The prevalence of postural deformities among children age 11 to 13 years in some Western Cape Schools

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DECLARATION

I, the undersigned, hereby declare that the work contained in this thesis is my own original work and has not previously, in its entirety or partially, been submitted at any university for the purpose of obtaining a degree.

ABSTRACT

Postural deformities are a commonly encountered problem among children. Most of the aches and pains of adults are the result, not of injuries, but of the long-term effects of distortions in posture or alignment that have their origins in childhood or adolescence. Television, video entertainment, motorized transportation, fast food and lack of regular physical activity contribute to the poor physical condition of children. School screening for scoliosis is mandated in schools in 26 states of the United States (US) for children between 10 and 16 years of age. Previous studies conducted in the US found that 160 out of 1000 people suffer from scoliosis. This means that scoliosis is as prevalent as hypertension or diabetes mellitus (Boachie-Adjei & Lonner, 1996). Identification of postural deformities at an early stage makes early treatment possible, which may, in future, prevent serious postural abnormalities. The American Academy of Orthopedic Surgeons approved the implementation of screening programs in schools in 1974 (Lonstein, 1988).

Few studies have included the entire musculoskeletal system. The purpose of this study was to determine the prevalence of postural deformities among children aged 11 to 13 years in selected primary schools in the Western Cape. The study also proposes to investigate factors that may influence the prevalence rate of postural deformities. These factors included age, gender, school district, weight, height, BMI (Body Mass Index), fat%, waist-hip ratio, and physical activity.

Letters were sent to 15 primary schools within a 30km radius of Stellenbosch. This region included Stellenbosch, Strand, and Kuilsrivier. Four schools replied, giving permission to conduct the study at their schools. The sample (N=288, mean age=12.36, SD=0.92) consisted of 78 scholars from grade five; 104 scholars form grade six; and 106 scholars from grade seven. Of the total number of scholars examined (288), 154 were boys, and 134 were girls. Only children with parental consent were allowed to participate in the study. Anthropometric measures included stature, mass, skinfolds (two-site skinfold), waist- and hip circumferences and trochanterion leg length. Level of physical activity and family history of deformities were obtained by means of a questionnaire. The New York Posture Test was

used for postural evaluation (Bloomfield *et al.*, 1994:320; Reedco Inc., 2001. This Posture Test was designed for the screening of 13 categories of deformities. Using a "see-through" posture grid, lateral and posterior examinations were performed. The "Adam's position" (forward bending) was used for further scoliosis evaluation.

Quantitative data was analyzed, using Statistica (Statsoft, 2001) and classification tree methodology (Breiman *et al.*, 1993). The anthropometric results indicated that the subjects had a mean stature of 1.54m, mass of 47.48kg, BMI of 19.75, waist-hip ratio of 0.79 and fat% (Lohman, 1987) of 21.35%. The prevalence of postural deformities was as follows: Lordosis, 70%; Kyphosis, 57%; Uneven shoulders, 55%; Inclined trunk, 43%; Winged scapulae, 42%; Pronated feet, 30%; Flat feet, 30%; Flat chest, 29%; Forward head, 28%; Protruding abdomen, 28%; Uneven hips, 11%; Scoliosis, 10%; and Twisted head, 1%. Uneven hips, scoliosis and twisted head were not considered for statistical purposes, because of their low incidence compared to the other deformities. The factors that influenced the prevalence rate of deformities the most were BMI and fat%. A higher BMI and fat% resulted in a higher prevalence rate in most deformities.

The prevalence rate of postural deformities in this study was considerably high. Sedentary lifestyles of children (watching television, computer games, junk food and physical inactivity) were a contributing factor in the high prevalence rate of postural deformities. It is known that overweight and sedentary behavior of children is increasing and this could pose an alarming concern to the health of a child. Also, if a significant correlation does exist between the prevalence of postural deformities and conditions such as back pain, the high prevalence rate reported in this study is a matter of concern.

OPSOMMING

Postuurafwykings is 'n algemene probleem wat dikwels onder kinders voorkom. Baie van die skete en pyne by volwassenes spruit nie uit beserings nie, maar vanuit langtermyn gevolge van swak postuur wat hul oorsprong uit die kinderjare het. Televisie, videospeletjies, vervoer per motor, kitskos en gebrek aan fisieke aktiwiteit dra by tot die swak fisieke kondisie van kinders. Evalueringsprogramme in skole word in 26 state in die Verenigde State van Amerika (VSA) toegepas vir kinders tussen die ouderdomme van 10 en 16 jaar. Vorige studies in die VSA het getoon dat 160 uit 1000 mense skoliose het (Boachie-Adjei & Lonner, 1996). Dit beteken dat skoliose net so veel voorkom soos hipertensie of diabetes mellitus. Identifikasie van postuurafwykings op 'n vroeë stadium maak vroeë behandeling moontlik, wat in die toekoms ernstige postuurafwykings kan voorkom. Die "*American Academy of Orthopedic Surgeons*" het reeds in 1974 die implementering van assesseringsprogramme goedgekeur (Lonstein, 1988).

Volgens navorsing het slegs 'n beperkte aantal studies die hele spierskeletale stelsel geëvalueer. Die doel van hierdie studie was om die voorkoms van postuurafwykings by kinders tussen die ouderdomme van 11 en 13 jaar in geselekteerde Wes-Kaapse skole te bepaal. Die studie het ook faktore wat 'n invloed op die voorkoms van postuurafwykings kan hê, ingesluit. Hierdie faktore het onder andere ouderdom, geslag, skool, gewig, lengte, LMI (Liggaamsmassa-indeks), vet%, middel-heup-ratio en fisieke aktiwiteit ingesluit.

Uitnodigingsbriewe is na 15 laerskole binne 'n 30km radius vanaf Stellenbosch gestuur. Dit het ingesluit Stellenbosch, Strand, en Kuilsrivier. Vier skole het toestemming verleen om die studie by die betrokke skole te loods. Die steekproef (N=288, gemiddelde ouderdom = 12.36, SD=0.92) het bestaan uit 78 leerlinge uit graad vyf; 104 leerlinge uit graad ses en 106 leerlinge uit graad sewe. Uit die totale aantal leerlinge wat geëvalueer is, was daar 154 seuns en 134 dogters. Antropometriese metings het die volgende ingesluit: lengte, gewig, velvoue (twee-velvou meting), middel- en heupomtrekke en trochanterion beenlengte. Fisieke aktiwiteitsvlak en familiegeskiedenis van postuurafwykings is bepaal met behulp van 'n vraelys. Die "*New York Posture Test*" is gebruik vir postuurevaluasie (Bloomfield *et al.*,

1994:320; Reedco Inc., 2001). Hierdie toets is ontwerp vir die evaluering van 13 deformiteite. Die kinders is vanuit 'n posterior en anterior aansig ge-evalueer met behulp van 'n "deurskynende " postuurruitnet (grid). Die "*Adam's-*" toets (vooroorbuig-toets) is gebruik vir verdere evaluering van skoliose.

Statistica (StatSoft, 2001) en klassifikasieboom-metodologie (Breiman *et al.*, 1993) is gebruik vir statistiese ontleding. Die proefpersone het 'n gemiddelde lengte van 1.54m, gewig van 47.48kg, LMI van 19.75, middel-heup-ratio van 0.79 en vet% (Lohman, 1987) van 21.35% gehad. Die voorkoms van die onderskeie postuurafwykings was as volg: Lordose,70%; Kifose , 57%; Ongelyke skouers, 55%; Romp na posterior gebuig, 43%; Gevleuelde skapulas, 42%; Voetpronasie, 30%; Plat voete, 30%; Plat bors, 29%; Protraksie: skedel, 28%; Uitstaan buik, 28%; Ongelyke heupe, 11%; Skoliose, 10%; en Gekantelde hoof, 1%. Ongelyke heupe, skoliose en gekantelde hoof het minder voorgekom in vergelyking met die ander deformiteite, daarom is die deformiteite nie vir statistiese analise in aammerking gebring nie. LMI en vet% was die faktore wat die voorkoms van postuurafwykings die meeste beïnvloed het. 'n Hoër LMI en vet% het 'n toenemende voorkoms in meeste deformiteite veroorsaak.

Die voorkoms van postuurafwyking in hierdie studie was hoog. Sedentêre leefwyses van kinders (TV, rekenaarspeletjies, gemorskos, en fisieke onaktiwiteit) het bygedra tot die hoë voorkoms. Die voorkoms van oorgewig en sedentêre leefwyses is besig om te verhoog by kinders en kan ernstige gevolge vir die gesondheid van die kind inhou. Indien daar 'n betekenisvolle korrelasie tussen die voorkoms van postuurafwykings en kondisies soos rugpyn is, dan blyk die hoë voorkoms, wat in hierdie studie gevind is, 'n bron van bekommernis te wees. Postuurevalueringsprogramme is 'n effektiewe metode vir die vroeë identifikasie van postuurafwykings, aangesien dit vroeë identifikasie en konserwatiewe behandeling moontlik maak.

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Dedication

To my parents, Hennie and Susan Stroebel

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

CHAPTER 1

STATEMENT OF THE PROBLEM

1.1 INTRODUCTION

Posture means that the body as a whole or in part is held in a certain position. This definition for posture is indicative in several languages, e.g. in German "*haltung*", Afrikaans "*houding*", and French "*tenue*". The Latin word *"positura*", implies the same idea as it describes a state of having been "placed" or "arranged" (Shrecker, 1971:3). *Orthopedics* is Greek for "straight child," emphasizing the significance society places on deformity as well as the functional impact it may have on the child (Boachie-Adjei & Lonner, 1996).

For many years anatomists and kinesiologists have studied the body's ability to maintain a functional musculoskeletal balance between the forces of gravity and the muscular imbalances that normally occur in human beings (Kendall *et al*., 1977:5). When agonist muscles or muscle groups in the body are weak, a tightness or contraction of antagonist muscles or muscle groups compensates for this weakness. The body is subjected to these imbalances and therefore makes the necessary adjustments through deviations that attempt to maintain a correct musculoskeletal balance and correct posture. Postural deformities among children in primary and secondary schools are often associated with a lack of postural awareness. Although some musculoskeletal deformities are congenital, more are acquired (Francis & Bryce, 1987).

Whatever their cause, postural deformities are commonly encountered problems in the practices of the pediatrician and the orthopedic surgeon. It may dramatically change the physical appearance of the child and have a significant psychological impact on the child, particularly on the adolescent to whom self-image is important (Bloomfield *et al*., 1994:95; Boachie-Adjei & Lonner, 1996).

Bones and joints from the foot to the spine do not function independently but rely on the smooth function of one another to work properly and stay healthy. Mechanical and postural problems within any area of the foot, leg, hip or back will alter the way one bears his or her weight and the way one moves. This can produce continued stress in an area, which in return creates strain and new problems in related areas.

Conditions like flat feet, ankle pronation, bow legs, abnormal stride length, leg length differences, pelvic tilt, spinal abnormalities, weak asymmetric muscle strength and loss of flexibility, can disrupt the normal function of the back and lower extremities producing strain, pain and eventually irreversible postural deformities (Hargis, 1998).

Posture is unique to every individual and no two people have the same postures, although some are very similar. The determinants of a person's posture are linked to the structure and size of bones, the position of the bony landmark, injury and disease, static and dynamic living habits and the individual's psychological state (Bloomfield *et al.*, 1994:95).

1.2 PROBLEM

There is a growing concern that the current behavior patterns of children and youth may accelerate lifestyle-related diseases and result in higher incidence of postural problems. Children prefer to watch television, surf the Internet and play video games instead of engaging in more physically active leisure activities (Tremblay & Willms, 2000).

Children who spend hours surfing the net or sitting hunched over video games are running a high risk of damaging their backs and developing repetitive strain injuries. They are still developing their bone structure and muscle tension, therefore bad posture could cause debilitating pain for life. Most of the aches and pains of adults are the result, not of injuries, but of the long-term effects of distortions in posture or alignment that have their origins in childhood (Hargis, 1998).

The addictive nature of computer games makes them doubly hazardous because children spend hours in a position that is bad for their backs. Although most children may not currently experience any musculoskeletal discomfort due to working at computers, researchers are concerned that as children spend increasing time at computers, sitting in positions that put undue strain on their bodies, they may be more likely to develop postural deformities. The Australian Physiotherapy Association is concerned about the number of children seeking physiotherapy treatment for back, neck and shoulder pain caused by poor computer posture (Fullarton & Emmerson, 1999).

Recently scientists have begun to examine the effects of carrying heavy backpacks. A study at Auburn University, including 421 children found that backpacks carried with one strap increased the risk of lateral spinal bending and uneven shoulders. Additionally, they noted that carrying a backpack in this manner promoted significant forward leaning of the head and trunk (Pascoe *et al*., 1997).

These days children are transported by cars and busses and are spending less time carrying their backpacks. However, studies have shown that children are now carrying much heavier backpacks than in the past. A study by Negrini *et al*. (1999) showed that one third of Italian pupils, aged between 11 and 12 years, are carrying bags that weigh more than 30% of their body weight. Results of a study by Chansirinukor *et al*. (1999) revealed that both backpack weight and time carried influenced cervical and shoulder posture. Also, forward head posture increased when they carried a heavy backpack. An academy survey by 101 physicians disclosed that 58% had seen school-aged patients complaining of back and shoulder pain caused by heavy backpacks (Alexander, 1999). The impact of these complaints, caused by modern living, on children's spines makes them more vulnerable to chronic back pain.

It is believed that back pain probably coincides with bad postural habits. According to Fysh (2001) a Scandinavian study identified the prevalence of back pain in a group of 1 174 school children at 51%. A significant increase in back pain prevalence occurred at the age of 12 years and older. Children who watched television for extended periods were also more likely to suffer from back problems. Of those children who watched TV between 1-2 hours daily, 59% had suffered from back pain. When viewing time was increased to more than two hours daily, the prevalence of back pain increased to 68.8%. Studies across Europe (Balaque, 1999) have shown that back pain is very common amongst children. Approximately 55% of children experienced back pain at some stage.

Back pain has shown to be an enormous economic burden. In the UK at least five million adults consult their GP annually concerning back pain. This leads to costs in primary care of £140.6 million. At any given time 430 000 people in the UK are receiving Social Security payments primarily for back pain (Maniadakis & Gray, 2000). A *Medical World News* release stated that four out of five adult Americans suffer, will suffer, or have suffered from lower back pain and that $5 billion a year is spent on lower back treatments (Francis & Bryce, 1987). The only South African figures found was that of Delport *et al*. (1985) that reported a low back pain prevalence rate of 21.7% among males aged between 40 and 60 years. It is certain that back pain is one of the primary reasons for people visiting a doctor and thus could lead to a great economic burden.

A lack of physical activity shadows life in our age and as a result, formerly unknown, postural problems now appear. Physical activity is essential for good posture, as antigravity muscles must be strong and flexible to maintain skeletal balance. A prolonged lack of dynamic exercise results in the degeneration of bone tissue in the skeleton, primarily at the spinal column (Junghanns, 1986:165).

The steepest decline in physical activity is during the teen years and by high school, only a minority of adolescents are meeting health-related activity guidelines (Sallis, 2000). To make matters worse, schools have reduced the amount of time allocated to physical education. In some cases, only one hour a week is devoted to physical education, which is definitely inadequate when compared to the recommended minimum of 20 minutes a day (Laventure, 2000). According to the American Medical Association regular physical activity is linked to a wide array of physical and mental health benefits. According to this association, 85% of all five-year-old children in the United States cannot pass a basic physical fitness test (Loveless, 1999).

Physical activity is vital for weight control. Excess weight around the middle for example, can put additional stress on the posture muscles of the lower back. According to Gleick (1999) six million children in the United States are currently overweight, with an additional five million on the threshold. A study in Canada determined that the prevalence of obesity among children aged 7 to 13 years increased from 5% in 1981 to 13.5% in 1996. The prevalence of obesity more than doubled over that period (Tremblay & Willms, 2000). In The United States of America obesity has become such a concern that it lead to the development of so called "Fat Camps" in an attempt to counteract this problem of children becoming increasingly overweight (Gleick, 1999).

Tremblay and Willms (2000) also assessed changes in BMI over a 15-year period (1981-1996), using representative samples of Canadian children and youth. For children aged 11 to 13 years the average increases were 1.38 and 0.58 for boys and girls, respectively. Given that the study spanned over a 15-year period, the average increase is nearly 0.1 of a BMI unit per year. Moreover, the results indicate that BMI has increased from 1981 to 1996. According to the American Obesity Association, obesity increased from 7% in 1980 to 13% in 1999 for children aged 6 -11 years and from 5% to 14% in the 12-19 years age group. There is no published data examining secular changes in BMI for nationally representative samples of South African children. A review article by Walker (1972) showed that white South African boys are significantly heavier and taller than their American counterparts and that white South African girls, although slightly shorter, are heavier than American girls. These results can be a matter of concern, keeping in mind that six million children in the United States are currently overweight (Gleick, 1999). However, the data of Walker (1972) is now 30 years old and trends could have changed, but still these results indicate that the problem of overweight children does exist in South Africa.

Children are already showing up in record numbers with inactivity and weight-related health risks previously only seen in adults. If a relationship exists between BMI, inactivity and the prevalence of postural deformities, these secular trends in BMI and physical inactivity would appear to be alarming.

The increase in spinal problems, such as lower back pain in adolescents, points to the need for continued screening. A study in the United States found that up to 56% of teenage spines are deformed. The culprit was identified as poor posture and extended sitting during growth spurts (Newbound, 2002). Screening can help determine some of these risk factors, such as poor posture. In addition children can be provided with educational counseling on proper spinal health and correct posture (Mertz, 2000).

Although there are numerous causes of spinal deformity in the pediatric population, scoliosis, kyphosis and lordosis account for most of these conditions (Phelps *et al.*, 1956:144; Shtern, 1975; Lonstein, 1977; Boachie-Adjei & Lonner, 1996). Francis & Bryce (1987) affirmed that spinal screening for scoliosis, kyphosis and lordosis is a proven program, which should be implemented in all schools. In 1974 the American Academy of Orthopaedic Surgeons released the following statement on the importance of screening programs:

> The American Academy of Orthopaedic Surgeons hereby gives its official recommendation to any program of routine examination of school children for the detection of scoliosis and other crippling spine deformities. The Academy recognizes that by early detection more appropriate treatment can be given and a better total treatment of this disabling health problem can be carried out (Lonstein, 1977:35).

It is important to conduct periodic screening programs for the possible detection of postural deformities, particularly during the growth spurts as conservative measures of treatment could still be possible at this stage. Lonstein (1988:1198) made the following statement:

> Screening is defined as the presumptive identification of unrecognized disease or defect by the application of tests, examination, or other procedures that can be applied rapidly. A screening test is designed to detect people at risk for disease.

It is evident from these statements that the stated goals of screening for postural deformities are early diagnosis, early appropriate referral for non-operative treatment and prevention of progression (Lonstein, 1988; Mertz, 2000).

1.3 AIM OF THE STUDY

Interest in scoliosis and in the spine in general, has increased greatly (Baker & Zangger, 1970; Kane & Moe, 1970; Grant *et al.*, 1973; Segil, 1974; Sells & May, 1974; Lonstein, 1977; Francis & Bryce, 1987). However, there is a lack of comparable research completed in the broad spectrum of postural deformities. The majority of screening programs are aimed at the detection of scoliosis only. This study aims to include almost the entire musculoskeletal system.

It is clear that children are engaging in much different activities than they did 10 years ago. However, there seems to be a lack of awareness concerning this situation. Most parents are not aware of the detrimental effects these changes may have on their children's physical development. Good posture is very hard to establish once used to bad postural habits for many years. Parents are concerned about posture, but they think it is voluntary and just a matter of disciplining their children e.g. "Stand up straight!" or "Pull your shoulders back!"

Posture though, is not just a voluntary matter, and children do not usually outgrow posture problems (Roaf, 1977:8).

The main purpose of this study is to determine the prevalence of postural deformities among children in selected primary schools in the Western Cape. The study also proposes to investigate factors, such as physical inactivity and overweight, that may contribute to the appearances of these deformities.

1.4 TERMINOLOGY

Clarity was needed in the sense of describing postural problems. *Postural deformity*, *postural deviation*, and *postural defect* are terms that are used interchangeably among several authors. Stedman's Medical Dictionary (Stedman, 1990) define these terms as follows:

- Deformity: A deformation; a deviation from the normal shape or size resulting in disfigurement; it may be congenital or acquired.
- *Deviation*: A turning away or aside from the normal point or course; an abnormality.
- *Defect*: An imperfection, malformation, dysfunction, or absence.

For the purpose of this study the researcher prefers to use the term, *postural deformity*.

CHAPTER 2

LITERATURE STUDY

2.1 INTRODUCTION

This chapter aims to define the concept of good posture, analyze normal postural development and postural deformities, present examination and treatment procedures and discuss some of the developmental factors affecting posture.

Posture is a concept that goes back as far as the early Greek times, when already then emphasis was laid on "good posture" (Solberg, 1993). In the last Victorian half century (1850–1902) it was common for physical educators to be preoccupied with "posture".

Good posture is a good habit. Once well established, it should take little voluntary effort to maintain it. Attainment of good posture should not be seen as a rigid disciplinary measure, but rather as a habit that contributes to the general health of the individual. Conversely bad posture is a bad habit and has become a condition of relatively high incidence (Cailliet, 1975:45; Kendall *et al*., 1977:1; Junghanns, 1986:84; Newbound, 2002).

If postural deformities were simply an aesthetic problem the concern about them might be limited to appearance. However, it must be recognized that postural faults that persist into adulthood may cause discomfort, pain or a permanent deformity (Kendall *et al*., 1977:1).

Views and ideas concerning correct posture have changed a great deal. The physical educators and hygienists were once dogmatic about it, and rigid standards were established (Watson & Lowrey, 1962:98). Good posture is not an end in itself but a part of general well being. While correction of postural deformities requires the use of special therapeutic measures, the prevention of faults depends to a great extent on teaching the fundamental aspects of proper alignment (Kendall *et al*., 1993:114).

Overall screening for postural deformities with the use of a simple test appears to be an effective means for the early detection and non-operative treatment of postural deformities.

Furthermore, school screening programs generate invaluable data regarding, not only the prevalence, but also the natural history of postural deformities. Such data is fundamental to understand the development of postural faults and, ultimately, its treatment (Soucacos *et al.*, 1997).

2.2 NORMAL POSTURAL DEVELOPMENT

To diagnose postural abnormalities in children, one must know the normal range of spinal curvatures and alignment, as well as postural characteristics at different ages.

2.2.1 NORMAL CURVATURES AND ANGLES

In the coronal or frontal plane, represented by an anteroposterior radiograph, no deviation from the midline should be present. There is a wider range of normal curvature in the sagittal plane represented by a radiograph of the spine. Moreover, the degree of curvature varies within regions of the spine so that thoracic kyphosis changes, for example, depending on levels of the spine measured. For the purpose of this study and for a general understanding of the pediatric spine, average values for the entire thoracic spine and lumbar spine are provided here for simplicity (Junghanns, 1986:33; Boachie-Adjei & Lonner, 1996).

