 'n baie lae risiko vir bestraling vir u kind. Navorsing studies toon dat die lae dosis x-straal masjien bestraling is 95% laer as gewone x-strale. Hoe laer die dosis bestraling, hoe laer is die risiko. Hierdie masjien word nou by die Rooi Kruis kinderhospitaal gebruik om kinders te ondersoek vir beserings.

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 en video materiaal sal in 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 Menslike Fisiologie by Universiteit Kaapstad. 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, u of u kind sal nie betaal word vir deelname aan die projek nie, maar u/u kind se vervoer en etes ten opsigte van elke studiebesoek sal betaal word. Deelname aan die projek sal u niks kos nie.

Is daar enigiets anders wat u moet weet of doen?

- U kan dr kontak by tel indien u enige verdere vrae het of enige probleme ondervind.
- U kan die Komitee vir Mensnavorsing kontak by 021-938 9207 indien u enige bekommernis of klagte het wat nie bevredigend deur u studiedokter hanteer is nie.
- 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.

- Die studiedokter/verpleegster 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: (beskryf enige indringende prosedures, insluitende die trek van bloed, die opstel van druppe, ens.)
- 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 studiedokter gedwing is om deel te neem nie.

.....
Naam van kind

.....
Onafhanklike getuie

(Deur kind geskryf te word indien moontlik)

Verklaring deur ouer/wettig 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 (*Titel van projek*).

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 as 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.
- 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*)
..... 2006.

.....
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. (*Indien 'n tolk gebruik is, moet die tolk die onderstaande verklaring teken.*)

Geteken te (*plek*) op (*datum*) 2006.

.....
Handtekening van navorser

.....
Handtekening van getuie

VERKLARING DEUR TOLK

Ek (*naam*) verklaar dat:

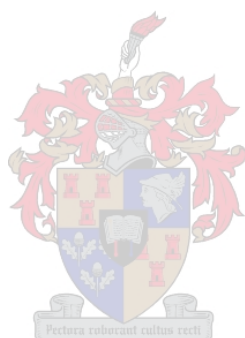
- Ek die navorser (*naam*) bygestaan het om die inligting in hierdie dokument in Afrikaans/Xhosa aan (*naam van ouer/wettige voog*) te verduidelik.
- Ons hom/haar aangemoedig het om vrae te vra en voldoende tyd gebruik het om dit te beantwoord.
- Ek 'n feitelik korrekte weergawe oorgedra het van wat aan my vertel is.
- Ek tevrede is dat die ouer/wettige voog die inhoud van hierdie dokument ten volle verstaan en dat al sy/haar vrae bevredigend beantwoord is.

Geteken te (*plek*) op (*datum*) 2006.

.....
Handtekening van tolk

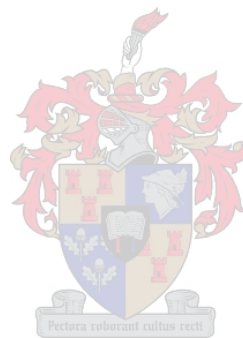
.....
Handtekening van getuie

Appendix E: Ethical Approval



Appendix F: Preliminary Data from Pilot Study

Subject 1	Photo 1	Photo 2	Photo 3	Photo 4	Photo 5
Sagittal head tilt	-166.3	-166.96	-169.21	-170.78	-172.97
Cervical angle	-21.56	-22.15	-23.4	-22.33	-26.63
Shoulder protraction/retraction	-98.54	-101.1	-94.41	-92.3	-91.01
Thoracic	56.09	57.26	54.24	54.59	54.79
Arm angle	-0.75	-1.84	-5.49	-3.40	-5.11



Appendix G: Pain Questionnaire

SCREEN TEST FOR UPPER QUADRANT MUSCULOSKELETAL PAIN AMONG HIGH SCHOOL CHILDREN

Name: _____
Gender: _____
Age _____
School: _____
Date: _____

Please answer the following questions:

1. Do you experience any discomfort, pain, stiffness or tingling in your muscles or joints at present?

Yes No

2. In which area of the body do you experience these feelings?

Head Left Hand Left Shoulder
 Lower Back Upper Back Right Shoulder
 Right Elbow Right Hand Left Elbow
 Neck Mid-Back

3. When do you experience these feelings in your muscles or joints?

Sitting in front of your school desk Doing School Work at home
 Working on a computer at school Working on a computer at home
 During or after sports Elsewhere

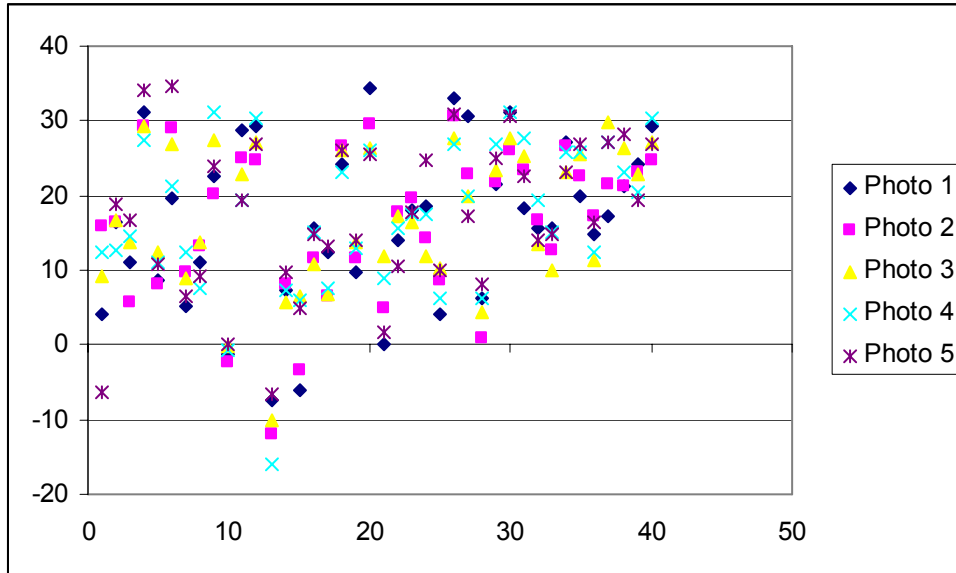
4. Do you know why you felt discomfort, pain or stiffness in your muscles or joints? If yes, please specify.