The normal range of thoracic kyphosis is 20 – 45 degrees, and the range for lumbar lordosis, 25 – 60 degrees (Figure 1). In figure 1 the superior to inferior plumb line is indicated by x. At the junction of the thoracic and lumbar spine, there should be a straight spine, or only slight kyphosis. The apex of thoracic kyphosis normally lies at the T6-7 (thoracic vertebrae 6 to 7) level, and the apex of lumbar lordosis generally falls at the L3-4 (lumbar vertebrae 3 to 4) level (Cailliet, 1975:21; Bernhardt & Bridwell, 1989).

Normally, there should be minimum or no rotation of the spine, which is assessed by viewing the location of the pedicles on an anteroposterior radiograph of the spine. Each pedicle should be located at the lateral margins of the vertebral body (Nash & Moe, 1970; Boachie-Adjei & Lonner, 1996).

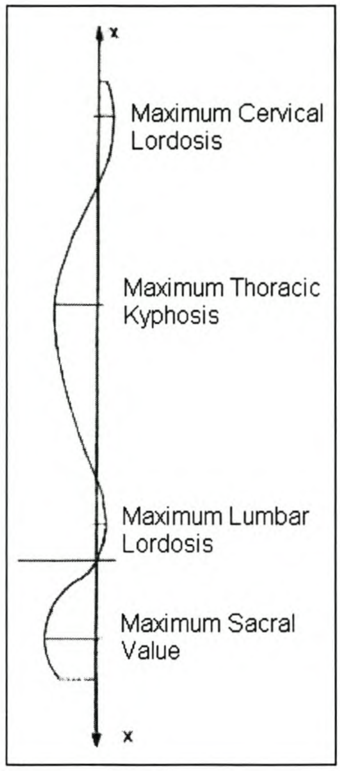


FIGURE 1: NORMAL SPINAL ALIGNMENT AS SEEN IN THE SAGITTAL PLANE (ANTEROPOSTERIOR PLANE) (JUNGHANNS, 1986:33)

2.2.2 AGE-RELATED CHANGES IN POSTURE

Posture changes with age. There are many factors involved, but according to Watson and Lowrey (1962:98) the two important ones are the variations of spinal curvature and the shifting center of gravity.

Curves that are found at birth are called primary curves. These curves maintain the original position found during birth. The thoracic spine and sacrum are classified as primary curves of the spine. During child growth secondary curves develop that are convexed forward or extended (Magee, 1987:377).

At birth the entire presacral vertebral column is extremely flexible, and has the shape of a single C curve (Watson & Lowrey, 1962:99; Sherrill, 1993:371). In the cervical spine, at about the age of three months, when the child starts lifting the head, the cervical spine becomes convexed forward, developing a cervical lordosis (Magee, 1987:377).

In the lumbar spine, at about the age of six to eight months the secondary curve develops when the child begins to sit up and walk. Young children with disabilities, that prevent upright locomotion, characteristically have *flat backs*. This condition is normal during the months when the child is gaining confidence in walking and running. However, if flat back persists beyond the toddler stage it is considered a postural deformity (Magee, 1987:377; Sherrill, 1993:371).

Generally the normal preschool child has an exaggerated lumbar curve, or excessive lordosis that may persist throughout elementary school (Sherrill, 1993:378). This accentuated curve is due to presence of large abdominal contents, which constitutes the *protruding abdomen*, weakness of the abdominal muscles and the small pelvis is a normal feature at this age (Watson & Lowrey, 1962:99; Kendall *et al.*, 1977:172; Magee, 1987:379).

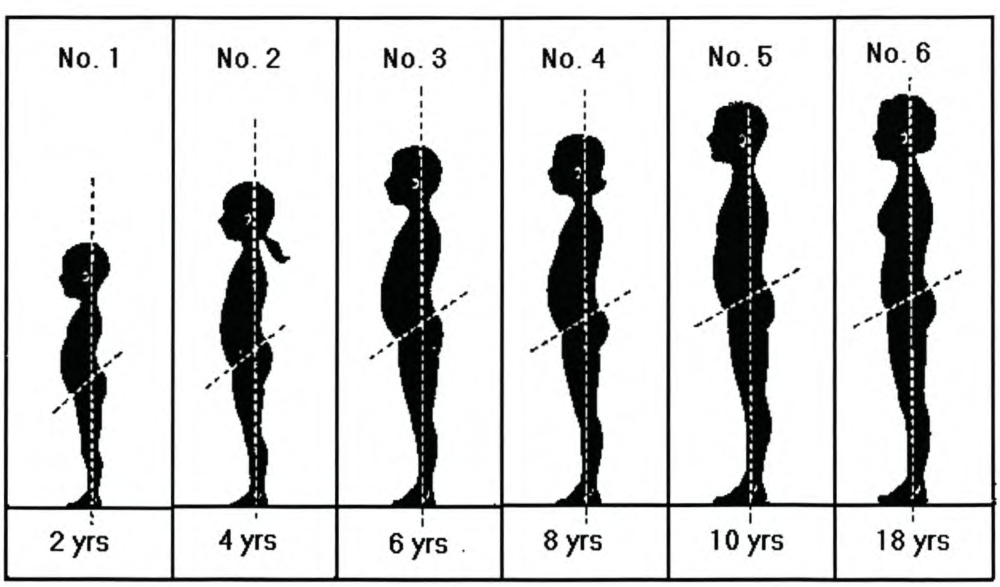


FIGURE 2: POSTURAL CHANGES WITH AGE (MAGEE, 1987:378)

In a preschool child, the center of gravity is at the level of the T12 vertebra. As the child grows older, the center of gravity drops to reach the level of the second sacral vertebra. The child will stand with a wide base of support and knees will be flexed (Magee, 1987:377; McCoy & Dickens, 1997).

During the first two to three years after an erect posture is assumed, the feet are relatively flat and the lower limbs start to show a posture of knock knees (inward bowing of the legs from knees to ankle) (Watson & Lowrey, 1962:99). By four to five years, most children develop a medial longitudinal arch in their feet and are no longer flat-footed. The knock-kneed posture corrects by the age of seven to eight years (McCoy & Dickens, 1997).

In the early school period, the child has the feature of round shoulders, and is minimally influenced by exercise (Watson & Lowrey, 1962:100).

According to Magee (1987:378) apparent kyphosis at ages six and eight is due to scapular winging. The reason for this may stem from the fact that winged scapulae are usually accompanied by round shoulders. This may alter the normal mechanics of the neck and back, resulting in a possible kyphosis (Arnheim & Prentice 2000:708). According to Kendall *et al.* (1977:177,178) the degree of scapular winging is normal for children of about eight years. By the age of seven, a child's posture is nearly identical to that of an adult (McCoy & Dickens, 1997).

2.3 BONE GROWTH AND DEVELOPMENT

The growth of the skeleton determines the size and proportions of the body. The bony skeleton begins to form about six weeks after fertilization, when the embryo is approximately 12mm long. During subsequent development, the bones undergo a tremendous increase in size. Bone growth continues through adolescence, and portions of the skeleton (clavicle, vertebrae) do not stop growing until age 25 (Martini, 1995:181).

2.3.1 OSSIFICATION

Ossification is the process of forming new bone (White, 1991:22; Martini, 1995:181). According to Meiring *et al.* (1994:46) there are two forms of ossification namely, intramembranous ossification and endochondral ossification. The only difference between the two mechanisms of ossification is the environment in which ossification occurs, but there is no difference between the type of bone produced (White, 1991:22).

a) Intramembranous ossification

In intramembranous ossification, bones ossify by apposition on tissue within an embryonic connective tissue membrane. Most dermal bones (e.g. parietal bones of the cranial vault, the mandible and clavicle) form as result of this form of ossification (Steele & Bramblett, 1988:13; Martini, 1995:181). Intramembranous ossification occurs as follows:

- **Step 1:** The ossification process begins through the mesenchymal cells that aggregate and differentiate. Osteoblasts cluster together and secrete the organic components of the matrix. The osteoblasts are trapped inside bony pockets and start to differentiate into osteocytes.

- **Step 2:** The developing bone grows outward from the ossification center in small struts, called spicules. The spicules interconnect and trap the blood vessels within the bone.

- **Step 3:** Over time, the bone assumes the structure of spongy bone. Areas of spongy bone may later be removed creating marrow cavities. Subsequent remodeling around the trapped blood vessels can produce compact bone (Meiring *et al.,* 1994:48; Martini, 1995:182).

b) Endochondral ossification

Most bones of the skeleton, however, grow through endochondral ossification, which is the process of converting cartilage into new bone (Steele & Bramblett, 1988:13; White, 1991:22; Martini, 1995:182). Endochondral ossification occurs as follows:

- **Step 1:** Blood vessels invade the cartilage model, and osteoblast activity begins in cartilage lacuae localized in one or more ossification centers. The shaft of the cartilage becomes ensheathed in a superficial layer of bone. The body formed by this process is called the diaphysis.

- **Step 2:** Blood vessels penetrate the cartilage and invade the central area, growing toward the epiphyses at either end. Fibroblasts differentiate into osteoblasts that start producing spongy bone.

- **Step 3:** As growth continues, remodeling creates a marrow cavity. The bone becomes thicker, and shafts of bone replace the cartilage near each epiphysis. Much of the longitudinal growth of a long bone occurs at the epiphyseal plate. The bone now grows in length and diameter. (Steele & Bramblett, 1988:14; White, 1991:23; Haywood, 1993:57; Meiring *et al.*, 1994:47; Martini, 1995:183).

The times that various epiphyseal ossification centers appear, are reliable indicators of the skeletal age and growth patterns throughout childhood. The last epiphyseal joint to close, is the medial end of the clavicle, which ossifies at about age 20-25 years (Watson & Lowrey, 1962:240-258; Martini, 1995:181).

About 5% - 10% of our existing bone is replaced each year throughout our lives. The process gradually slows as we get older, resulting in brittle bones (Martini, 1995:191). The age at which this occurs is determined individually, as it has been recognized that healthier individuals will have stronger bones, thus delaying this process of gradual bone loss (Junghanns, 1986:165; Bass & Kerr, 2000).

Growth monitoring is an important technique for identifying individuals, groups or communities whose growth is not keeping up with the expected pattern. Poor growth, whether as a result of infection, malnutrition or other cause, needs to be detected in order for correction to take place.

2.3.2 PHYSICAL ACTIVITY VS. BONE DEVELOPMENT

According to Bass and Kerr (2000) peak bone mineral density (BMD) is the maximal lifetime amount of bone tissue accrued in the skeleton during growth. It can be a more important determinant of low BMD in older people than age-related bone loss. Maximizing the attainment of peak bone mass is considered to be an important component for the prevention of osteoporosis. Bass and Kerr (2000) state that physical activity and diet may be the most important modifiable environmental factors that can increase peak BMD in both children and adults.

Habitual physical activity has been recognized as an important component of a healthy lifestyle. Exercise is known to increase bone development in teenagers (Junghanns, 1986:165; Haywood, 1993:80).

Long-term physical activity, with moderate intensity, promotes bone density and might increase the diameter of bones. Bone adapts favorably to the stimulation that physical activity provides (Haywood, 1993:80).

A sustained level of activity leads to greater peak bone mass, as demonstrated by a 15-year longitudinal study in the Netherlands in which physical activity over time was correlated with the lumbar bone mineral density at the age of 27 years (Welten *et al*., 1994).

According to Rodrigues *et al*. (1988) immobility during fetal development, which may result from neuromuscular diseases, leads to reduced skeleton size, with smaller bone cross-section.

A study by Lloyed *et al*. (2000) concluded that the amount of exercise a teenage girl gets between the ages of 12 and 18 years is an important determinant in the density and strength of the proximal femur, and thus a crucial factor in the prevention of hip fractures due to osteoporosis in postmenopausal women.

According to Twisk (2001) research done with adults indicate that particularly vigorous physical activity can prevent osteoporosis, while research by Welten *et al*. (1994) has demonstrated that this is probably also the case for children and adolescents.

Results of many retrospective studies support the notion that physical activity in non-athletic children is associated with higher BMD in adults. However, how much or how often children need to exercise to elicit a clinically important increase in bone density is unknown. It is also not known how long children need to exercise before residual benefits will be maintained into adulthood. The time during growth when exercise results in the greatest osteotrophic response is also a topic for further investigation (Bass & Kerr, 2000).

Kemper *et al.* (1976) studied the effect of a 5 versus 3-lesson-a-week physical education program on the physical development of 12 and 13 year old schoolboys. Achievement in physical education and performance in handgrip were the only variables that showed a significant increase. The effects of two extra lessons of physical education could not be confirmed. A possible reason my stem from the fact that a control group was not used in this study.

A recent study by Janz *et al.* (2001) was the first to examine the effects of low-impact everyday activities on bone density in children. High motion levels and physical activity ratings were associated with higher bone density and mineral content in both boys and girls. Comparisons showed a 12% greater hipbone content in the most active children, compared to children in the least active group. Also, girls who watched more television tended to have lower bone densities than those who watched less. Boys showed a greater level of total physical and vigorous activity than girls, which may account for their higher bone densities. These findings suggest that exercise, or even mild physical activity, may increase bone density in children.

2.4 POSTURAL DEFORMITIES

In order to recognize postural deformities one needs to have a clear understanding of what "normal", or "good", posture is. The concept of posture is employed in many ways, yet its exact definition is elusive. Different definitions may be found in the literature pertaining to posture.

According to Delisle (1995) you have proper posture when your body is in segmental alignment. A body is segmentally aligned when the shoulders, hips, knees and ankles are level on both sides when viewed from the front, and is directly above one another when looked at from the side. There are no twists, rotations, tilts or imbalances, and knees and feet point straight ahead.

Kendall *et al.* (1977:5) describe a "standard posture" and refer to an "ideal" posture rather than an average posture. In the standard posture, the spine presents the normal curves and the bones of the lower extremities are in ideal alignment for weight bearing. The "neutral" position of the pelvis is conducive to good alignment of the abdomen and trunk, and that of the extremities below. The chest and upper back are in a position that favors optimal function of the respiratory organs. The head is erect in a well-balanced position that minimizes stress on the neck musculature (Kendall *et al.*, 1993:5).

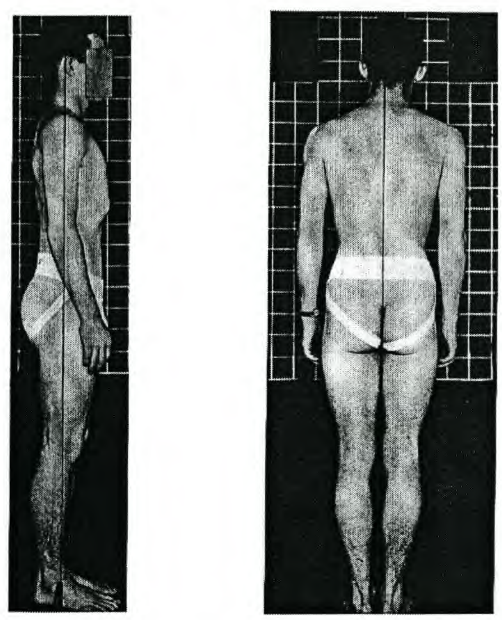


FIGURE 3: STANDARD POSTURE (KENDALL *ET AL.*, 1977:9,11)

For several generations too much emphasis had been placed on a plumb line and a "military standard." Roaf (1977:2) argued that it is impossible to define bad or abnormal posture. He preferred to define posture as the position the body assumes in preparation for the next movement. According to Roaf (1977:2) mere uprightness, which is static, is not true posture.

According to Schrecker (1971:3), good posture, in general terms, means a free and erect carriage of the body, in standing and other positions, as well as in walking and running.

Psychologists have contributed to the moving concept, describing posture as an adjustment mainly in the erect position, which does not necessarily mean standing as it pertains to problems of locomotion, manipulation and gestural communications. Posture is thus specie's adjustment to the environment, and applies both to the maintained and the changing relations of different parts of the body to each other and to the surrounding media or surfaces (Phelps *et al*., 1956:59).

Normal posture may be defined as the average or mean of a large number of postural evaluations under similar environmental conditions. There would be, within this normal, many other "normals", if the large group were to be divided into body types. Thus, another difficulty in identifying postural principles arises from the many varieties of human physique. The normal for the slender or linear type would be different from the normal for the obese or fat type. Judgment of posture should depend, not on the question of slenderness or obesity, but on the mechanical efficiency of the position. The mechanics of the individual must be evaluated as a whole (Phelps *et al*., 1956:59).

Thus the habitual or mean posture of the individual represents a combination of effects, namely, species' adaptation, genetic conditioning and individual responses to behavioral and environmental factors (Phelps *et al*., 1956:59).

Notwithstanding the above, posture-awareness has become a fundamental concern in almost every part of our daily activities. This researcher contends, therefore, that there is value in making efforts to understand some mechanical aspects of good body alignment.

Chukuka *et al*. (1986) found that the tension in the upper portion of the trapezius muscle was significantly greater in a mechanically inefficient "forward head" position.

Wells and Luttgens (1976:403-405) concluded that the skeletal structure should be architecturally and mechanically sound so that there is a minimum of strain on the weight bearing joints, and pressure within the joints equalizes. In the growing scoliotic spine, the loss of mechanical stability directly affects the vertebral bodies, the facet, and the growth endochondral zones at intervertebral load-transfer areas (Harrington, 1977).

Gluckman (1995) stated that correct segmental alignment allows the body to move fluently and efficiently. The bones move in such a way that gravitational force is evenly distributed across joint surfaces. Proper segmental alignment permits the internal organs to function properly. Overall, good posture allows the body to perform its daily functions with less effort and energy (Hellebrandt, 1938; Gluckman, 1995).

Forward head, flat chest, uneven shoulder, inclined trunk, protruding abdomen, uneven hips, and pronated feet are deformities that usually occur in combination with other deformities. For the purpose of this study it will be discussed with the other deformities. Scoliosis, kyphosis, lordosis, winged scapulae and flat feet will be discussed in detail.

2.4.1 SCOLIOSIS

Scoliosis is the most deforming orthopedic problem found during childhood. It is a potentially progressive condition that affects children during their active growth phase and essentially subsides upon completion of spinal growth, which can leave a child with a marked deformity (Cailliet, 1975:v). According to Loveless (1999) scoliosis is the most common of all deformities evaluated in the primary care setting.

a) Definition

Scoliosis, a term of antiquity first used by Hippocrates (460 – 377 BC), implies abnormal curvature of the spine (Cailliet, 1975:1). Shrecker (1965:39) defines scoliosis as a lateral curvature of the spine. According to Loveless (1999) scoliosis refers to a lateral deviation of the spine in the coronal plane. Benetti and Podesta (1991) define scoliosis as a lateral deviation of the spine, often associated with vertebral rotation and twisting of the longitudinal axis. Magee (1987:147) defines scoliosis as a deformity in which there are one or more lateral curvatures of the lumbar or thoracic spine. Magee (1987:147) defined scoliosis as torticollis, should the lateral curvature be situated in the cervical spine. According to Cailliet (1975:19) scoliosis is by definition lateral rotatory deforming curving of the spine. Many definitions exist, but in general it is a term used to describe any lateral curvature of the spine (Phelps *et al.*, 1956:73; Kendall *et al.*, 1977:195; Roaf, 1977:41; Stedman, 1990:1394; Arnheim & Prentice, 2000:709).

b) *Etiology*

Intensive research is being carried out throughout the world, but the etiology and pathogenesis of scoliosis remain unknown. In 80 – 85% of people, the cause of scoliosis is unknown. This is called idiopathic scoliosis (Cailliet, 1975:45; Harrington, 1977; Anon, 1998a). Statistically, an estimated four adolescent girls in 1000 suffer from scoliosis, and approximately one in 2 500 boys have some type of scoliosis (Cailliet, 1975:45).

Scoliosis is evidently a complex disorder in which expression of the defect is variable. Causes of curves are classified as either non-structural or structural (Magee, 1987:383; Loveless, 1999).

Non-structural scoliosis is defined as a structurally normal spine that appears curved. This is a temporary, changing curve (Anon, 1998a). There is no bony deformity and it is not progressive. The scoliotic curve will disappear on forward flexion. This type of scoliosis is usually found in the cervical, lumbar, or thoracolumbar area (Magee, 1987:383). When a child's lateral spinal curvature reduces significantly during recumbence, and side bending is relatively symmetrical, a biomechanical imbalance must be considered. According to Christensen (n.d.) the causes include postural habits, muscle imbalances, pelvic and spinal mall alignments and subluxations, and leg length discrepancies (Arnheim & Prentice, 2000:709). Non-structural scoliosis can be caused by an inflammatory condition such as appendicitis (Anon, 1998a).

Structural scoliosis is characterized by a fixed curve. Structural scoliosis can be caused by neuromuscular diseases (such as cerebral palsy, poliomyelitis, or muscular dystrophy), birth defects (such as hemivertebra in which one side of a vertebra fails to form normally before birth), injury, certain infections, tumors, metabolic diseases, connective tissue disorders, rheumatic diseases, or unknown factors (Anon, 1998a). The most common cause of structural scoliosis is idiopathic scoliosis, followed by congenital scoliosis (Loveless, 1999; Christensen, n.d.)

A study by Geissele *et al.* (1991) has demonstrated abnormalities of posture, proprioception, and equilibrium control in patients with adolescent idiopathic scoliosis. Geissele *et al.* (1991)

stated that these functions are integrated by structures in and around the brainstem in such patients. Asymmetry in the ventral pons of the medulla in the area of the corticospinal tracts was noted in 30% of the patients. These findings may support previous studies that have suggested a nervous system abnormality as a cause of scoliosis. According to Cailliet (1975:47) scoliosis is more frequent and more severe in children with proprioceptive postural disturbances.

The gait of children with scoliosis had been found to be somewhat abnormal, but there is controversy about whether this causes a curvature to develop or simply results in walking with a curved spine (Christensen, n.d.). A study by Wasylenko *et al.* (1983) found excessive hip extension during the stance phase in scoliosis. Barrack *et al.* (1984) compared the walking velocity, cadence, gait cycle, single limb support time, and stride length of patients with scoliosis and healthy control subjects and reported no significant differences in any of these parameters. A study by Giakas *et al.* (1996) compared the gait patterns between healthy and scoliotic patients using time and frequency domain analysis of ground reaction forces. This study suggests that gait asymmetry could very well be the underlying cause of the balance and coordination problems that result in a curved spine.

Harrington (1977) also held several factors, in addition to genetic disposition, responsible for the development of idiopathic scoliosis namely, nutrition, hormonal and mechanical influences.

Research in etiology continues with basic science studies. The most exciting avenue of research is the effect of melatonin (a hormone that primary regulates the sleep-wake cycle) on scoliosis. Chickens and bipedal rats had their pineal gland removed with a dramatic increase in the incidence of scoliosis. Upon administration of melatonin the development of the scoliosis appeared to decrease significantly (Loveless, 1999). Application of research on humans (Hillibrand *et al.*, 1996) in this area has recently started.

Segil (1974) studied the incidence of idiopathic scoliosis in the African (Bantu) and white population groups in Johannesburg. The incidence in the Caucasians was more prevalent than in the Africans. These findings suggested that there was a genetic element in the incidence of idiopathic scoliosis. Wynne-Davies (1968) concluded that if genetics were a factor in the etiology of idiopathic scoliosis, it is a recessive (inherited characteristic) factor only.

Researchers are looking for the cause of idiopathic scoliosis. They have studied genetics, growth, structural and biochemical alterations in the discs and muscles and central nervous system changes. The changes in the discs and muscles seem to be a result of scoliosis and not the cause. Scientists are still hopeful that studying changes in the central nervous system in people with idiopathic scoliosis may reveal a cause of this disorder (Anon, 1998a).

Since no consistent, confirmed cause is currently known for idiopathic scoliosis and not all the mechanisms of the better-known causes are understood, diagnosis of scoliosis remains a clinical one.

Congenital scoliosis is the least common of the three major etiologies of scoliosis. Congenital scoliosis develops secondary to a bony abnormality of the sacrum, vertebrae, or hemi-vertebrae. In some cases, the abnormality will require corrective surgery. In many children, a heel lift or shoe build-up can provide sufficient structural support (Christensen, n.d.).

c) Diagnosis/Evaluation

In many cases potential scoliosis will first be diagnosed incidentally or even accidentally, because symptoms in early scoliosis are minimal or even absent. The pre-adolescent age of 10 to 13 years is a period of rapid growth and several studies have shown evidence that this age group is a primary population for alteration in vertebral growth (Kane & Moe, 1970; Brooks *et al.*, 1975). This fact is the basis of many international school-screening programs being initiated to ensure early recognition of scoliosis before irreversible defects occur (Cailliet, 1975:49).

- **Physical examination:** Understanding the basic anatomy and stance of the child is important. During the evaluation, observation of the child from the back, side and front is necessary to pick up subtle deformities. The only true pathognomonic sign of scoliosis is the presence of a curve on forward bending (Figure 4), termed a positive Adam's forward bending test (Renshaw, 1988; Loveless, 1999). Many studies have used this test as a screening method (Grant *et al.*, 1973; Sells & May, 1974; Shtern, 1975; Lonstein, 1977; Francis & Bryce, 1987; Solberg, 1993).

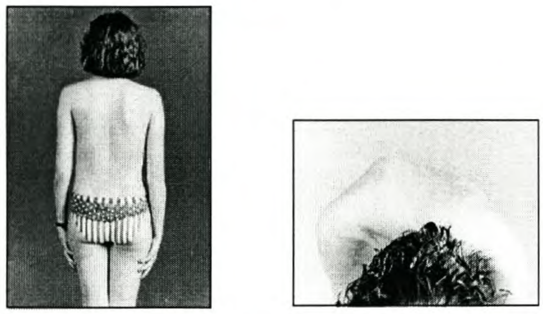


FIGURE 4: FORWARD BENDING TEST (BOWMAN, 2001)

A problem with the "Adam's test", was to decide when a rib hump was marked enough to justify referral. Accordingly, a study by Burwell *et al.* (1982) concluded that in children, a rib hump was a normal finding. Its presence should be used as an alerting sign to look for clinical evidence of structural scoliosis. The latter, together with the rib hump score, might provide a guide for further referral.

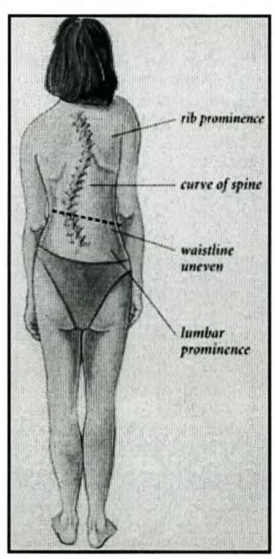


FIGURE 5: PHYSICAL CHARACTERISTICS OF SCOLIOSIS (ANON, 2000d)

In figure 5 the left shoulder is lower and the right scapula more prominent; there is a lateral spinal curvature; the left iliac crest appears higher; ribs are pushed posteriorly; and the thoracic cage is narrowed.

Whenever *uneven shoulders* and *uneven hips* are noted, a lateral spinal curve convex on the same side should be suspected. If scoliosis is not found, shoulder and hip asymmetries are not a problem. In normal development, the dominant side of the body has a slightly lower shoulder and slightly higher hip (Sherrill, 1993:381).

The sensitivity (probability that a test for the condition is positive given the presence of the condition) and specificity (probability that a test for the condition is negative given the absence of the condition) of the physical examination depend on the skills of the examiner and the degree of spinal curve being sought. In one study, public health nurses with special training in school screening were able to detect all children (sensitivity of 100%) with a Cobb angle greater than 20 degrees (Viviani *et al.*, 1984).

- **X-ray evaluation:** Curves are currently universally measured by the Cobb method (Cobb, 1958), as standardized by the Scoliosis Research Society (Cailliet, 1975:28). Physicians obtain a standing roentgenogram to measure the degree of curvature (cobb angle) (Figure *6*). The first step in determining the cobb angle is the identification of the end vertebrae. They are identified as follows: 1) The end vertebrae is the last vertebra that is tilted into the concavity of the curvature being measured. 2) The disc spaces are normally narrower on the concavity and wider on the convexity of a curve. After the cranial and caudal end vertebrae of each curve have been identified, the curves are measured. A line is drawn at the upper end of the cranial end vertebra along the end-plate. A line is drawn at the lower end of the caudal vertebra at the inferior end-plate of the body. Lines are drawn at right angles to the two end vertebral lines, and the angle formed constitutes the cobb angle (Cailliet, 1975:28; Moe *et al.*, 1978:32; Weinstein, 2001). A Cobb angle greater than 20 degrees requires treatment (Anon, 1998a).

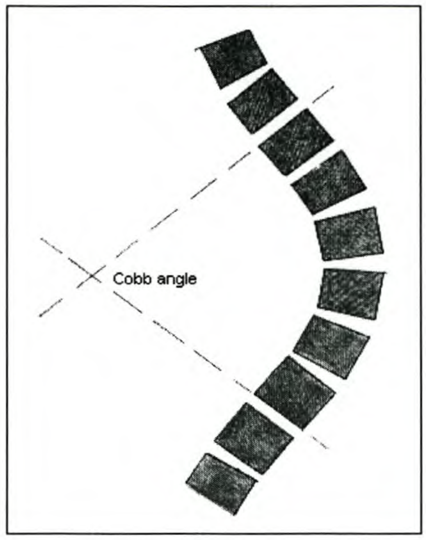


FIGURE 6: COBB METHOD OF MEASURING CURVATURE (CAILLIET, 1975:29)

Roentgenographic findings serve as the reference standard for estimating the sensitivity and specificity of screening tests (Anon, 2000b). Studies reported that the 95% confidence interval for intraobserver (the same person measures twice) and interobserver (two or more persons measures) variability in measuring the Cobb angle on radiographs is 3 – 5 and 6 – 7 degrees, respectively (Morrissy *et al.*, 1990).

Other scoliosis screening tests include the Scoliometer and Moire topography. The Scoliometer is an inclinometer that measures trunk asymmetry, or axial rotation, also commonly referred to as a "rib hump deformity". The Scoliometer has a reported sensitivity of 96 – 98%, specificity of 29 – 68%, and reliability coefficients of 0.86 – 0.97 in detecting a Cobb angle of 20 degrees or more (Amendt *et al.*, 1990). Moire topography (Figure 7) uses a light that is projected through a grating next to the patient's back and viewed from a different direction to produce interference fringes. The resulting image can be quantified by counting fringes or by measuring the inclinations of lines drawn between fringes of equal order. In figure 7 M, O, and W are examples of fringes that can be selected for comparison

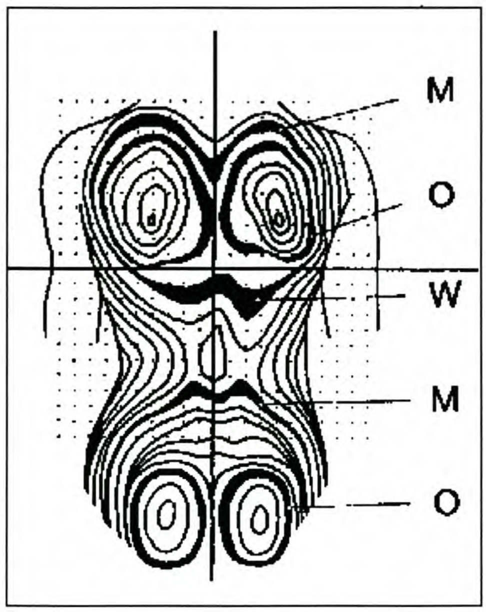


FIGURE 7: MOIRE TOPOGRAPHY (WARNER *ET AL.*, 1992)

In a study by Farady (1983) the “Adam’s test” proved positive in 46% and the Moire photographs in 94%. In some studies Moire topography correlated poorly with the Cobb angle (Anon, 2000b). According to Farady (1983) the Moire method is more accurate than is clinical observation.

Several authors have reported large variations in the accuracy and reliability of spinal function measurement. Many attempts of standardization of measurement have been made and various methods used. However, until a reliable, readily available measure of scoliosis is shown to have high validity compared to radiographs, clinicians will probably continue to use visual assessment and subjective definitions of lateral deviations in patient evaluation (Solberg, 1993).

d) Treatment

Cailliet (1975:61) stated the following concerning the treatment of scoliosis:

> Over the centuries, many forms of treatment have been advocated for scoliosis, and exponents of every form of treatment are found in the literature. Some aspects and principles of most concepts of treatment have merit and influence today’s concept of correct treatment. The objective of treatment is to ensure that the child reaches

maturity with a straight, balanced and stable spine. In minimal scoliosis that has been diagnosed early, this objective is accomplished by treatment aimed at preventing progression of the deformity. In more advanced cases of scoliosis the treatment objectives are correction if the lateral curving and rotational deformity to the greatest possible degree and holding the correction achieved for the remainder of spinal growth. Treatment either for prevention or correction of scoliosis is either non-operative or operative.

Many children who are referred for further evaluation via a school scoliosis screening program have very mild spinal curves that do not need treatment. When a child does need treatment, he or she may be sent to an orthopedic spine specialist. The best treatment for each patient will be based on the patient's age, how much more he or she is likely to grow, the degree and pattern of the curve, and the type of scoliosis. Observation, bracing or surgery may be recommended (Anon, 1998a).

The rationale behind screening is the assumption that early detection of curves permits prompt initiation of conservative therapeutic measures that may prevent progression of the curves and thereby avoiding the complications of advanced scoliosis. A study by Ascani *et al.* (1986) found that there is a curve increase after the end of growth. The general average progression seems to be 0.4 degrees per year.

The principle forms of conservative treatment for curves detected through screening include spinal orthoses (braces), electrical stimulation and exercise therapy. Surgery may also be recommended for cases detected through screening, and it is argued that early surgery for large curves may produce better outcomes than surgery performed at later ages (Anon, 2000b.).

The efficacy of bracing for idiopathic scoliosis has been called into question, and now with several types of bracing, application of braces, is becoming more complex (Nachemson & Peterson, 1995). According to Loveless (1999) only a nighttime bending brace for curves less than 30 – 35 degrees is recommended as it has been shown to be as effective as full time underarm braces.

Braces are generally effective in providing immediate correction of curves. Initial standing roentgenograms often demonstrate a 50-60% correction in the curve (Jonasson-Rajala *et al.*, 1984).

The effectiveness of braces in preventing progression is less certain. Most existing evidence regarding the effectiveness of brace therapy comes from uncontrolled case series reports. A study by Emans *et al.* (1986) found that although gradual loss of correction over the course of treatment was noted, follow-up one to two years after discontinuing brace treatment revealed significant improvement over pre-brace values in a large proportion of patients.

Outcome measures in most bracing studies relate only to curve correction and provide little information on health outcomes (e.g., back pain, patient's feelings about their appearance, psycho-social impact). Available evidence is limited to an uncontrolled study, which found that braced patients noted an improvement in back "surface shape" as determined by a computerized photogrammetric surface mapping procedure (Weisz *et al.*, 1989). Compliance problems limit the effectiveness of brace treatment. A study by Gratz and Papalia-Finlay (1984) reported that compliance was uncommon among adolescents who wore braces.

Lateral electrical surface stimulation (LESS), in which surface electrodes are applied to the skin nightly for at least 8 hours until skeletal maturity is attained, has only been evaluated in uncontrolled case series reports. By 1988, studies had already indicated that LESS was not effective. A chart review of patients who had completed treatment with LESS and were fully compliant found that over two thirds of curves progressed at least five degrees; 50% of the patients required fusion or ended treatment with a curve greater than 40 degrees (O'Donnell *et al.*, 1988).

Exercises have been advocated as prophylactic therapy to prevent the need for more extensive treatment (e.g. braces) and as adjunctive therapy to enhance the effectiveness of braces (Farady, 1983). Exercise alone has historically demonstrated poor effectiveness in preventing curve progression (Stone *et al.*, 1979; Farady, 1983), although there have been few published studies in this area. A study of a school-based exercise program for adolescents with scoliosis found that curve progression after one year was not significantly different between the study group and a matched control group (Stone *et al.*, 1979).

Studies of the effect of exercise on scoliosis are lacking in the English-language literature. Exercise alone is not currently used in managing scoliosis because clinical experience has historically demonstrated progression of curves despite vigorous exercise regimens. Rather, exercise is thought to be beneficial when performed by patients wearing trunk orthoses such as the Milwaukee or Boston braces (Solberg, 1993).

Studies by Blount and Bolinke (1967) and Brooks *et al.* (1975) emphasized physical therapy in the non-operative treatment of scoliosis in a population of braced patients only.

Treatment of scoliosis by exercise therapy remains controversial, with most of the investigators reporting poor results and questioning its effectiveness (Roaf, 1956; Cobb, 1958; Stone *et al.*, 1979). Most of these authors contend that exercise of any kind is not beneficial in inhibiting scoliotic development.

However, there are only a few longitudinal studies concerning the effect of exercise on the treatment of scoliosis. The reason for this is that adherence to exercise programs is very low and studies using a control group are very difficult. Also, the mentioned studies are old and new advances in exercise techniques such as the swissball and pilates exercises could prove to be an effective treatment therapy if further research were to be conducted.

Researchers continue to examine how a variety of braces, surgical procedures, and surgical instruments can be used to straighten the spine or to prevent further curvature. They are also studying the long-term effects of a scoliosis fusion and the long-term effects of untreated scoliosis (Anon, 1998a).

2.4.2 KYPHOSIS

Of the deformities, which may develop during childhood and adolescence, kyphosis is one of the most frequent, and also one of the most frequently neglected. The natural tendency of the thoracic and lumbar spine is a posture of kyphosis and lordosis, respectively, and moderate increases in these sagittal curvatures may be easily missed. Most screening programs are instituted mainly to detect scoliosis, and children with Scheuermann's vertebral changes and kyphosis are most likely to be missed. Also, kyphosis tends to appear at a later age than scoliosis and probably progresses later as well (Drummond *et al*., 1979). More often than not, if noticed, it is diagnosed as "poor posture" and ignored (Bradford, 1977).

a) Definition

The Scoliosis Research Society defines kyphosis as a curvature of the spine measuring 45 degrees or greater on an x-ray. The normal spine has only 20 to 45 degrees of curvature in the upper back area (Magee, 1987:155; Anon, 1999a).

The term kyphosis is used to describe the normal curve of the thoracic spine. Sometimes adolescents may develop an excessive degree of kyphosis, called hyperkyphosis (Vaughan, n.d.). Kyphosis is commonly referred to as the excessive curvature in the thoracic spine. It is associated with *round shoulders* and a hump back (Kendall *et al*., 1977:15; Davis *et al*., 1986:130; Boachie-Adjei & Lonner, 1996; Loveless, 1999).

According to Arnheim and Prentice (2000:708) kyphosis is characterized by an increased thoracic curve and by protracted scapulae, which produces a rounded shoulder appearance.

FIGURE 8: STANDING LATERAL VIEW OF A MARKED KYPHOSIS (MOE *ET AL*., 1978:308)

b) *Etiology*

Trauma (repeated minor injuries) and congenital indentations in the bony vertebral endplates have been shown by Schmorl and Junghanns (1971:348) to be the major etiological factors. Their opinion is based on the dissection of the spinal column of 10 000 human cadavers.

Schmorl and Junghanns (1971:348) made the following statement:

> If these spines are exposed to heavy physical labour, or if the youth participates in sports where the spine is exposed to stress or to considerable shock (motor cycle riding, etc.) then the thin cartilaginous plates become fissured and disc tissue prolapses into the spongiosa of adjacent vertebral bodies.

This statement was also concurred by White *et al*. (1977).

Two other factors merit consideration. Firstly, short hamstrings which limit flexion of lumbo-sacral segments and contribute to excessive flexion at lower thoracic level. According to Dommisse (1998) 50% of the 290 cases thoracic kyphosis, displayed evidence of short hamstrings. Secondly, juvenile osteoporosis has been postulated as a factor and remains in doubt. The growing spine of the adolescent is normally less dense, with less calcium content and fewer trabeculae than the adult (Dommisse, 1998).

No evidence has been brought forward of an infective or an inflammatory reaction. Equally, there is no evidence of avascular necrosis (Dommisse, 1998). Mechanical factors, heavy physical labor, muscle weakness, inflammation, and genetic abnormalities have all been implicated but concrete proof of any one or all of these etiologies is lacking (Bradford, 1977).

c) *Types*

According to Dommisse (1998) most types of abnormal kyphosis can be entered into one of the three following categories:

- **Postural Kyphosis:** Postural kyphosis is a non-structural, functional deformity with onset during the late juvenile period, usually 9 to 12 years. Postural kyphosis does not involve the centers of ossification of the vertebral bodies (Dommisse, 1998).

The cause of postural kyphosis is purely postural. Slouching and poor posture can stretch spinal ligaments, thus increasing the natural curve of the spine (Anon, 2000e). Postural kyphosis bears a clinical resemblance to Scheuermann's disease (Figure 9) in the form of a hyperkyphotic thoracic spine, but the radiological appearances of the vertebrae are within normal limits. Postural kyphosis is usually not progressive and is easily corrected (Dommisse, 1998).

- **Congenital kyphosis:** This category of spinal deformity refers to an abnormal development in the spine. The bones may not form as they should, or a bone bar may develop between two vertebrae and cause progressive kyphosis as the child grows. Children born with spina bifida usually have severe kyphosis (Boachie-Adjei & Lonner, 1996; Anon, 2000e).

- **Scheuermann's disease / Juvenile kyphosis:** Juvenile kyphosis had been a poorly understood disease until 1920, when Holger Scheuermann first outlined the radiographic manifestations of this deformity. Since then, Juvenile kyphosis became better known as Scheuermann's disease (Bradford, 1977; Moe *et al.*, 1978:331; Murray *et al.*, 1993). This disease is related to the abnormal development of the vertebrae in the spine, which leads to wedge-shaped, instead of rectangular-shaped vertebral bodies. Scheuermann's disease involves the secondary ossification centers of the vertebral bodies, usually at mid-thoracic and thoracolumbar levels, which appear at puberty and develop during the adolescent years, the period of the normal "growth spurt" (Dommisse, 1998).

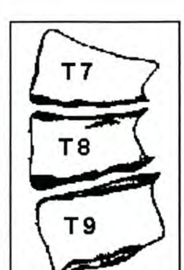


FIGURE 9: TRACING FROM AN X-RAY OF A 23-YEAR-OLD MALE, SHOWING LATE RESULTS OF SCHEUERMANN'S DISEASE (DOMMISSE, 1998)

Scheuermann's disease has been defined based on radiographic features as an increased kyphosis exceeding 45 degrees with 5 degrees or more wedging of at least three adjacent vertebrae at the apex of the kyphosis (Boachie-Adjei & Lonner, 1996). According to Junghanns, (1986:84) there is radiological evidence of Scheuermann's disease in at least half of all adolescents, and 50% of those experience difficulties.

Magee (1987:383) described the following four types of kyphosis:

(a) Round back: The individual with a round back has a long rounded curve with decreased pelvic inclination (less than 30 degrees) and thoracolumbar kyphosis. The patient will often present with the trunk flexed forward and a decreased lumbar curve (Dommisse, 1998). A *forward head* posture usually accompanies a round back (Sherrill, 1993:374).

(b) Humpback or gibbus: There is a localized sharp posterior angulation in the thoracic spine.

(c) Flat back: The vertebral column as a whole is too straight, with a decreased pelvic inclination to 20 degrees and a mobile lumbar spine.

(d) Dowager's hump: The combined prominence of the seventh cervical vertebra and excess adipose tissue (Sherrill, 1993:374).

d) Diagnosis/Evaluation

Usually, a visit to the doctor is precipitated by a postural evaluation at school, concern about the cosmetic deformity of a rounded back, or pain combined with poor posture (Anon, 2000e).

- **Physical examination:** On examination, an increase in normal thoracic kyphosis and lumbar lordosis will readily be apparent (Bradford, 1977; Boachie-Adjei & Lonner, 1996). The kyphosis will have lost a good deal of its mobility and will not fully correct when the patient attempts thoracic hyperextension in the prone position. The lumbar lordosis (Figure 10), however, is rarely structural and is readily correctable on forward bending. With forward bending the thoracic "hump" becomes even more marked as seen on the lateral view. Direct tenderness with muscle spasm may be elicited over the kyphosis. Muscle tightness and apparent "contractures", particularly of the pectoral and hamstring groups are common (Bradford, 1977). According to Sherrill (1993:384) a flattened appearance of the anterior thoracic wall (*flat chest*) usually accompanies kyphosis.

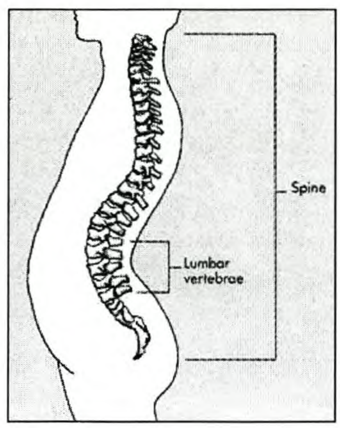


FIGURE 10: LUMBAR LORDOSIS (ANON, 1998b)

- **Radiographic evaluation:** According to Junghanns (1986:87) radiodiagnostics should be used even in the initial stages of a possible kyphosis, because they allow the observation of details that are important for the evaluation and progress of the disease and therefore also for therapy.

According to Boachie-Adjei and Lonner (1996), initial radiographic evaluation is indicated for patients who show obvious spinal deformity or who have an angle of trunk rotation of 7 degrees or more. X-rays of the spine will show if there are any bony abnormalities.