5. Choose a face that most accurately describes your level of pain presently?

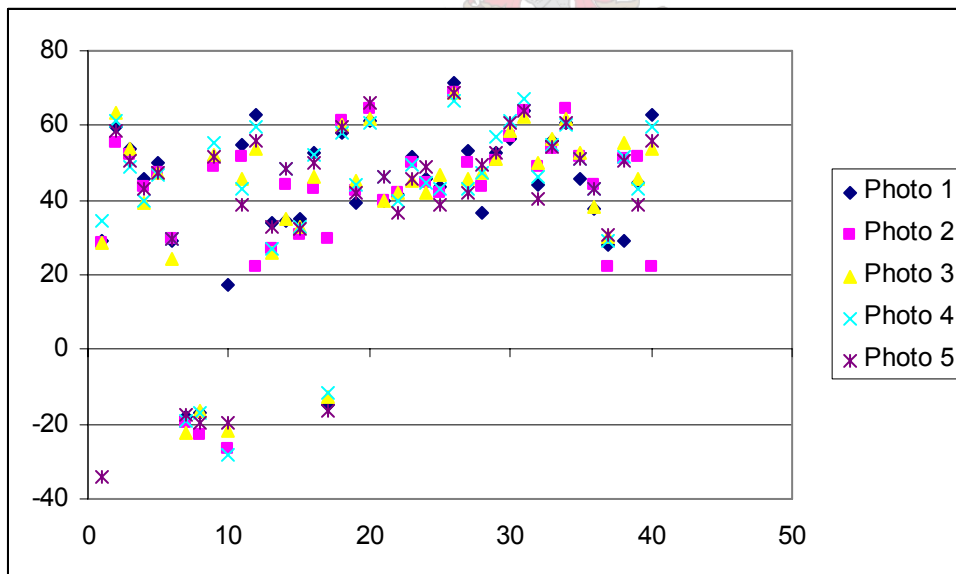
 No Pain  Mild Pain  Severe Pain

Appendix H: Scatterplots

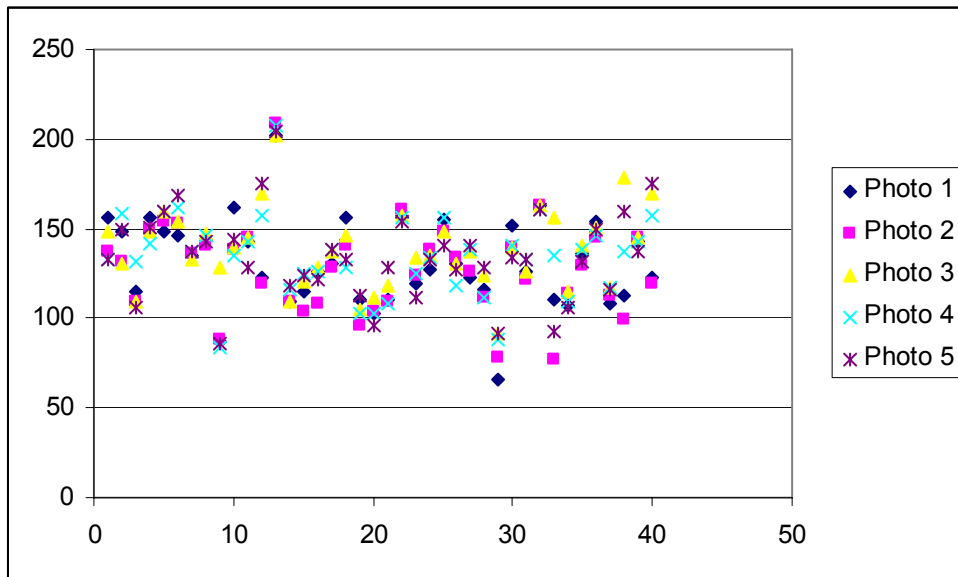
Sagittal Head Angle



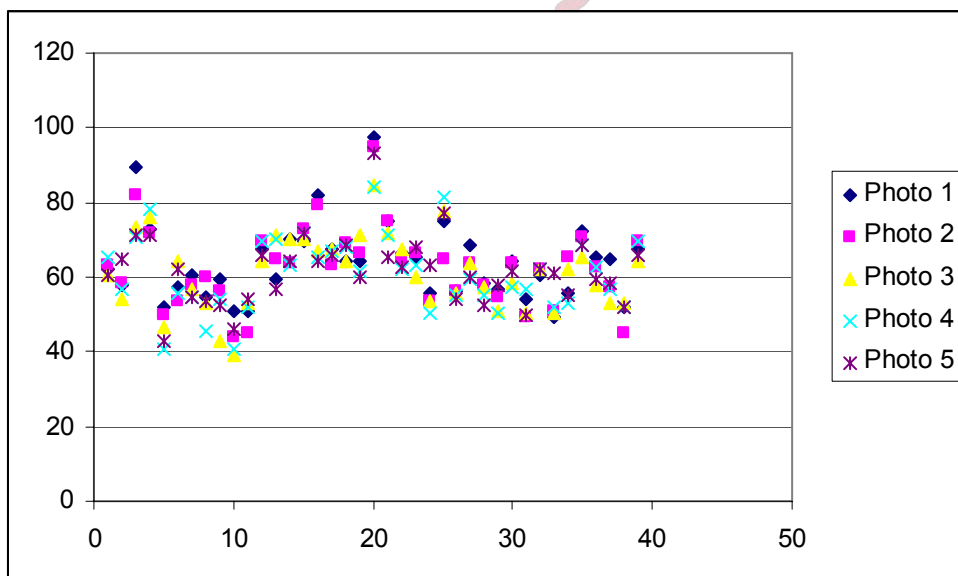
Cervical Angle



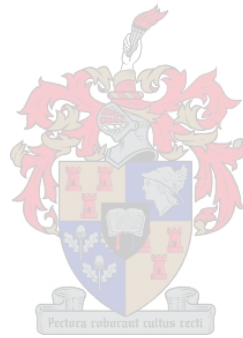
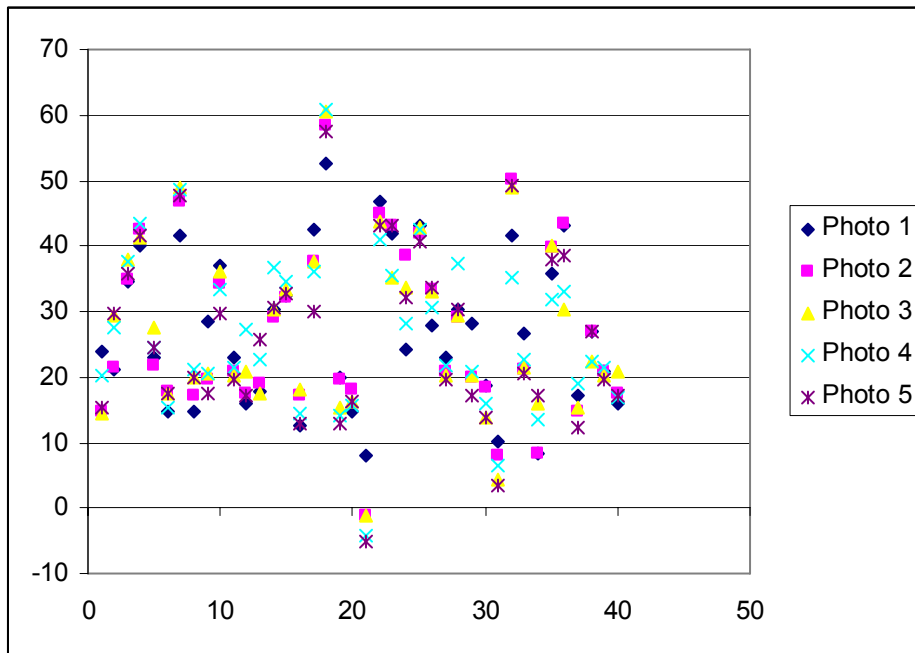
Protraction/retraction Angle



Thoracic Angle



Arm Angle



Appendix I: Learners with definite deviation in head posture

Photo 1



Photo 2



Photo 3



Photo 4



Photo 5



Photo 6



Photo 7



Photo 8



Photo 9



Photo 10



Navrae
Enquiries **Dr RS Cornelissen**
IMibuzo
Telefoon
Telephone **(021) 467-2286**
IFoni
Faks
Fax **(021) 425-7445**
IFeksi
Verwysing
Reference **20060915-0026**
ISalathiso



Wes-Kaap Onderwysdepartement

Western Cape Education Department

ISEBE leMfundo leNtshona Koloni

Ms Sjan-Mari Van Niekerk
72 Jonkershoek Road
STELLENBOSCH
7600

Dear Ms S. Van Niekerk

RESEARCH PROPOSAL: MEASUREMENT OF HIGH SCHOOL LEARNERS IN A SITTING POSTURE. A RELIABILITY AND VALIDITY STUDY.

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 **18th September 2006 to 22nd September 2006.**
6. No research can be conducted during the fourth term as schools are preparing and finalizing syllabi for examinations (October to December 2006).
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 following schools: **Settlers High, Simonstown High and Macassar Secondary.**
10. A brief summary of the content, findings and recommendations is provided to the Director: Education Research.
11. The Department receives a copy of the completed report/dissertation/thesis addressed to:

**The Director: Education Research
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: 15th September 2006

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