According to Vaughan (n.d.) the radiographic diagnostic criteria for Scheuermann's disease is hyperkyphosis with wedging of 5 degrees or more of three central adjacent vertebrae.

The degree of kyphosis, lordosis and the amount of vertebral wedging is calculated, using the Cobb technique, described earlier in this chapter (Bradford, 1977, Anon, 2000e). Tomography and CT scans are useful in defining bony anatomy in patients with congenital deformities (Boachie-Adjei & Lonner, 1996).

Willner and Johnson (1983) used a non-invasive technique for describing kyphosis. The sagittal curves of the spine were determined with a spinal pantograph. Willner (1981) has studied the connections between this technique and X-ray, the reliability and the inter-investigator error. Concerning thoracic kyphosis the values from the pantograph and those from the X-ray investigations were comparable. In the lumbar lordosis, however, values given by the pantograph method were found to be systematically low. Limited information exists concerning the use and reliability of the pantograph.

e) Treatment

The treatment of kyphosis is individualized for each child, depending on the age, amount of curvature and the amount of time remaining for skeletal growth (Anon, 1999a). The treatment for kyphosis varies with the cause of deformity (Boachie-Adjei & Lonner, 1996).

Postural kyphosis treatment consists of reassurance, observation and an extension exercise program to strengthen the thoracic extensor muscles (Boachie-Adjei & Lonner, 1996; Loveless, 1999). According to Dommisse (1998) postural kyphosis demands no more than disciplined attention to posture, plus corrective exercises.

Although a wide variety of treatment techniques have been described in the literature, the only ones that have been shown to definitely be effective in correcting the deformity are casting and bracing (Bradford, 1977). The type of brace commonly used, is the Milwaukee brace (Blount & Bolinke, 1967; Farady, 1983; Nachemson & Peterson, 1995). This type of brace provides the necessary three-point bending corrective forces to the spine (Vaughan, n.d.). According to Loveless (1999), bracing kyphotic curves greater than 50 degrees allows some improvement in cosmesis and pain. A study by Bradford (1977) has demonstrated the effectiveness of this treatment in reversing vertebral wedging and improving kyphosis by 40% and lumbar lordosis by 36%.

In most cases, Scheuermann's disease can be successfully treated without surgical intervention. Surgery is never advised in growing children, bearing in mind that growth of the vertebrae does not cease until the age of about 25 years in males and about 23 years in females. The use of the Milwaukee brace may therefore be continued beyond the period of adolescence (Dommisse, 1998).

Surgical treatment continues to be controversial and should be limited to the extremely large curves (>70 degrees) and those with back pain not relieved by conservative methods (Loveless, 1999; Vaughan, n.d.).

2.4.3 LORDOSIS

The lumbar spine provides support to the upper body and transmits weight to the upper body, the pelvis and lower limb. The lumbar spine is strategically located and should therefore, be included in any whole examination of the spine (Magee, 1987:170). According to Schrecker (1971:29) lordosis is the counterpart of kyphosis.

a) Definition

Kendall *et al*. (1977:15) defines lordosis as an increased anterior curve of the spine, usually found in the lumbar region and associated with an anterior pelvic tilt.

Lordosis, also called swayback or hollow back, is an exaggeration of the normal posterior concave curve in the lumbar region. It not only affects the five lumbar vertebrae but also throws the pelvis out of correct alignment (Shrecker, 1965:29; Sherrill, 1993:375).

Davis *et al*. (1986:129) defines lordosis as an exaggerated hyperextension of the lumbar spine. Occasionally, lordosis is seen in the dorsal spine. The cervical spine position is similar to a lordosis in cases of round upper back with compensatory forward position of the head.

According to Arnheim and Prentice (2000:708) when lordosis is combined with kyphosis and a *forward head* posture it is referred to as a kypho-lordotic posture. In general, lordosis is associated with an exaggeration of the lumbar curvature (Phelps *et al*., 1956:65; Arnheim & Prentice, 2000).

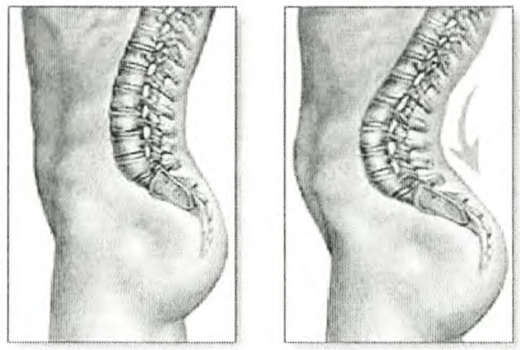


FIGURE 11: NORMAL AND EXAGGERATED LUMBAR CURVATURE (ANON, 2000a)

b) Etiology

Weak abdominal muscles allow the pelvis to tilt downward anteriorly; weak gluteal muscles and hamstrings, which cannot counteract this anterior tilt; overly tight lumbar extensors, which contribute to an anterior tilt; and over developed hip flexors, which cause anterior tilt (Magee, 1987:380; Sherrill, 1993:375). The degree of anterior pelvic tilt is often associated with marked shortness of the iliopsoas (hip flexor) muscles, e.g. the weakness of the anterior abdominal muscles and shortness of hip flexors causes a muscle imbalance, which could result in an anterior pelvic tilt (Kendall *et al.*, 1993:80).

There is some controversy about the relationship between lumbar lordosis, pelvic tilt and abdominal muscle performance. Two recent studies concluded that the magnitude of the lumbar lordosis and pelvic inclination in standing is not associated with the force production of the abdominal muscles (Levine *et al.*, 1996; Youdas *et al.*, 2000).

According to Anon (1998b) lordosis can occur when a person with kyphosis, excessively straightens his or her spine. A study by Willner and Johnson (1983) found the range of thoracic kyphosis and lumbar lordosis to be inter-dependent. The lordosis is considered to be compensatory to the thoracic kyphosis.

Any hip deformity caused by osteoarthritis, tends to make the body lean forward, which may also produce lordosis (Willner & Johnson, 1983).

Lordosis commonly occurs in obese people with weak back muscles and heavy abdomens. It may also develop in pregnant women (Magee, 1987:380; Anon, 1998b).

It has also been thought that participating in certain sport can cause lordosis. According to Junghanns (1986:291) lumbar lordosis plays a considerable part in many sports and gymnastics disciplines. The lordotic posture in some figures in thousands of training hours is constantly repeated and is deliberately gradually increased through relaxation of the intervertebral motor segments in the lumbar area. This compensatory posture is not physiological since it results in a strong pressure on the posterior portions of the lumbar intervertebral discs (Junghanns, 1986:291).

A study by Watson (1983) investigating posture and participation in sport found the incidence of lumbar lordosis to be significantly higher in individuals who specialized in soccer, football, and rugby. In a separate study it was shown that the degree of lumbar lordosis of a group of soccer players and footballers increased during 21 months of participation in these activities.

According to Magee (1987:380) lordosis can be caused by the failure of segmentation of the neural arch of a facet joint segment. In this case the fibrous bond that bridges this defect in the pars interarticularis of the neural arch is under considerable stress during weight bearing and other movements. When it is damaged or even gives way through injury or repeated stress, pain and a resulting deformity of lordosis may develop (Helfet & Gruebel Lee, 1978:83).

Other possible causes of lordosis include spondylolisthesis, and congenital problems, such as congenital dislocation of the hip (Magee, 1987:380).

c) Diagnosis/Evaluation

The diagnosis of lordosis can be made with a complete medical history, physical examination, and diagnostic tests.

- **Physical examination:** According to Sherrill (1993:376) true lordosis usually has the following characteristics:

  (a) Anterior tilt of pelvis (prominent buttocks).

  (b) Tight lower back muscles, tight lumbodorsal fascia, tight hip flexors, tight iliofemoral (Y) ligaments, weak abdominal muscles, weak hamstrings, and weak gluteals.

  (c) Hyperextension of the knees.

  (d) Kyphosis may develop to compensate for the increased concavity. In this case, the pectorals and anterior intercostals may be tight.

  (e) Upper body tends to shift backward resulting in an *inclined trunk* (trunk is inclined to the rear) posture as a compensatory measure.

  (f) Lower back pain.

  (g) Faulty functioning of internal organs, including those concerning digestion, elimination, and reproduction.

  (h) Increased incidence of back strain and back injuries.

  The above characteristics were also described by Kendall *et al*. (1977:19,22,23).

  Abdominal protrusion is normal in the young child and usually accompanied by lordosis (Davis *et al*., 1986:129). This posture defect is almost always present in adolescents and adults who lead sedentary lifestyles, especially if they are overweight. The protruding abdomen also characterizes paralysis or muscle weakness that results from spinal cord injuries (Shrecker, 1971:29; Sherrill, 1993:377).

- **Radiographic evaluation:** As mentioned earlier in this chapter, the sagittal alignment of the spine can be measured, using the Cobb method (Figure *6*). Lumbar lordosis is measured, using the superior end plate of L1 (first lumbar vertebra) and the inferior end plate of L5 (Ozonoff, 1992:68; Vedantam *et al.*, 1998).

d) Treatment

The goal of treatment is to stop the progression of the curve and prevent deformity. Management of lordosis will depend on the cause of the lordosis. Simple exercises may be sufficient if lordosis is associated with poor posture (Davis *et al.*, 1986:139). However, faulty conditioning may also contribute to the development of lordosis. Sit-ups and straight-leg leg-lifts are often used to strengthen the abdominal muscles. The main effect is actually on the iliopsoas and it is well known that these exercises tend to cause lordosis (Watson, 1983).

According to Sherrill (1993:377) correction of lordosis, at least in the early stages, is largely a matter of increasing proprioceptive awareness concerning an anterior and posterior tilt. Alternate anterior and posterior pelvic tilts should be exercised while lying supine, kneeling, sitting, standing, and doing various locomotor activities. Proprioceptive input is thought to contribute significantly to postural reflexes important in normal locomotion. Proprioceptive input from joints, ligaments and tendons has been recognized as an integral contribution to the body's postural equilibrium (Barrack *et al.*, 1984). Surgical treatment will only be considered in severe cases.

2.4.4 WINGED SCAPULAE

An understanding of the kinesiology of muscles acting on the scapula aids in the understanding of scapular winging.

The nomenclature of scapular motion about the thorax is described as elevation, depression, adduction (retraction), abduction (protraction), medial rotation of the inferior angle of the scapula, lateral rotation of the inferior angle of the scapula, and anterior and posterior tilting (Inman *et al.*, 1944; Gregg *et al.*, 1979). Upward rotation of the scapula is most important for arm elevation. The upward rotator muscles of the scapula are the trapezius and the serratus anterior muscles. However, Inman *et al.* (1944) have also included the levator scapula.

Maximum scapular rotations can only occur when the trapezius and the serratus anterior muscles function normally.

a) Definition

Schrecker (1971:55) defined winged scapulae as "jutting wings", where the medial edges of the scapulae are projected.

Schafer (1999) described winged scapulae as a distortion of the scapula in which the medial border flares overtly backward when the subject presses forward with the outstretched upper limb. When the involved arm is laterally abducted, the scapula pulls away from the chest wall in an abnormal manner so that the arm cannot be abducted much beyond the horizontal level.

Stedman (1990:1387) described winged scapulae as a condition wherein the medial border of the scapula protrudes away from the thorax. The protrusion is posterior and lateral, as the scapula rotates out.

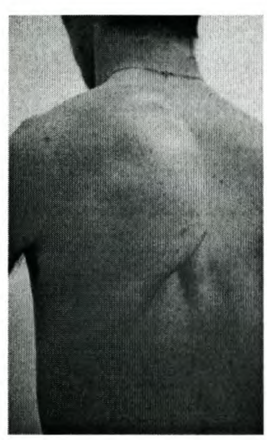


FIGURE 12: WINGED SCAPULAE (FROMM, 2002)

b) Etiology

Winged scapulae are normal in preschool and elementary school children since the serratus is slower in developing than is its antagonists (rhomboids, levator scapulae). It need not be a matter of concern at this age even though the scapulae are farther apart than in normal adult posture (Kendall *et al.*, 1977:178).

According to Sherrill (1993:384) winged scapulae often accompany *round shoulders*. Round shoulders is a forward deviation of the shoulder girdle in which the scapulae are abducted with a slight lateral tilt (Schrecker, 1971:21).

Weakness or paralysis of the serratus anterior, secondary to palsy of the long thoracic nerve of Bell, is the most common cause of winging. The serratus anterior functions to maintain scapular stability during arm elevation, by causing upward rotation and protraction of the scapula. Weakness of this muscle will cause winging of the scapula when the arm is elevated (Warner & Navarro, 1998).

The long thoracic nerve of Bell is derived from ventral rami C5 (fifth cervical vertebra), C6, and C7. Its course runs downward and passes either in front or behind the middle scalene muscle. Then, it reaches the upper slip of the serratus anterior muscle and descends along its anterior surface. The mechanism of injury to the long thoracic nerve may be as a result of viral illnesses, repetitive trauma or stretching, general anesthesia, or surgical procedures (Schafer, 1999). Gregg *et al.* (1979) reported winging of the scapula in a series of 10 young patients with traction injury to the long thoracic nerve of Bell.

c) Diagnosis/Evaluation

Scapular winging associated with serratus anterior dysfunction is characterized by prominence of the lower tip of the scapula and loss of scapula protraction during shoulder elevation. Discomfort is usually felt around the scapula and around the back of the shoulders (Warner & Navarro, 1998).

In the case of winging associated with shoulder joint stiffness, the clinician tests the joint for normal passive movement. If normal passive movement is absent, the winging is probably secondary to joint stiffness (Warner *et al.*, 1992).

With winging associated with instability of the shoulder joint, the clinician performs an "apprehension test", a test usually associated with recurrent shoulder dislocations (Arnheim & Prentice, 2000:610).

Nerve conduction studies and electromyography are usually undertaken to confirm the diagnosis of long thoracic nerve injury. Connor *et al.* (1997) and Iceton and Harris (1987) suggest that the spinal accessory nerve and trapezius should be included because concomitant trapezius palsy can compromise the results of subsequent surgery. Iceton and Harris (1987) recommend that serial electromyograms be performed at three-month intervals to demonstrate evidence of nerve recovery.

Electromyography may not be foolproof. Warner and Navarro (1998) describe 14 patients with symptomatic scapular winging. Only nine presented with electrical evidence of long thoracic nerve palsy on EMG analysis. The other five failed to show abnormal function of the long thoracic nerve or had an inadequate or incomplete study.

d) Treatment

Where the cause for winged scapulae is associated with weak serratus anterior muscles, especially in growing children, this condition can be corrected with therapeutic exercises. Since the serratus anterior is a prime mover for upward rotation and abduction, it is strengthened by exercises such as hanging, climbing, push-ups, overhead weights and other activities that are executed above the head (Schrecker, 1971:55; Sherrill, 1993:384; Schafer, 1999).

Foo and Swann (1983) reported on 20 patients with winged scapulae. The majority of the subjects experienced spontaneous onset of pain followed by deformity and associated loss of function. History of trauma was elicited in only three patients. Their functional recovery occurred within two years without any specific treatment.

Iceton and Harris (1987) reported on 15 patients with winged scapulae who were followed for 1 to 16 years after surgical treatment. The results were good in nine patients, fair in two, and poor in four.

2.4.5 FLAT FEET

Flat feet (pes planus) is a very common pediatric complaint. In Europe and America flat foot is a common reason for attendance at a children's clinic (Rao & Joseph, 1992).

a) Definition

According to Shrecker (1971:59) flat foot/pes planus, or sunken arch, means a lowering of the longitudinal arch of the foot. The term pes planus refers to a type of foot in which the medial longitudinal arch appears to be flat and is sometimes said to be fallen. In general terms pes planus refers to loss of the medial longitudinal arch of the foot. (Canale, 1998:1712; Arnheim & Prentice, 2000:463; Scher, 2001).

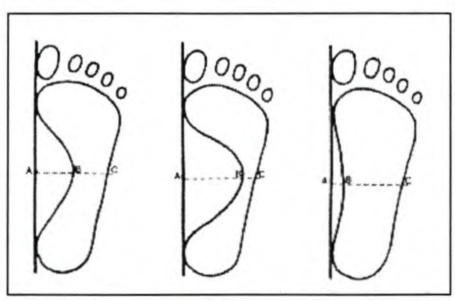


FIGURE 13: NORMAL FOOT (LEFT), FOOT WITH HIGH ARCH (CENTRE), FLAT FOOT (RIGHT) (RAO & JOSEPH, 1992)

b) Etiology

Pes planus may be congenital, or acquired (Magee, 1987:328). In infants and toddlers the longitudinal arch is not developed and flat feet are normal. The arch develops in childhood, and by adulthood most people have developed normal arches (Scher, 2001). If the condition persists into adulthood, it becomes a permanent structural deformity, leading to a defect or alteration of the tarsal bones as well as the talonavicular joints (Magee, 1987:328).

Pes planus is usually classified as flexible or rigid. Flexible pes planus is common, 15% to 20% of adults have some degree of flexible pes planus, and most of these are asymptomatic. Soft tissue structural changes are the cause of flexible pes planus, whereas, bony and soft tissue changes cause a rigid pes planus foot. It is possible to clinically distinguish the two types of pes planus. If an acceptable medial longitudinal arch does not develop on non-weight bearing, the flat foot is considered rigid (Canale, 1998:1712).

There are a number of pathologies that can cause flexible pes planus. Spastic valgus foot describes a flat foot seen in cerebral palsy, due to spasticity of muscles. Tibialis posterior dysfunction and an accessory navicular can both lead to pes planus. The most common cause of flexible pes planus would be secondary to, or compensation for biomechanical abnormalities. Flat feet may be associated with pronation, a leaning inward of the anklebones toward the center line (Phelps, *et al.*, 1956:130; Schrecker, 1971:59; Scher, 2001). According to Sherrill (1993:390) pronation causes a stretching of the bowstring ligaments and the subsequent dropping of the tarsal bones so that flat foot is a related disorder.

FIGURE 14: FLAT FEET (ANON, 2000c)

According to Magee (1987:329) flat foot may be caused by a postural deformity, such as medial rotation of the hips or medial tibial torsion. Pes planus may also be due to trauma. For example, a traumatic case of flatfoot may follow the fracture of the calcaneus (Magee, 1987:329).

According to Arnheim and Prentice (2000:463) the wearing of tight shoes or excessive exercise that repeatedly subjects the arch to severe pounding on an unyielding surface can contribute to pes planus. A study by Watson (1983) found a positive correlation between hurdlers, rugby players and flat feet.

A study by Rao and Joseph (1992) found a high concentration of flat foot among six-year-old children who wore shoes as compared to those who did not. This study implies that the critical age for development of the arch is before the age of six. This cross-sectional study also suggests that shoe wearing in early childhood is detrimental to the development of a normal or a high medial longitudinal arch.

A recent study by Ledoux and Hillstrom (2002) determined the distributed vertical ground reaction forces for a normative population and compared it with data from subjects with flat feet. Nineteen asymptomatic subjects, 11 with a neutrally aligned foot type (normal arch) and eight with a pes planus foot type were studied as they walked barefoot across a pressure plate. The pressure plate data were converted to force values at seven locations (subhallucal, five submetatarsal and subcalcaneal) on the plantar aspect of the foot. Pes planus feet had significantly more force at the subhallucal area with no difference seen under the other areas. This study is indicative of abnormal first ray mechanics in flat feet.

c) Diagnosis/Evaluation

According to Scher (2001) there is an absence of the longitudinal arch of flat feet when standing and feet lean inward. A wet footprint on cement shows large contact area with the ground. Watson (1983) assessed flat feet from a footprint made from a specially constructed inkpad.

Sherrill (1993:390) described the Feiss line method to evaluate the severity of flat foot. This entails drawing an imaginary line from the knee joint to the metatarsophalangeal joint of the big toe. The distance that the navicular (scaphoid) is from the Feiss line determines whether the condition is first, second, or third degree.

d) Treatment

Simple flat foot and pronation are not usually treated. If pain due to flexible flat feet occurs, an orthotic can bring relief (Arnheim & Prentice, 2000:464; Scher, 2001). According to preliminary findings of a research study at the Flinders Medical Center in Adelaide, young children with flat feet do not need orthotic shoe inserts to improve their physical skills or self esteem (Swan, 2000).

Schrecker (1971:63) describes therapeutic exercises for the treatment of flat feet, but there is lack of evidence in literature concerning the effectiveness of exercise as treatment for flat feet.

Flexible pes planus rarely requires surgical treatment. Any procedure for the correction of flexible flat foot should be done for disabling pain and then only after all conservative measures have been used. Rigid pes planus frequently causes enough symptoms to justify an operation (Canale, 1998:1713,1732).

2.5 THE INCIDENCE OF POSTURAL DEFORMITIES

As this study is mainly concerned with the prevalence of postural deformities among children, review of literature will include the prevalence rates of school-aged children only. There is a lack of comparable research completed in the broad spectrum of postural deformities. Thus, the researcher makes no attempt to compare the incidence of the various deformities among the population. For scoliosis, however, this data is obtained easily and therefore, the following incidence rates are applicable to scoliosis only:

Wynne-Davies (1968) conducted a screening program in Edinburgh, and estimated the incidence as 0.39% for adolescent females. A study by Brooks *et al*. (1975) in Los Angeles found a prevalence rate of 13.6%. Grant *et al*. (1973) found a prevalence rate of 13.4% in El Paso, Texas, which is very similar to the finding of Brooks *et al*. (1975).

In 1970 Kane and Moe conducted a study in Minnesota. They found a prevalence rate of at least 0.13% for scoliosis requiring referral to an orthopedist. In Minnesota the ration of positive rotational prominences of female to male was 1.5 to 1. The study by Brooks *et al*. (1975) found a ration of 1.25 to 1. This gives a nearly equal prevalence rate in boys and girls. In 1974 Sells and May conducted a study in Shoreline Public School, Washington and found a prevalence rate of 1.6%.

In certain areas the prevalence varies with different populations screened. Segil (1974) reported a prevalence of 2.5% in South African Whites but 0.03% in South African Blacks.

Span *et al.* (1976) reported that the prevalence in Orthodox Jewish schools in Jerusalem was twice that found in Jerusalem's public schools.

Except for the high rates in Los Angeles reported by Brooks *et al.* (1975) and in El Paso, Texas reported by Grant *et al.* (1973) the prevalence generally falls between 2.5% and 4%.

In 1982 Willner and Udèn conducted a prospective prevalence study of scoliosis in Southern Sweden for children aged between 7 and 16 years. Among the girls there was prevalence of 4.3% and among the boys 1.2%.

A recent two-year prospective study done by Soucacos *et al.* (1997) in northwestern and central Greece assessed the prevalence of scoliosis in school children 9 to 14 years old. The prevalence of scoliosis was 1.7%. The ratio of boys to girls was 1:2.1

It is clear that incidence studies have shown a wide variation. This can be due to different definitions of scoliosis, to different techniques of screening (with or without roentgenograms), to the "know how" of screening or to a true deviation of the frequency of scoliosis in different populations (Willner & Udèn, 1982).

Francis and Bryce (1987) reviewed 43 published articles on postural screening programs dating back to 1970. They found only one study, by Maloney and Hildebrand (as cited in Francis & Bryce, 1987) that screened other postural deformities. Francis and Bryce (1987) screened 18 postural deformities in school children grade six to nine. Lordosis was the most common postural deformity (45%), and torticollis (lateral curvature in cervical spine) was noted least commonly (0%). Scoliosis was noted in 7% of the total population, with a girl-boy ratio of 2:1. The other deformities screened were not considered for statistical purposes.

Screening for scoliosis has been ranked as one of the most impressive and important advances made over the past twenty years (Francis & Bryce, 1987). Thus screening for many postural deformities can become preventive in the sense that early detection and early treatment prevents the progression of the deformity. To disregard the need for a compulsory postural screening program in light of these findings and other research would be to forego the opportunity of early detection of progressive postural deformities that could require corrective treatment.

CHAPTER 3

EXPERIMENTAL METHODS AND PROCEDURES

3.1 INTRODUCTION

With any scientific endeavours, including medicine, there is a need for accurate measurement (Morrissy *et al.*, 1990). In the United States, the recent widespread use of school screening programs for the early detection of postural deformities has led to the development of various clinical methods. There is a growing need for standardization of screening methods, thus the development of rigorous measurements and evaluation has become necessary.

In recent years, school screening programs have received administrative endorsement in many states in the United States of America (Francis & Bryce, 1987). Opponents of school screening programs state that the costs of school screening outweigh its benefits and that conventional screening methods are too sensitive and result in too many numbers of false positive findings (normal subjects that are incorrectly diagnosed as having the condition or disease). Proponents of mandatory school screening claim that early screening and diagnosis allow for time and cost effectiveness as non-operative measures can be used (Amendt *et al.*, 1990).

This study was concerned with a complete postural analysis of almost the entire musculoskeletal system. To be successful, such a screening program requires careful preplanning, including informed consent, cooperation from the school administrators, an examiner competent in evaluating postural deformities visually, and a well organized, efficient screening method.

3.2 SUBJECTS

The age group selected, was based on the idea that early recognition could lead to preventive measures for more serious conditions.

A letter (Appendix A) was sent to 15 schools in the Western Cape region, explaining the importance and purpose of the study and to find out if any of these schools were interested in participating in this study. The 15 schools selected, were chosen randomly from a list that was provided by the Western Cape Schools Board. Four schools namely, Lochnerhoff, Stellenbosch, De Kuilen, and Mikro Primary responded, giving permission to conduct the study at their schools.

The final sample was arrived at after all incomplete measurement forms were taken out. Also, only whites were included in the final sample as there were to few scholars from other races. The final sample (N=288) consisted of 78 scholars from grade five; 104 scholars from grade six; and 106 scholars from grade seven. Of the total number of students examined, 154 were boys, and 134 were girls.

3.3 DESIGN OF THE STUDY

An informed consent form with a questionnaire (Appendix B) was sent to the children's parents one month prior to the screening program. The questionnaire included questions regarding the following: Personal details of child; child's level of physical activity, family history of any postural deformities and if parents were aware of any deformity the child may have.

The questionnaires and informed consent forms were collected by the physical educators of the participating schools and were returned to the researcher on the day of the screening program. Children without parental consent were not allowed to participate in the study.

The measurements and examinations were completed over a two-month period (August/September 2001) during scheduled physical education classes.

3.4 MEASUREMENT PROCEDURE

The first stage of the measurement procedure was conducted with the children divided into groups according to grade and gender. The aims of the study and measurement procedures were explained to them. With help from assistants, the subjects were requested to complete section A and C (see Appendix C) of the questionnaire. Section A included personal details namely, age, gender, language, handedness, school, grade, race and contact numbers. Assistants recorded race without the subject knowing. Section C determined the level of physical activity. This questionnaire was designed to estimate the volume (frequency and duration) of physical activity from assigning points to the different activities. The greater the frequency (times per week) and duration (amount of hours) of an activity, the higher the points scored. Also, walking or cycling to school rather than traveling by car/bus/taxi or train, and spending less time in front of the television or computer would result in a higher score. Points were then added to obtain an overall score for physical activity (See Appendix C, Section C).

Information was treated as strictly confidential. Thereafter followed the anthropometric measurements (Section B) and postural evaluation (Section D).

3.4.1 ANTHROPOMETRIC MEASUREMENTS

The anthropometric measurements chosen, were those that could have a functional role in the prevalence of postural deformities. The following measurements were made:

a) Height

The subjects were positioned barefoot on a level-measuring platform directly in front of the stadiometre. The subjects stood erect with heels together and arms hanging by the sides. The subjects were instructed to look straight ahead and to take a deep breath. Using both hands, the subject's head was cupped along the mastoid processes to correctly position it in the Frankfort Plane. The measurement was taken as the maximum distance from the floor to the vertex of the head, which is the highest point on the skull when the head is held in the Frankfort Plane (Norton & Olds, 1996) (Figure 15).

FIGURE 15: MEASURING STATURE WITH A STADIOMETRE

b) Body weight

Body weight was measured on an accurately calibrated UWE BW-250 electronic scale and was recorded to the nearest 100 grams. The weight of the subjects included their physical education clothing, but excluded their shoes. Subjects were asked to empty the bladders before measurement was taken.

c) Body Mass Index (BMI)

Using stature and body weight measurements, BMI was calculated with the following formula (Balady *et al*., 2000:63):

- BMI = weight (kg) / height (m)^2

d) Waist girth

Waist girth was measured at the narrowest part of the torso when viewed from the anterior aspect. This perimeter is located approximately halfway between the ribs and the iliac crest. The subjects stood erect with hands at the side, and not contracting the abdominal muscles or holding their breath. The flexible tape was placed horizontally around the torso so that it is snug, but not compressing the skin and underlying tissue (Figure 16).

FIGURE 16: MEASUREMENT OF WAIST GIRTH

e) Hip girth

Hip girth was measured at the level of the greatest posterior protuberance of the gluteals. The subjects stood erect in minimal clothing, with feet together and no contraction of the gluteal muscles. The tape was placed horizontally around the site, compressing any overlying clothing but not the soft tissue.

f) Waist-Hip Ratio (w-h ratio)

W-h ratio was determined by calculating the ratio between the waist and hip circumference (Balady *et al.*, 2000:63).

g) Skinfold measurements

Fat% was determined, using two skinfold measurements, tricep and subscapular, as described by Lohman (1987).

- **Tricep skinfold:** The measurement was taken with a Harpender skinfold caliper. The mid-acromiale-radiale line was marked with a pencil. The caliper was placed 1 cm distally from the left thumb and index finger, raising a vertical fold at the marked mid-acromiale-radiale line on the anterior surface of the arm (Figure 17).

FIGURE 17: MEASUREMENT OF TRICEP SKINFOLD.

- **Subscapular skinfold:** The subscapular site was located by palpating the scapula to locate the inferior angle. The fold was picked up just inferior to the inferior angle, along the natural diagonal cleavage of the skin. The Harpender skinfold caliper was placed 1 cm inferior-lateral (oblique) to the thumb and index finger.

h) Leg lengths

The trochanterion height was used as measurement for determining possible leg length discrepancies. The head of the trochanter was palpated to obtain the most superior part of the greater trochanter. To obtain this landmark easier a subject were asked to flex the hip and knee. The sliding pointer of the anthropometer was moved vertically to measure the distance to the floor while the subjects were instructed to stand in a comfortable erect position. Leg length differences equal to and greater than 5mm was considered for statistical purposes, as it is difficult to obtain discrepancies smaller than 5mm.

3.4.2 POSTURAL EVALUATION

Students were dressed in physical education clothing. Boys wore cotton shorts without shirts. Girls were dressed in cotton shorts with an aerobic top. The ability to detect postural deformities through an aerobic top was not considered a limitation because musculoskeletal curvatures and rib elevations can be seen clearly. This method of evaluation represents a major alternative to obtain parental consent and the cooperation of female subjects who might be reluctant to participate without aerobic tops. Boys and girls were evaluated separately and individually. Privacy is considered to be essential for reducing the children's anxiety.

The New York Posture Test (See section D of Appendix C) was used for evaluation and identification of possible deformities. This test is described in many textbooks (Davis *et al.*, 1986:136; Magee, 1987:394; Sherrill, 1993:368; Bloomfield *et al.*, 1994:320) and a well recognized company in the United States (Reedco Inc.) that manufactures anatomical measuring devices uses this test as a posture evaluation tool (Reedco Inc., 2001).

There are thirteen items in the test. Each test item is scored on a 5-3-1 basis. The score is based on the criteria and drawings located on the score sheet (Appendix C).

5 = normal

3 = slightly abnormal

1 = abnormal

A subject with a score of 3 or 1 was considered to have a postural deformity. The maximum score under this procedure is 65 and an overall posture rating was obtained through the following table (Table 1):

TABLE 1: TABLE FOR CALCULATING THE OVERALL POSTURE SCORES (DAVIS *ET AL.*, 1986:138).

Achievement Level	Percentile Rank	Posture Score
10	99	-
9	98	65
8	93	63
7	84	61

6	69	59
5	50	55 – 57
4	31	49 – 53
3	16	45 – 47
2	7	39 – 43
1	2	35 – 37
0	1	0 - 33

A "see-through posture grid" was used for postural evaluations (Figure 18). The "posture grid" comprises 12.5cm "big blocks", which is further subdivided into 2.5cm "small blocks". The vertical and horizontal strings are attached onto a frame. The vertical lines are at right angles to the horizontal lines. A plumb line is dropped from the top to bottom of the frame. These lines provide reference points for ascertaining the correct alignment of body parts. The use of gridlines to evaluate posture is described in many textbooks (Kendall *et al.*, 1977:20; Davis *et al.*, 1986:135; Arnheim & Prentice, 2000:708).

FIGURE 18: SIDE VIEW (LEFT) AND BACK VIEW (RIGHT) POSTURES BEHIND THE "SEE-THROUGH POSTURE GRID"

The subjects stood behind the "posture grid". The subjects were examined from a lateral, and posterior (side-and back) view. When subjects were evaluated in the rear view, he or she steps into powdered white chalk and then onto a black board to check for foot abnormalities (e.g. flat feet) (Figure 19). The subjects then stood with their sides towards the posture grid.

FIGURE 19: THE MEASUREMENT OF FLAT FEET

To reduce the degree of subjectivity the following criteria was provided by the New York Posture Test (Reedco Inc., 2001) to score uneven shoulders:

The most superior-lateral edge of the acromions was marked with a pencil. Degree of lateral asymmetry was measured by counting the amount of blocks the one shoulder was lower than the other one. The examiner stood 4m from the posture grid. Using a goniometer, the amount of degrees for each block was measured beforehand.

Subjects with a broader chest (greater bi-acromial width) will exhibit a greater angle of asymmetry. To account for these differences two bi-acromial widths were used. A subject was either 3 "big blocks" (37.5cm) wide or 4 "big blocks" (50cm) wide. However, all the subjects had a bi-acromial width within the 3 "big block" (37.5cm) range, thus the following goniometer measurements only included the bi-acromial width of 37.5cm:

Bi-acromial width of 37.5cm (3 big blocks):

- ½ block deviation = 2 degrees
- 1 block deviation = 4 degrees
- 1½ block deviation = 6 degrees
- 2 block deviation = 8 degrees

According to The New York Posture Test (Reedco Inc., 2001) uneven shoulders are scored as follows: 5 (0 – 2 degrees); 3 (3 – 4 degrees); 1 (> 4 degrees).

For example, a subject with an acromion height difference of "1 block" and a bi-acromial width of approximately "3 blocks wide" will have an angular deviation of 4 degrees, and thus a score of 3.

The following mathematical calculation was used to determine the reliability of the goniometer measurements (Figure 20):

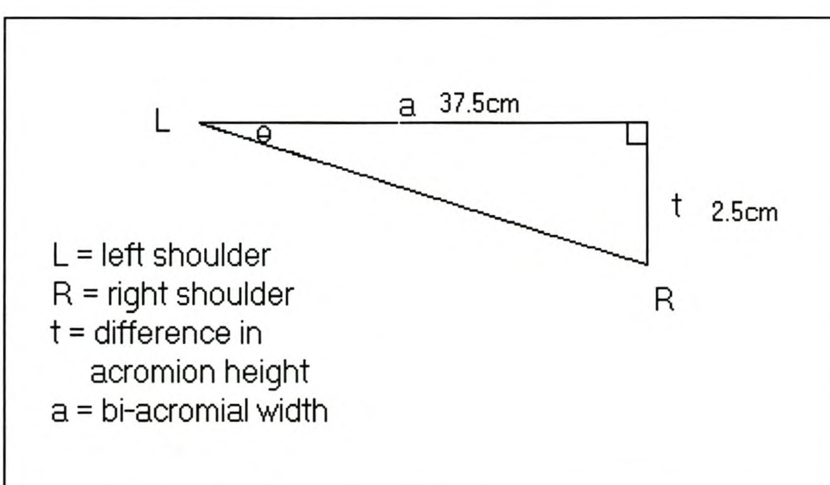


FIGURE 20: ASYMMETRY OF ACROMIAL HEIGHT

Tan θ = t/a, where t = difference in acromion height; a = bi-acromial width.

E.g. acromion height difference of “1 block” (2.5cm) and a bi-acromial width of “3 big blocks” (37.5 cm):

$$Tan\theta = \frac{t}{a}$$
$$= 2.5cm / 37.5cm$$

Θ = *4 degrees (rounded to nearest whole number)*

This mathematical measurement was compared to all goniometer measurements. The goniometer measurements correlated well with the mathematical measurements, and thus constitute a reliable method of measurement.

Uneven hip level was difficult to score, because the subjects' shorts covered their hips and shorts that fitted slightly skew, could have been scored incorrectly as uneven hips. Therefore, hips were palpated at the iliac spines to measure for differences in height of the Anterior Superior Iliac Spines (ASIS), which is the vertical distance from each ASIS to the floor.

The “Adam's test” (forward bending test) was used for further scoliosis evaluation (Figure 21). Each subject was asked to stand erect with weight on both feet, feet slightly apart and parallel. As subjects were bending forward upon request, reaching his/her fingers toward the floor, the bony prominences of the spine were marked with a pencil marker. If an apparent rib hump was noted the test was recorded as positive and the position of the rib hump was recorded (left/right). When subject stood erect again, the examiner observed the alignment of the dots.

FIGURE 21: INSPECTION OF CHILD WITH THE FORWARD BENDING TEST ("ADAM'S TEST")

After the postural evaluation was completed the scores on each item was added and recorded. Table 1 (see p. 56) was used to obtain the overall posture rating of each subject.

After all evaluations were completed, assistants checked the questionnaires to make sure all measurement were recorded and that all questionnaires were handed in to the researcher.

3.5 ASSISTANTS

The assistants in this study were experienced in clinical testing and familiar with the protocols and equipment being used. The researcher is a certified Biokinetics intern and the assistants were certified Biokinetics students-in-training. To ensure complete reliability of the study the researcher did all the postural evaluations. Where possible, the same assistants were used for all the measurements.

3.6 DATA ANALYSIS

A statistician from the Center of Statistical Consultation of the University of Stellenbosch analyzed the data collected from this study. An explanation of the statistical package used for data-analysis, will follow in the next chapter (Breiman *et al.*, 1993).

CHAPTER 4

RESULTS AND DISCUSSION

4.1 INTRODUCTION

Quantitative data was analyzed, using Microsoft Excel Version 7.0 Analysis Tool and Statistica (StatSoft, 2001). Further statistical analysis was done, using classification tree methodology (For clarity see Appendix D).

In the case of classification trees the dependent (response variable y is a discrete variable consisting of two or more classes (e.g. yes/no, present/not present, low/medium). The concept of entropy (chaos) is used as basis for constructing classification trees. The aim of classification trees is to divide the data set into subsets in such a manner that the subsets have a lower entropy than the full data set. Thus, it strives to group the classes together into subsets as best possible based on the independent or predictor variables. This is achieved as follows:

For continuous variables (e.g. age) the method selects a point x_p between the minimum and maximum that splits the data into two sets (or nodes in a tree). All the cases where $x \leq x_p$ goes to the left node and all the cases where $x > x_p$ goes to the right node. The point where the split is made is the point that decreases the entropy from the parent node to the child nodes the most. This procedure is then repeated for each of the two nodes.

In the case of a categorical independent variable (e.g. gender), all combinations of binary splits of the levels of the variable are considered and the combination that most successfully decreases the entropy is used as splitting criteria. In the case of more than one independent variable (combination of continuous and discrete) the procedure mentioned above is applied to each variable independently. Then the variables are compared to one another and the one that provides the best split over all the variables is used as the splitting variable.

For more information on classification tree methodology, see Breiman *et al*. (1993).

4.2 SUBJECTS

The final sample of the study consisted of 288 children from selected primary schools in the Western Cape Region. See Table 2 for descriptive subject information.

TABLE 2: ANTHROPOMETRICS AS STATED IN METHOD (N = 288).

Variable	Mean	Standard Deviation
Age (years)	12.36	0.92
Body weight (kg)	47.48	11.22
Body height (m)	1.54	0.09
Fat (%) (Lohman, 1987)	21.35	9.81
BMI	19.75	3.70
Waist-hip ratio	0.79	0.15

4.3 POSTURAL EVALUATION

The highest incidence of abnormality was lordosis (70%) and the lowest incidence was twisted head, with a prevalence rate of 1% (Figure 22). Of the 13 different deformities of the musculoskeletal system examined, 10 were considered for statistical purposes in this study. Twisted head, scoliosis and uneven hips were excluded from the data analysis because of their low incidence.

TABLE 3: INCIDENCE RATES FOR 288 SUBJECTS FOR 13 POSTURAL DEFORMITIES.

Deformity	Slightly abnormal (%)	Abnormal (%)	Total (%) with the deformity
Forward head	27	1	28
Flat chest	28	1	29
Winged scapulae	37	5	42
Kyphosis	52	5	57
Inclined trunk	40	3	43
Protruding abdomen	25	3	28
Lordosis	57	13	70
Twisted head	1	0	1
Uneven shoulders	47	8	55
Scoliosis	10	0	10
Uneven hips	11	0	11
Pronated feet	29	1	30
Flat feet	28	2	30

Lordosis, kyphosis, uneven shoulders, inclined trunk, winged scapulae, pronated feet, flat feet, flat chest, forward head and protruding abdomen were the deformities seen most often among the 288 subjects examined. Scoliosis and uneven hips were noted less often with twisted head being almost nonexistent (Figure 22).

In accordance with research (Francis & Bryce, 1987) the prevalence rate for lordosis was the highest. The rate of 70% found in the present study is much higher than the rate of 45% reported by Francis and Bryce in 1987. Other prevalence rates found by Francis and Bryce

(1987) were pronated feet (38%); flat feet (10%); kyphosis (13%); protruding abdomen (15%) and scoliosis (6.6%). The prevalence rates in the present study is higher for all deformities than those found in 1987 except for, pronated feet, which had a higher prevalence rate of 38% compared to 30% in present study.

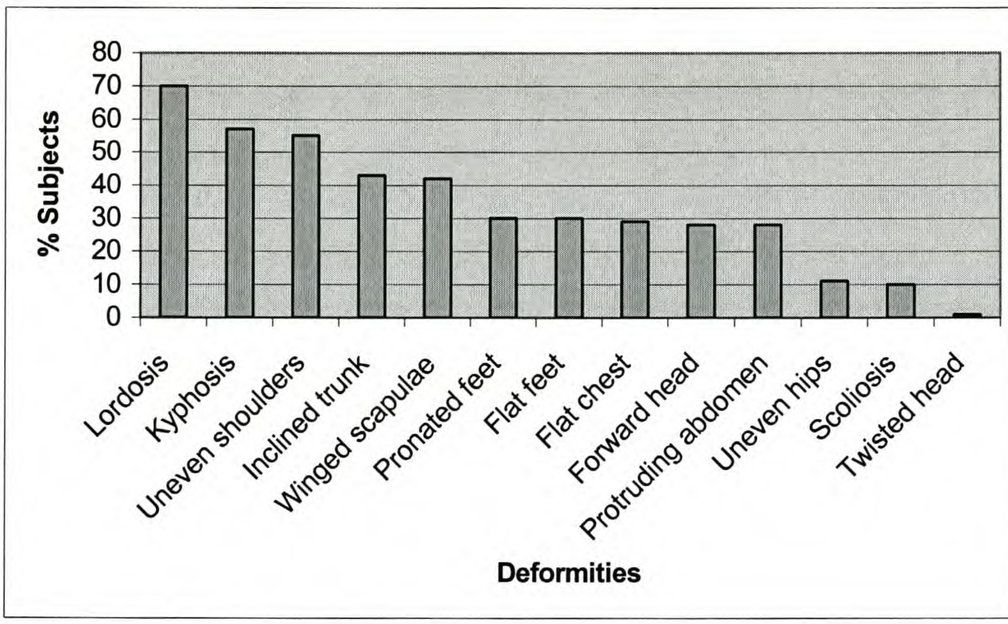


FIGURE 22: THE PREVALANCE OF POSTURAL DEFORMITIES WITH SLIGHTLY ABNORMAL AND ABNORMAL POOLED TOGETHER

In the present study scoliosis was omitted from the statistical analysis, because of the low prevalence rate compared to the other deformities. This finding was unexpected because in the literature there is an enormous amount of information concerning the prevalence rates of scoliosis and the importance of scoliosis screening programs. As mentioned before, most screening programs are used for the detection of scoliosis only and one would therefore expect a higher prevalence rate for this deformity compared to other deformities. High prevalence rates were reported by Brooks *et al.* (1975) and Grant *et al.* (1973), but the prevalence rate in the literature generally ranges between 2.5% and 4%. Scoliosis was not considered for statistical purposes in the present study, but the prevalence rate of 10% in the present study is still higher than the average rates reported in the literature.

Of the total number of children examined, pronated feet occurred in 30% and flat feet in 30%. This finding confirms those of other researchers (Phelps *et al*., 1956:130; Schrecker, 1971:59; Francis & Bryce, 1987; Scher, 2001) who reported a close association between these two postural deformities. Lordosis is thought to be a compensatory deformity following kyphosis (Bradford, 1977; Willner & Johnson, 1983; Boachie-Adjei & Lonner, 1996). These findings are supported by the present study when comparing the prevalence rates for lordosis (70%) and kyphosis (57%), which both had high prevalence rates.

The prevalence rate for forward head (28%) differed markedly from the prevalence rate for kyphosis (57%). Also, the prevalence rate for inclined trunk (43%) differed from the rate for lordosis (70%). These findings differ from those described in Sherrill (1987:374) and Kendall *et al*. (1977:19,22,23) which stated that forward head postures usually accompany kyphosis and an inclined trunk is a physical symptom of lordosis.

Family history, leg length differences, handedness and posture rating was not considered for statistical purposes, as these variables have not produced any significant results.

Classification tree methodology mentioned earlier in this chapter was used to determine the effect of the following factors on the prevalence rates:

- Fat %
- Subscapular (subscap) skinfold
- BMI
- Waist-Hip Ratio (w-h ratio)
- School
- Gender
- Age

- Body weight
- Height
- Physical activity

The number of subjects that had scores of one (abnormal) was not considered in the classification tree methodology, because of the low incidence. Only lordosis had a relatively high number of subjects (13%) with a score of one. (See Appendix D for explanation of a classification tree).

4.3.1 FORWARD HEAD

The overall prevalence rate for forward head postures was 28%.

a) Fat %

At a fat% ≤ 18.7% of the overall prevalence rate decreased to 20% and at a fat% > 18.7% the overall rate increased to 35%. At a fat% ≤ than 12.9% the prevalence rate (33%) was not much different than the overall prevalence rate of 28%. However, in the fat% range between 12.9% and 18.7% there was a lower prevalence rate of 12% (Figure 23).

b) Physical activity

More physically active subjects had a lower prevalence rate (19%), compared to the less active individuals (34%). More physically active subjects also had a lower rate than the overall rate of 28%. It should be noted that the values given for physical activity (e.g. 9.5) is arbitrary values (Figure 24).

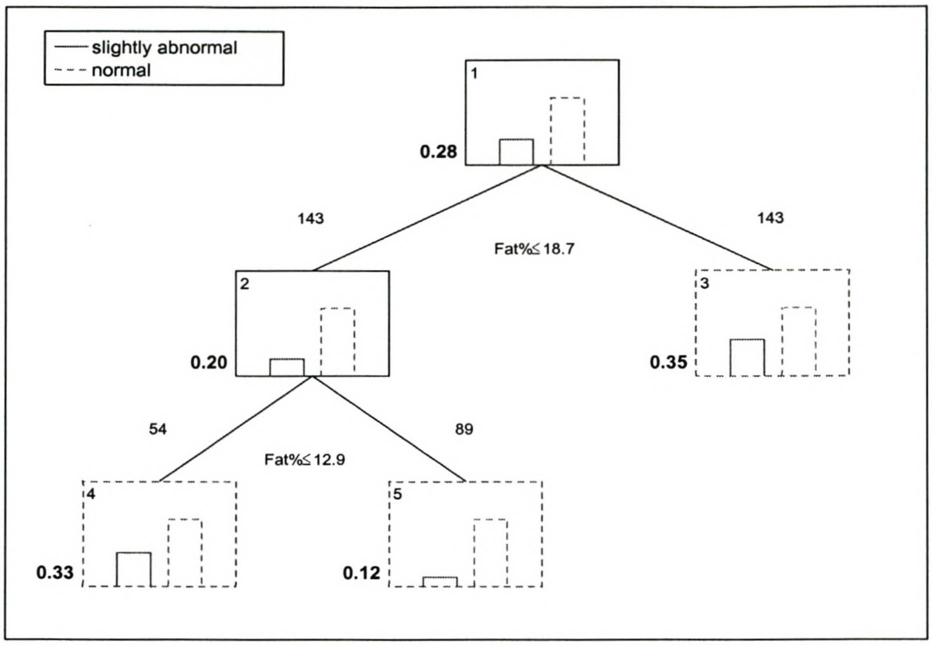


FIGURE 23: CLASSIFICATION TREE FOR FORWARD HEAD AND FAT%

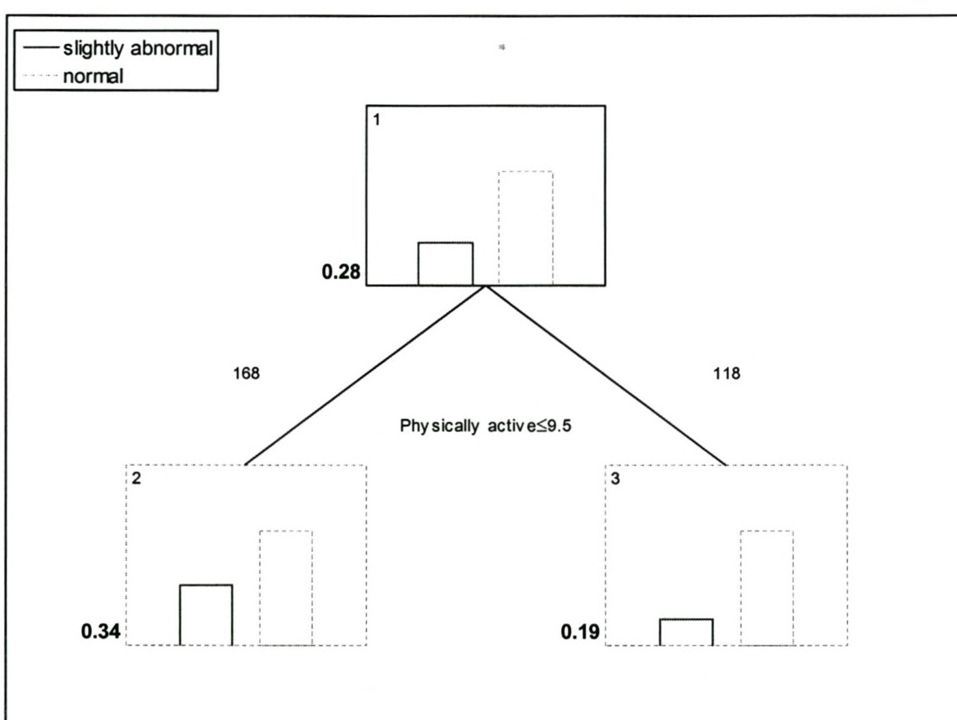


FIGURE 24: CLASSIFICATION TREE FOR FORWARD HEAD AND PHYSICAL ACTIVITY PROFILE

4.3.2 FLAT CHEST

The overall rate for flat chest postures was 28%.

a) Age

The prevalence of flat chest varied according to the age of subjects. Younger individuals (≤ 12.2 years) had a higher rate (36%) compared to older subjects (> 12.2 years) with a rate of 21%. The rate for younger individuals was also higher than the overall rate of 28% (Figure 25).

b) Physical activity

The subjects that were considered to be more physically active (> 8.5) had a lower prevalence rate (15%) than those subjects that were less active (≤ 8.5) with a rate of 30% (Figure 26).

c) BMI

At a BMI ≤ 16 the prevalence rate was 47% and at a BMI > 23 the prevalence rate was 42%. Both these rates are much higher than the overall rate of 28% (Figure 27).

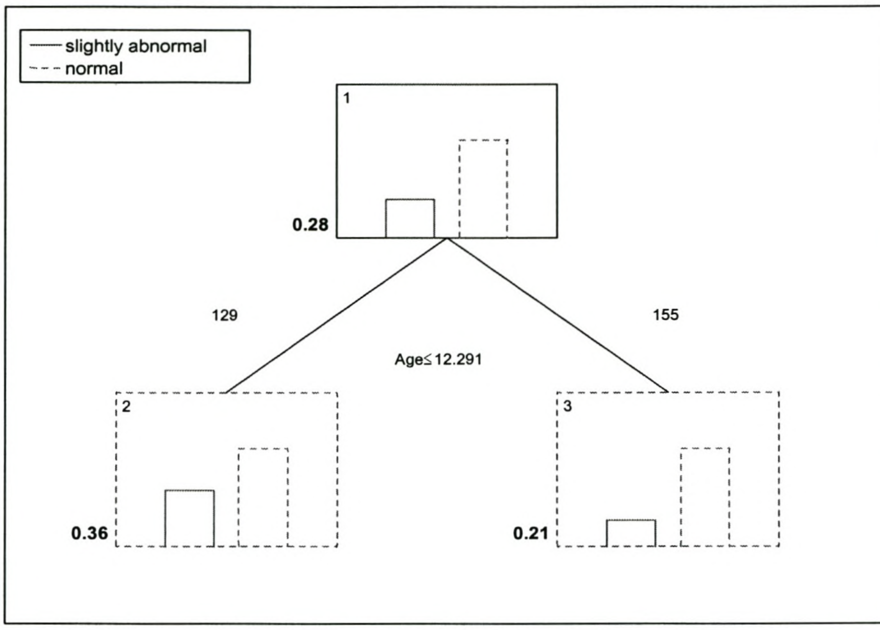


FIGURE 25: CLASSIFICATION TREE FOR FLAT CHEST AND AGE

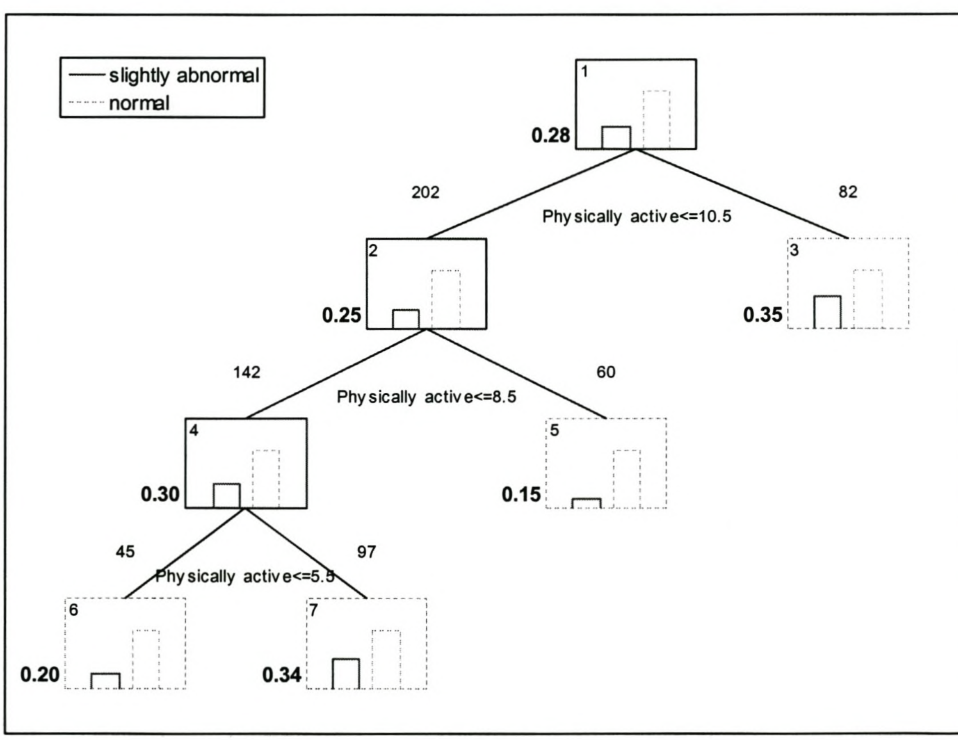


FIGURE 26: CLASSIFICATION TREE FOR FLAT CHEST AND PHYSICAL ACTIVITY PROFILE

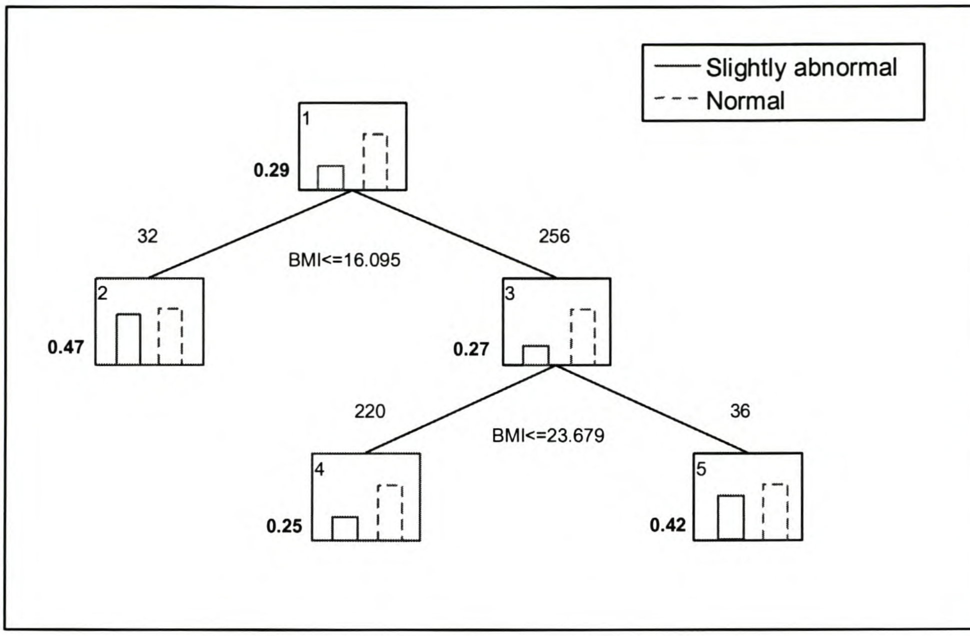


FIGURE 27: CLASSIFICATION TREE FOR FLAT CHEST AND BMI

4.3.3 WINGED SCAPULAE

The overall prevalence rate for winged scapulae was 39%.

a) School

Lochnerhoff had a much higher prevalence rate (53%) compared to the rate of the other three schools (33%). The rate of 53% is also higher than the overall rate of 39%. However, Lochnerhoff had the lowest percentage girl subjects and because boys had a higher prevalence rate than girls, gender was the deciding factor on the prevalence rate and not the school (see *Gender* at 4.3.3 b) (Figure 28).

b) Gender

Winged scapulae were more prevalent in boys (57%), compared to the prevalence rate of 19% in girls. The rate of 57% is also higher than the overall rate of 39% (Figure 29).

c) Body weight

Winged scapulae were more prevalent (44%) in subjects with a smaller weight (≤ 54.9kg) than subjects with a heavier weight (> 54.9kg), which had a rate of 19%. The rate for heavier subjects was also much lower than the overall rate of 39% (Figure 30).

d) Subscap skinfold

Subjects with a subscap skinfold ≤ 9.3mm had a higher prevalence rate (49%) than those with a subscap skinfold > 9.3mm, which had a rate of 22%. The rate for subjects with a lower skinfold thickness is more than double than that of subjects with a greater skinfold thickness (Figure 31).

e) Fat %

Subjects with a fat% ≤ 15.55% had a greater prevalence rate (64%) than those > 15.55% (27%). The prevalence rate almost doubled from the overall rate of 39% for subjects < 15.55% (Figure 32).

f) BMI

Subjects with a smaller BMI (≤ 21.21) had a higher prevalence rate (46%), than those with a greater BMI (>21.21), who had a rate of 20%. The rate for subjects with a greater BMI had a much lower rate than the overall rate of 39% (Figure 33).

g) Physical activity

Physically active individuals had a higher prevalence rate (42%) than less active individuals who had a rate of 27% (Figure 34).

h) w-h ratio

At a w-h ratio ≤ 0.78 the prevalence rate was lower (29%) compared to a rate of 46% for subjects with a w-h ratio > 0.78 (Figure 35).

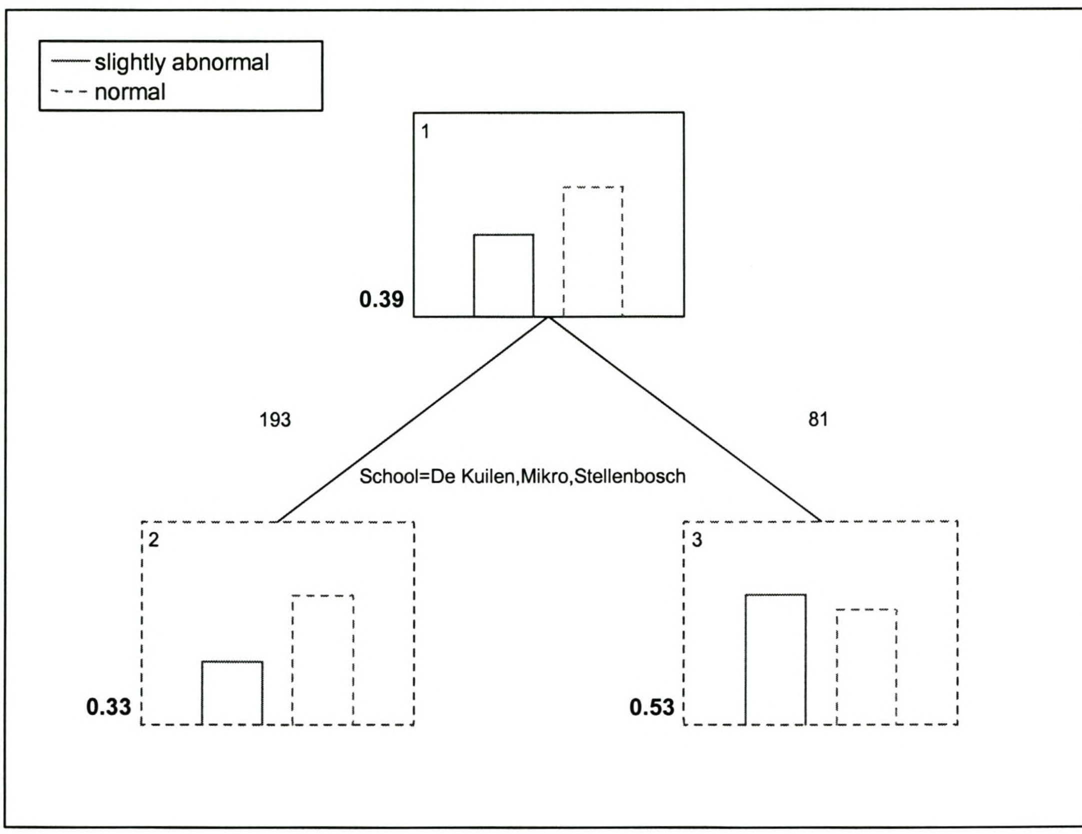


FIGURE 28: CLASSIFICATION TREE FOR WINGED SCAPULAE AND SCHOOL

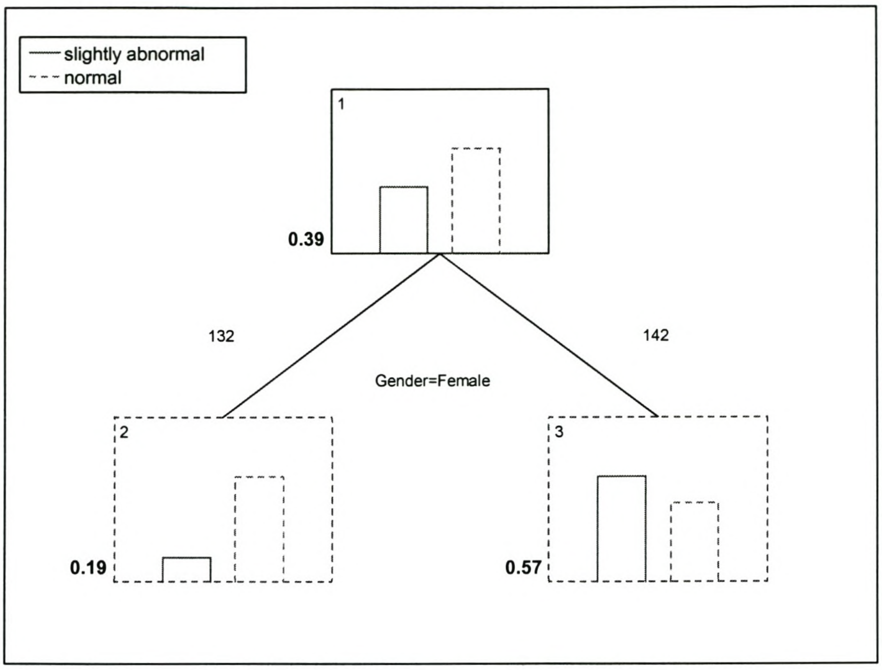


FIGURE 29: CLASSIFICATION TREE FOR WINGED SCAPULAE AND GENDER

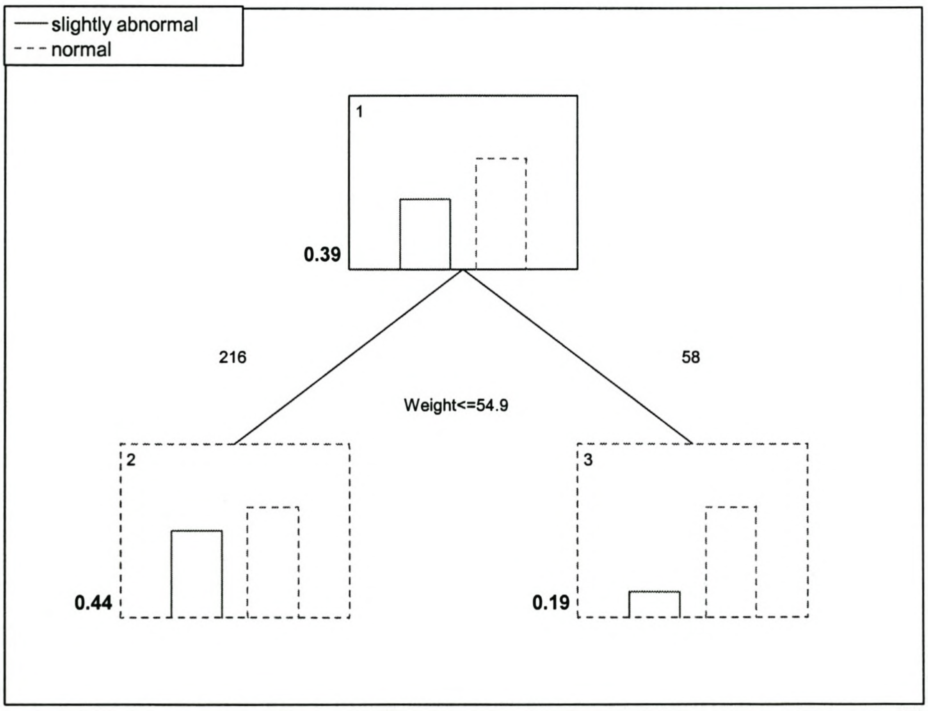


FIGURE 30: CLASSIFICATION TREE FOR WINGED SCAPULAE AND BODY WEIGHT

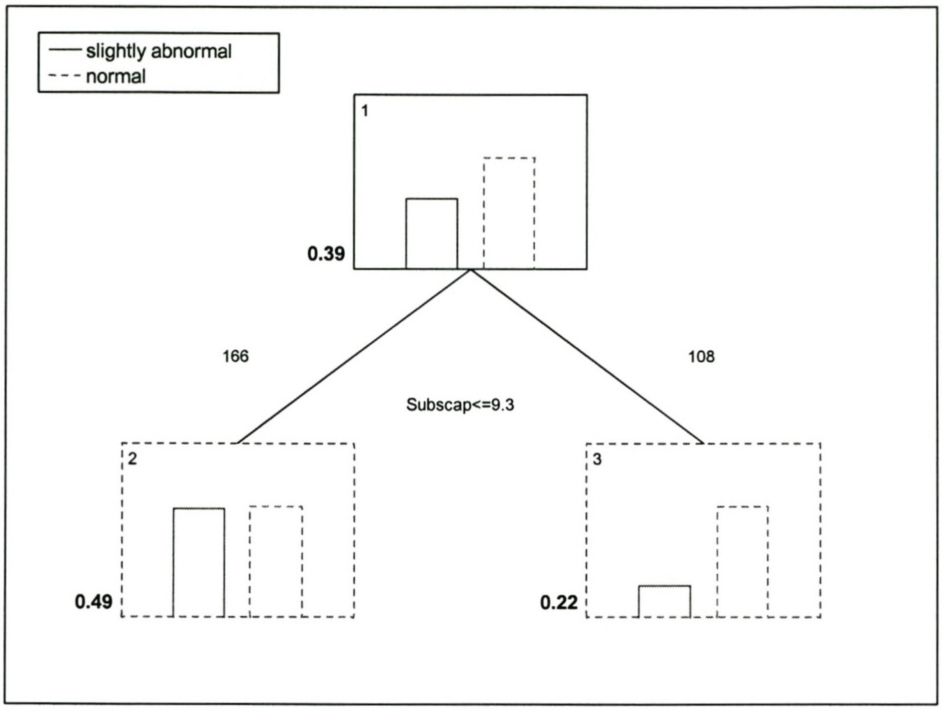


FIGURE 31: CLASSIFICATION TREE FOR WINGED SCAPULAE AND SUBSCAP SKINFOLD

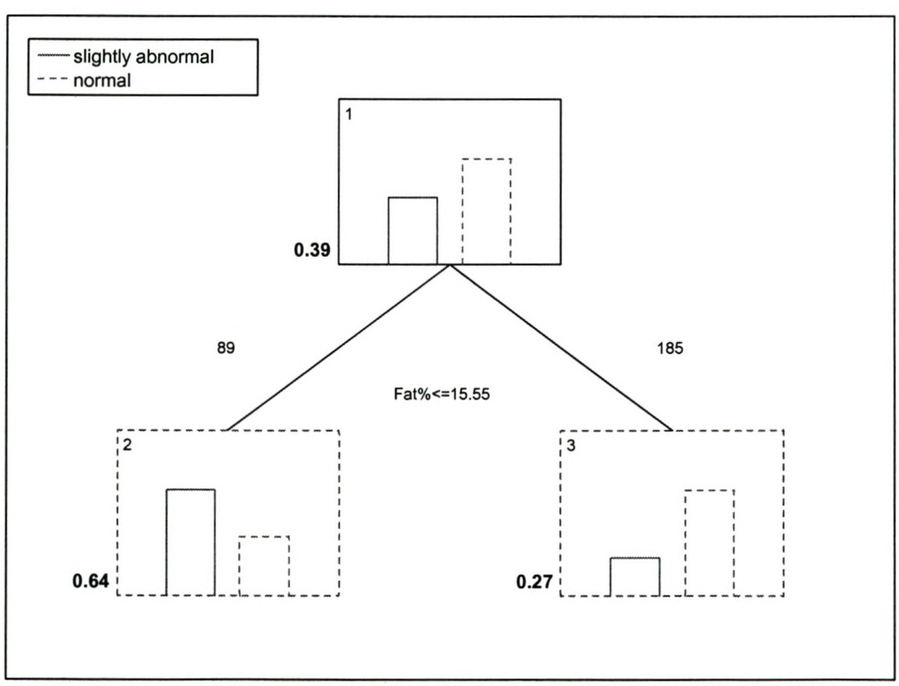


FIGURE 32: CLASSIFICATION TREE FOR WINGED SCAPULAE AND FAT %

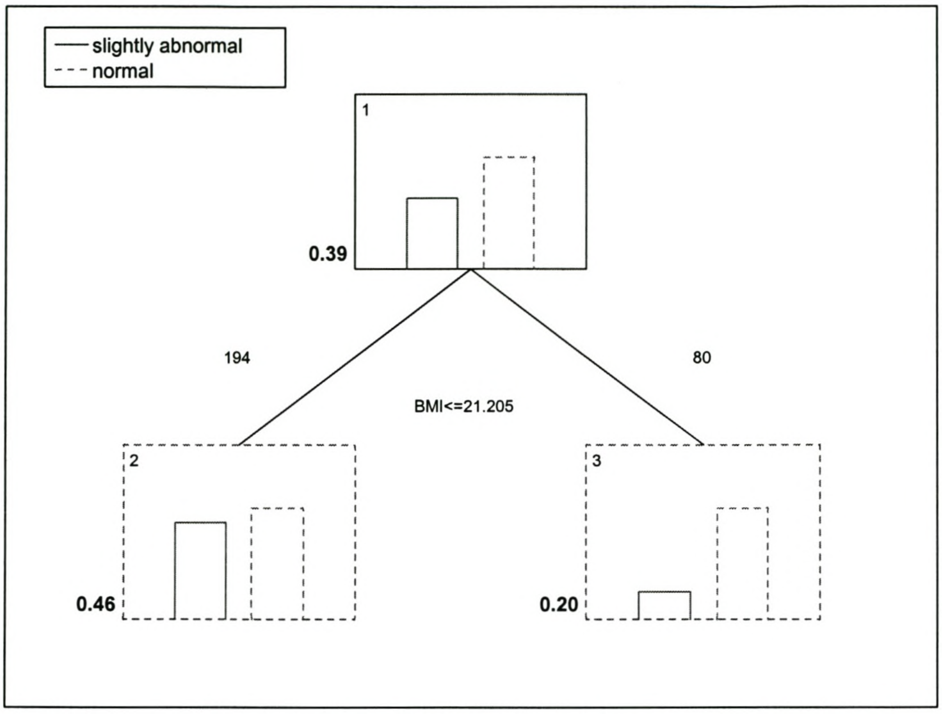


FIGURE 33: CLASSIFICATION TREE FOR WINGED SCAPULAE AND BMI

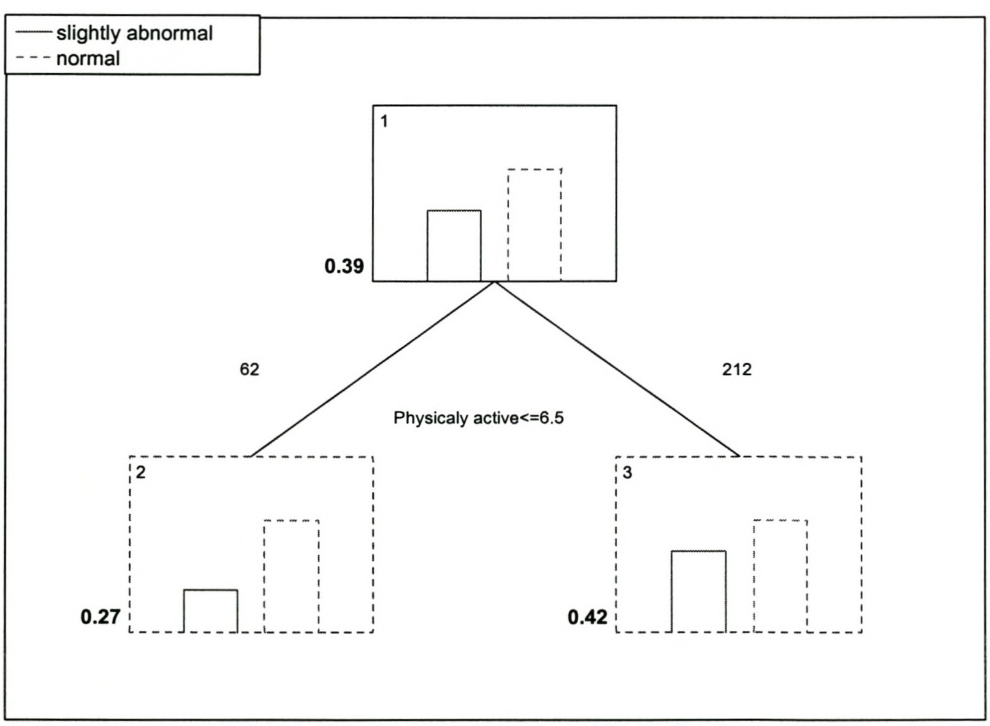


FIGURE 34: CLASSIFICATION TREE FOR WINGED SCAPULAE AND PHYSICAL ACTIVITY PROFILE

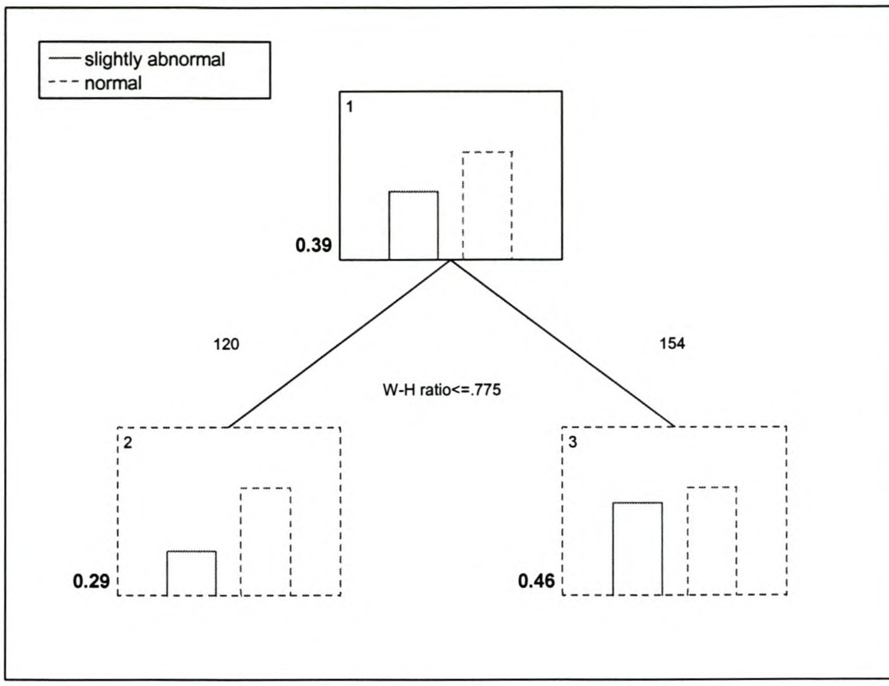


FIGURE 35: CLASSIFICATION TREE FOR WINGED SCAPULAE AND W-H RATIO

4.3.4 KYPHOSIS

The overall rate for the prevalence of kyphosis was 55%.

a) School

Lochnerhoff had a lower rate (37%) than the other schools that had a prevalence rate of 62%. The rate for Lochnerhoff is also lower than the overall rate of 55%. This time the tree did not split on gender. Thus, gender cannot be used to explain why Lochnerhoff had a lower rate than the other schools (Figure 36).

b) Body weight

Subjects with a smaller weight (≤ 44.95kg) had a lower prevalence rate (43%) than subjects with a heavier weight (>44.95kg) who had a rate of 63% (Figure 37).

c) Fat %

Subjects with a higher fat% (> 38.3%) had a very high prevalence rate (89%), compared to those subjects with a lower fat% (≤ 38.3%), who had a rate of 51%. The rate for subjects with a higher fat% is also much higher than the overall rate of 55%. However, it must be noted that only 26 subjects had a fat% > 38.3%, but it is still worth mentioning (Figure 38).

d) BMI

Subjects with a greater BMI (>23.05) had a much higher prevalence rate (76%) than those with a smaller BMI (≤ 23.05), who had a rate of 50%. The rate for subjects with a greater BMI was also much higher than the overall rate of 55% (Figure 39).

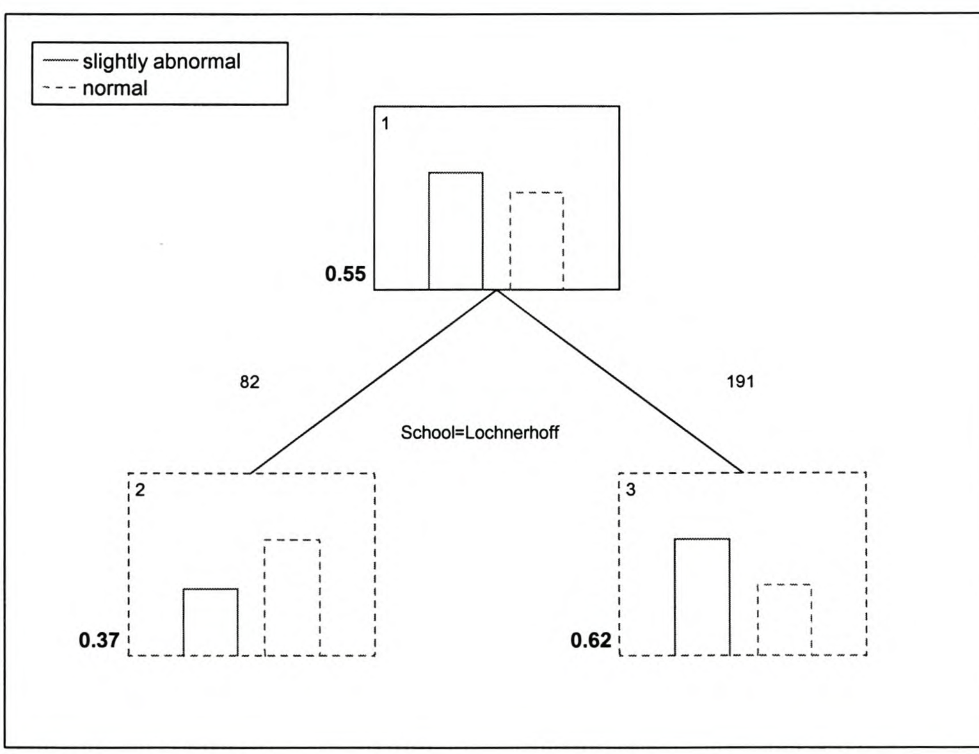


FIGURE 36: CLASSIFICATION TREE FOR KYPHOSIS AND SCHOOL

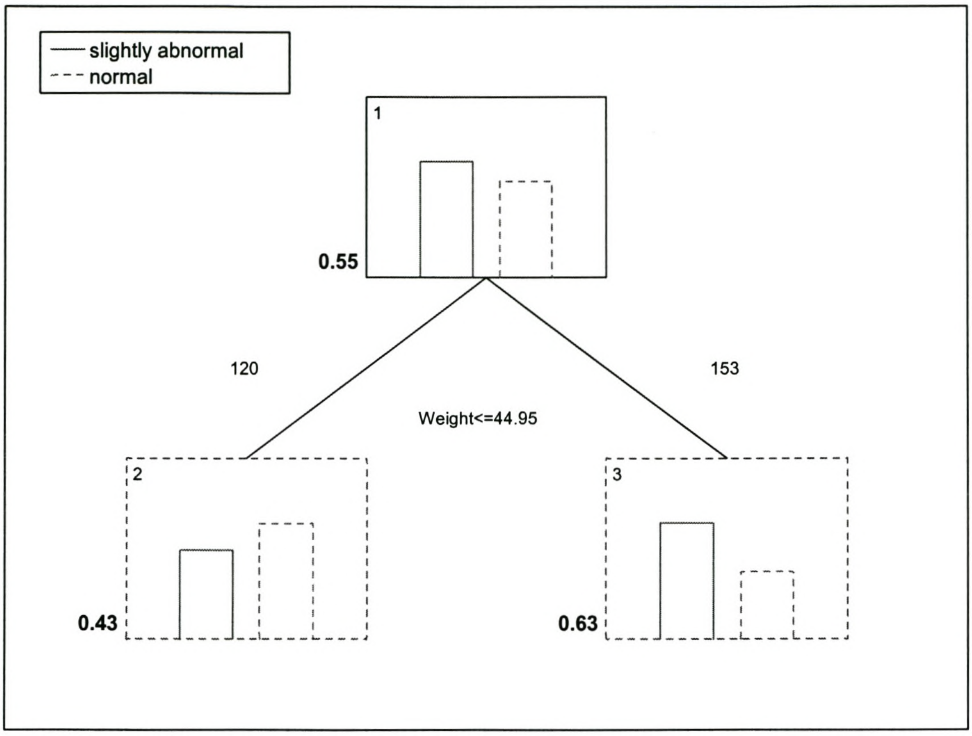


FIGURE 37: CLASSIFICATION TREE FOR KYPHOSIS AND BODY WEIGHT

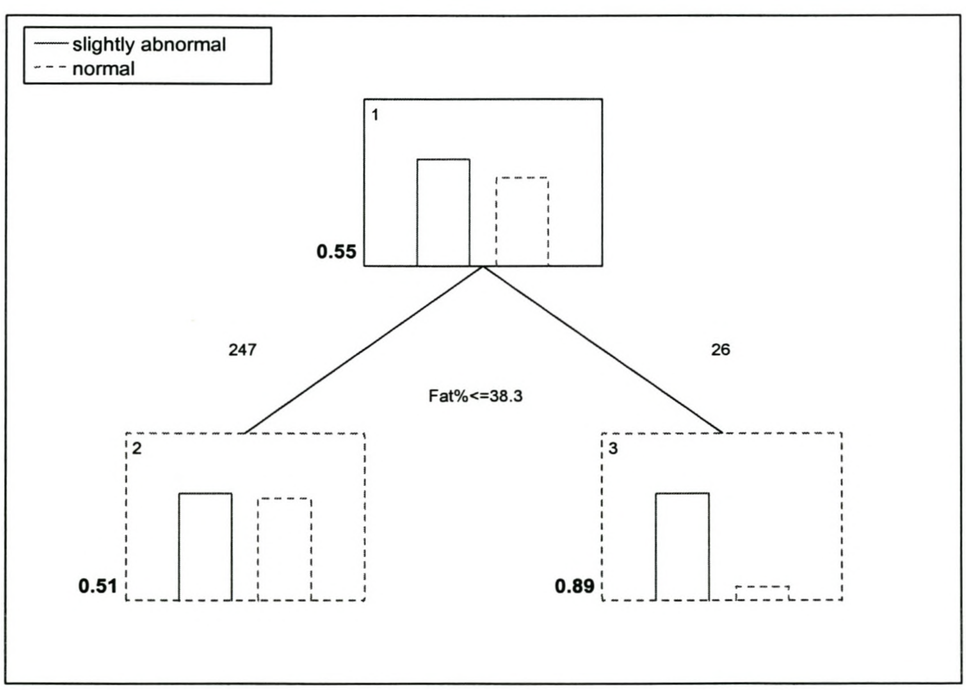


FIGURE 38: CLASSIFICATION TREE FOR KYPHOSIS AND FAT %

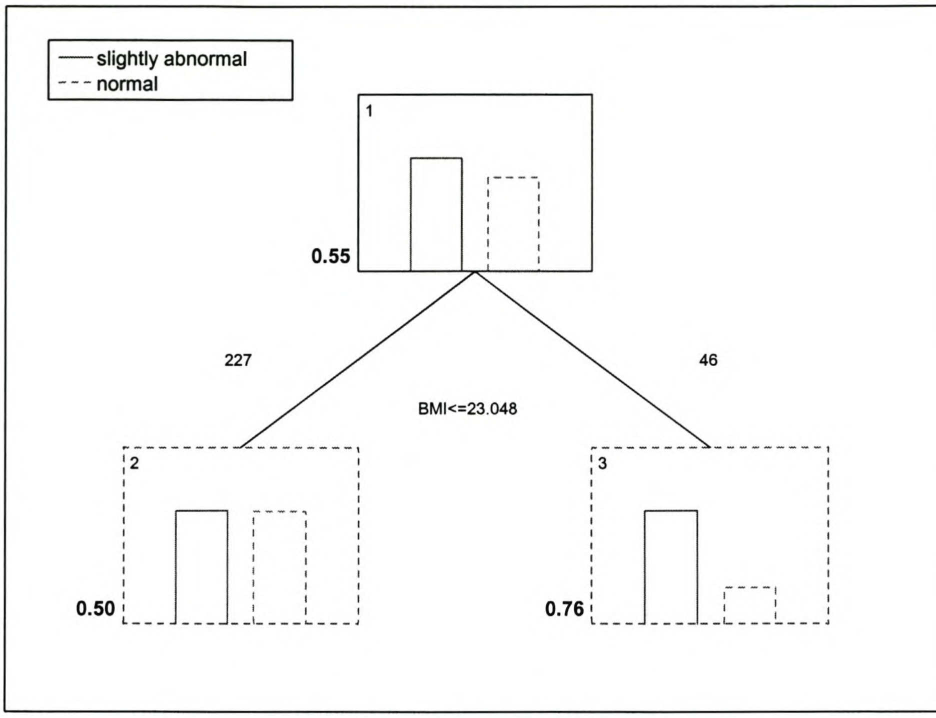


FIGURE 39: CLASSIFICATION TREE FOR KYPHOSIS AND BMI

4.3.5 INCLINED TRUNK

The overall rate for the prevalence of inclined trunk was 42%.

a) School

Lochnerhoff had a higher prevalence rate (60%) than the other three schools that had a rate of 34%. The rate for Lochnerhoff is also much higher than the overall rate of 42%. However, the tree splits on gender as well (see 4.3.5 b), thus gender was the deciding factor and not school (Figure 40).

b) Gender

The prevalence rate for boys (57%) was much higher than the 26% for girls (Figure 41).

c) Body weight

The prevalence rate was higher for subjects with a smaller weight (≤ 48.75kg) (49%), compared to those with a heavier weight (> 48.75kg), who had a rate of 31%. The subjects with the heavier weight had a rate smaller than the overall 42% rate (Figure 42).

d) Subscap skinfold

The prevalence rate (54%) was higher for subjects with a subscap skinfold ≤ 7.9mm compared to subjects with a subscap skinfold > 7.9mm, who had a rate of 31%. The rate for subjects with a greater subscap skinfold was also higher than the overall rate of 42%. The rate for boys was also higher than for girls (see *Gender* at 4.3.5 b) and thus supports this finding because boys have a lower average subscap skinfold thickness (Figure 43).

e) Fat %

The prevalence rate for subjects with a fat% ≤ 18.25% was higher (57%) than subjects with a higher fat% (> 18.25%), who had a rate of 29%. The rate for subjects with a greater fat% was also less than the overall rate of 42% (Figure 44).

f) w-h ratio

At a w-h ratio ≤ 0.76 the prevalence rate was lower (31%) compared to a rate of 51% at a w-h ratio > 0.76 (Figure 45).

g) BMI

Subjects with a smaller BMI (≤ 17.63) had a higher prevalence rate (57%) compared to those with a greater BMI (>17.63), who had a rate of 35%. This rate is also lower than the overall rate of 42% (Figure 46).

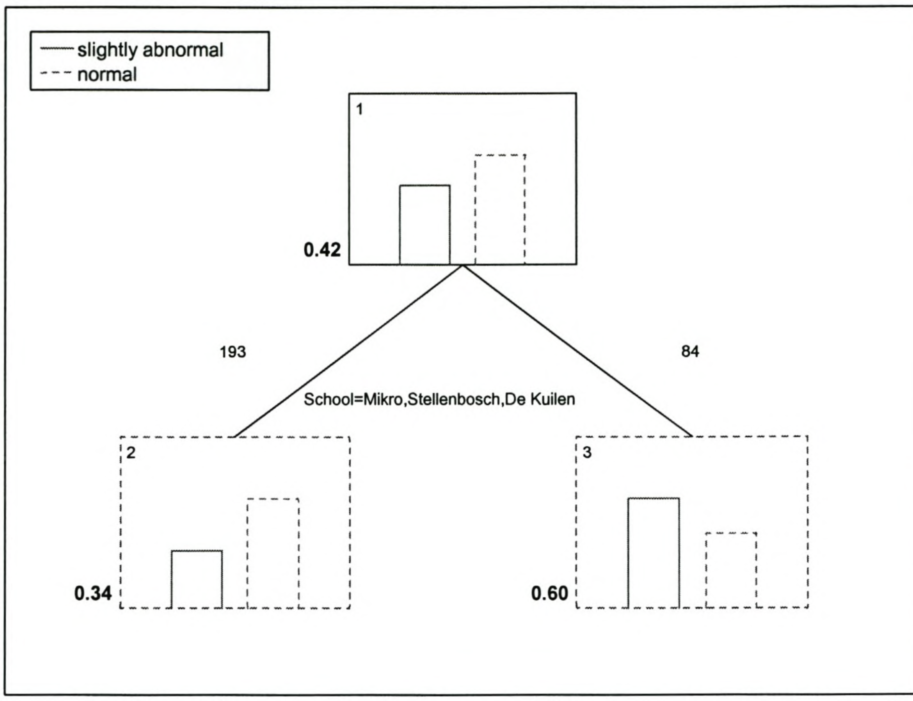


FIGURE 40: CLASSIFICATION TREE FOR INCLINED TRUNK AND SCHOOL

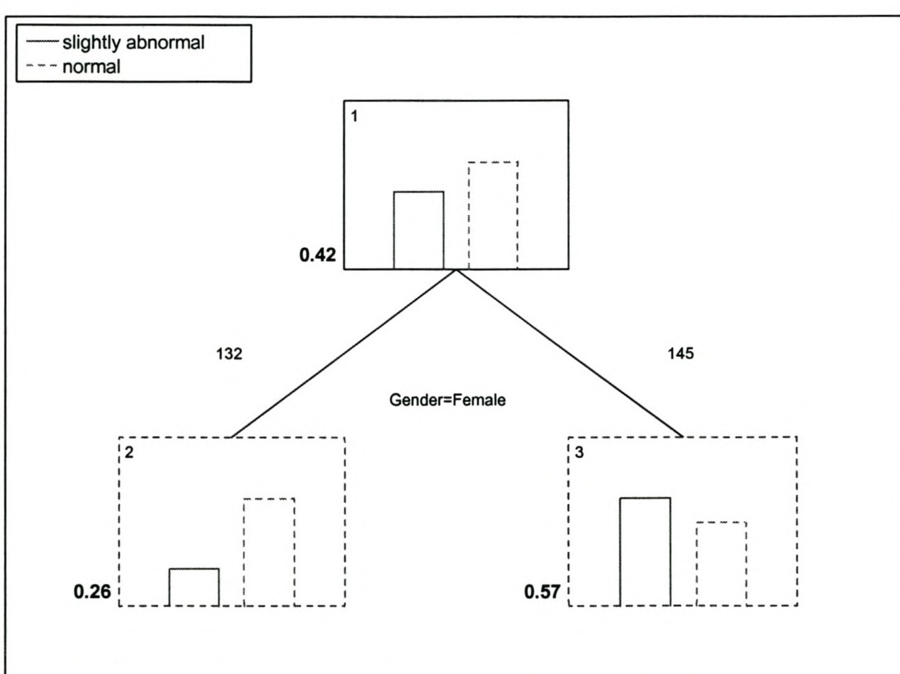


FIGURE 41: CLASSIFICATION TREE FOR INCLINED TRUNK AND GENDER

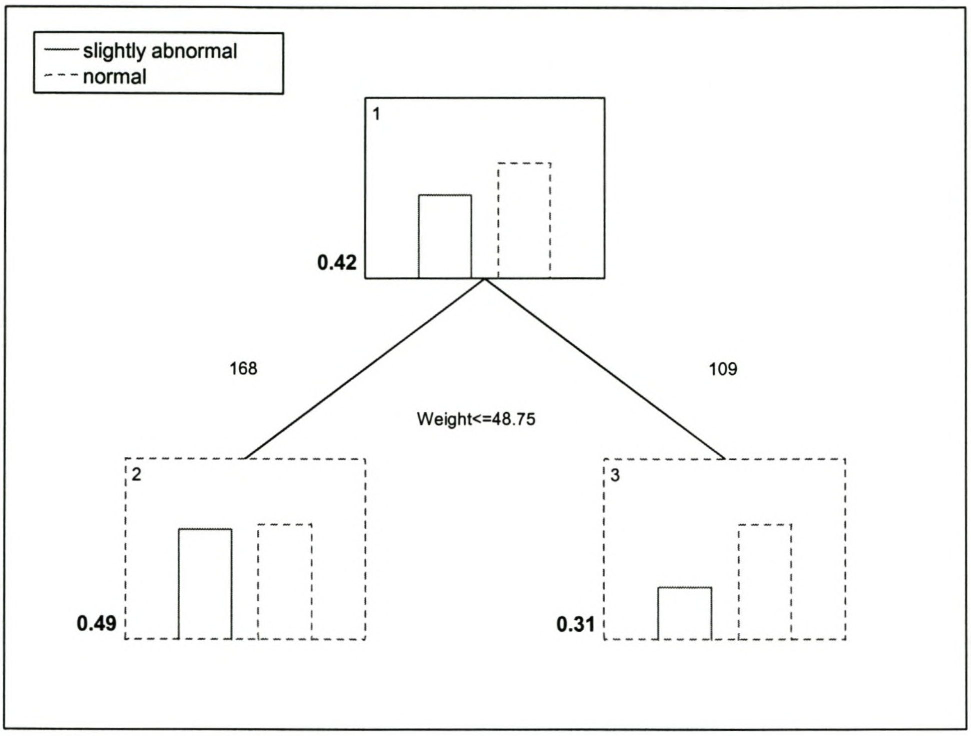


FIGURE 42: CLASSIFICATION TREE FOR INCLINED TRUNK AND BODY WEIGHT

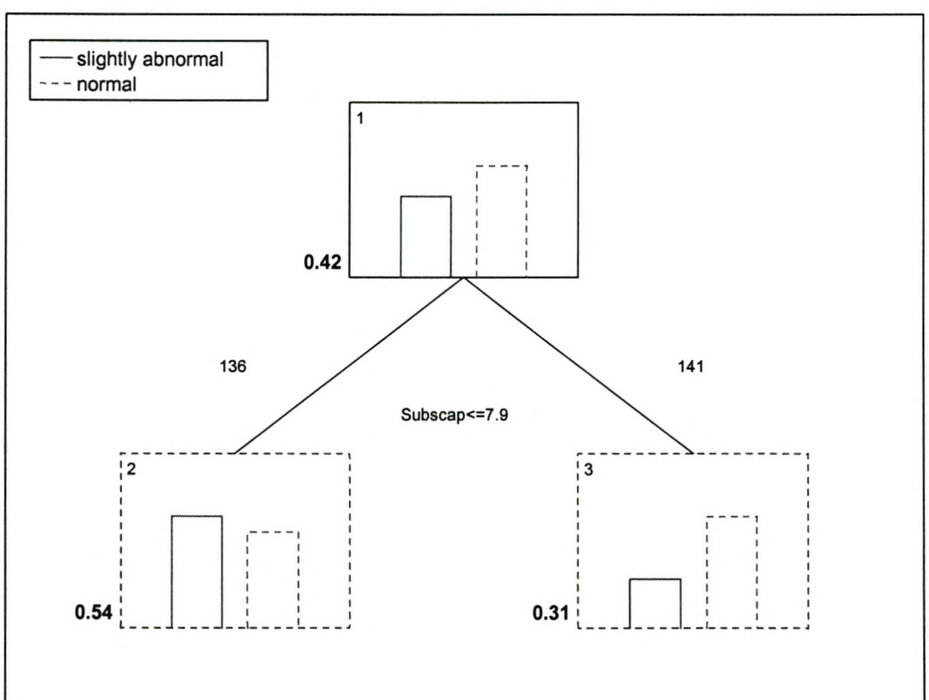


FIGURE 43: CLASSIFICATION TREE FOR INCLINED TRUNK AND SUBSCAP SKINFOLD

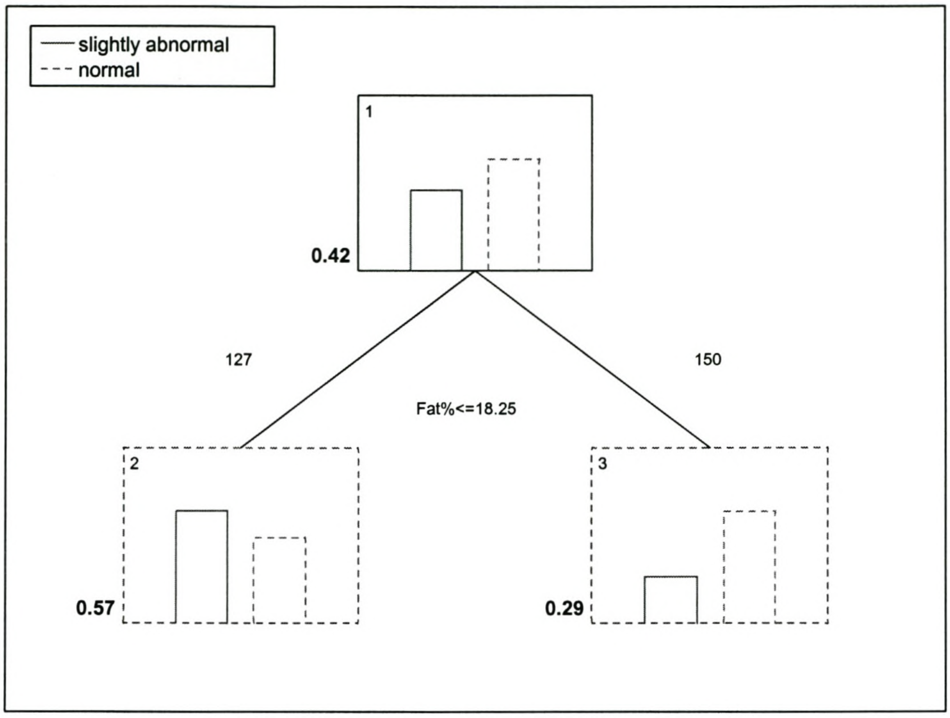


FIGURE 44: CLASSIFICATION TREE FOR INCLINED TRUNK AND FAT %

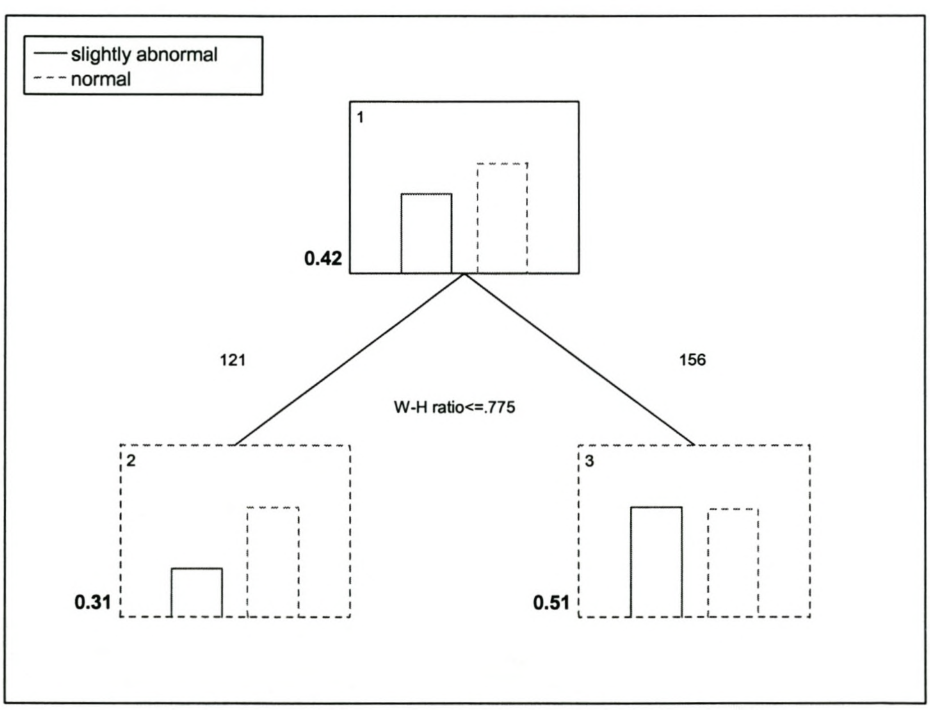


FIGURE 45: CLASSIFICATION TREE FOR INCLINED TRUNK AND W-H RATIO

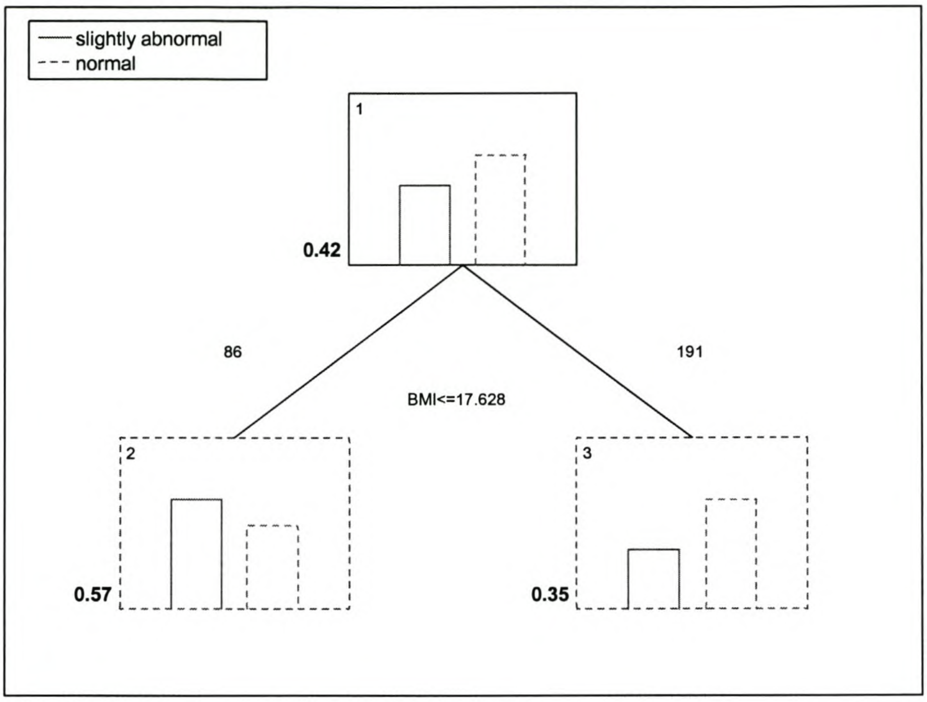


FIGURE 46: CLASSIFICATION TREE FOR INCLINED TRUNK AND BMI

4.3.6 PROTRUDING ABDOMEN

The overall prevalence rate for protruding abdomen was 26%.

a) Body weight

The prevalence rate was higher for subjects with a greater weight (>46.3kg) which had a rate of 34%, compared to subjects with smaller weight (≤ 46.3kg), which had a prevalence rate of 19% (Figure 47).

b) Fat %

Subjects with a smaller fat% (≤ 22.3%) had a lower prevalence rate (17%) than subjects with a higher fat% (>22.3%) with a rate of 41%. The rate for subjects with a higher fat% was much higher than the rate for subjects with a lower fat% and the overall rate of 26% (Figure 48).

c) BMI

The prevalence rate for subjects with a BMI >21.61 (49%) was higher than the rate for subjects with a BMI ≤ 21.61 (19%), and higher than the overall rate of 26% (Figure 49).

d) w-h ratio

The prevalence rate for subjects with a w-h ratio > 0.77 (32%) was higher than those subjects with a w-h ratio ≤ 0.77 (19%) and higher than the overall rate of 26% (Figure 50).

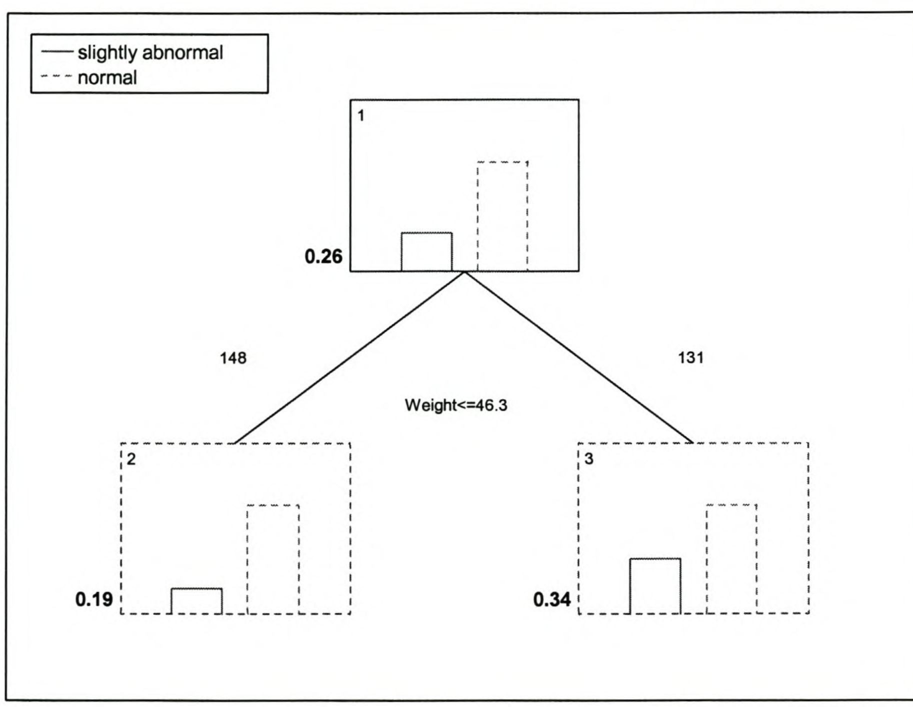


FIGURE 47: CLASSIFICATION TREE FOR PROTRUDING ABDOMEN AND BODY WEIGHT

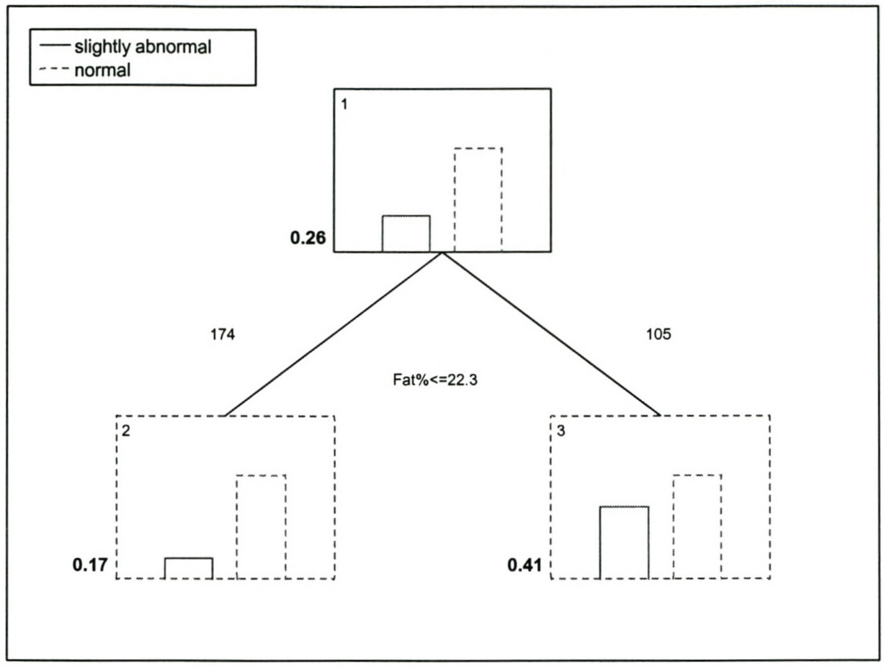


FIGURE 48: CLASSIFICATION TREE FOR PROTRUDING ABDOMEN AND FAT %

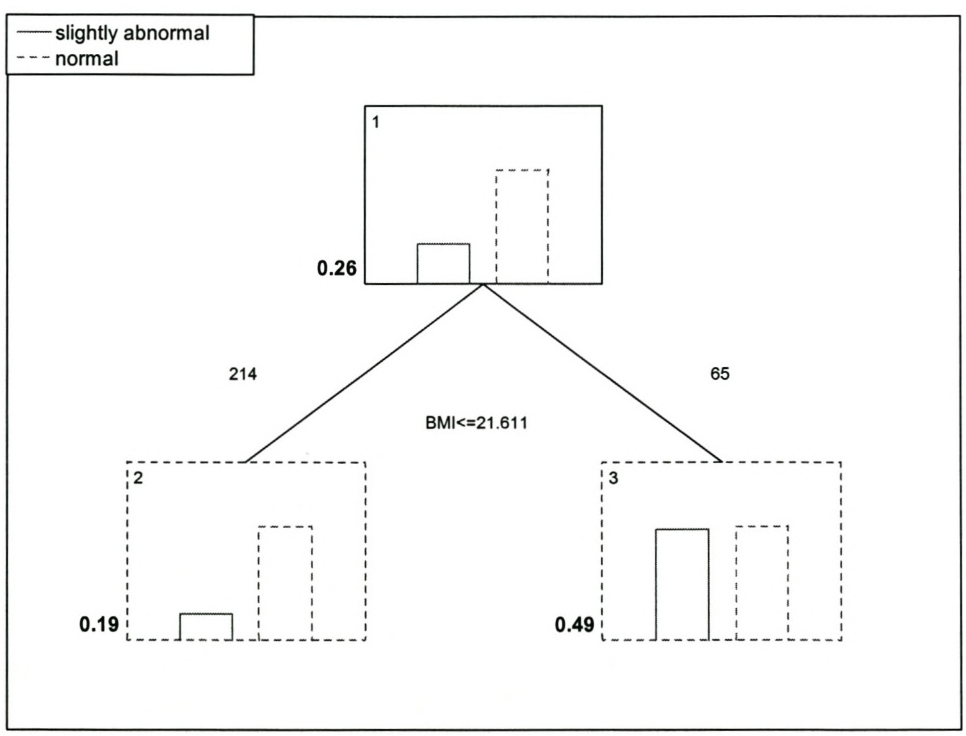


FIGURE 49: CLASSIFICATION TREE FOR PROTRUDING ABDOMEN AND BMI

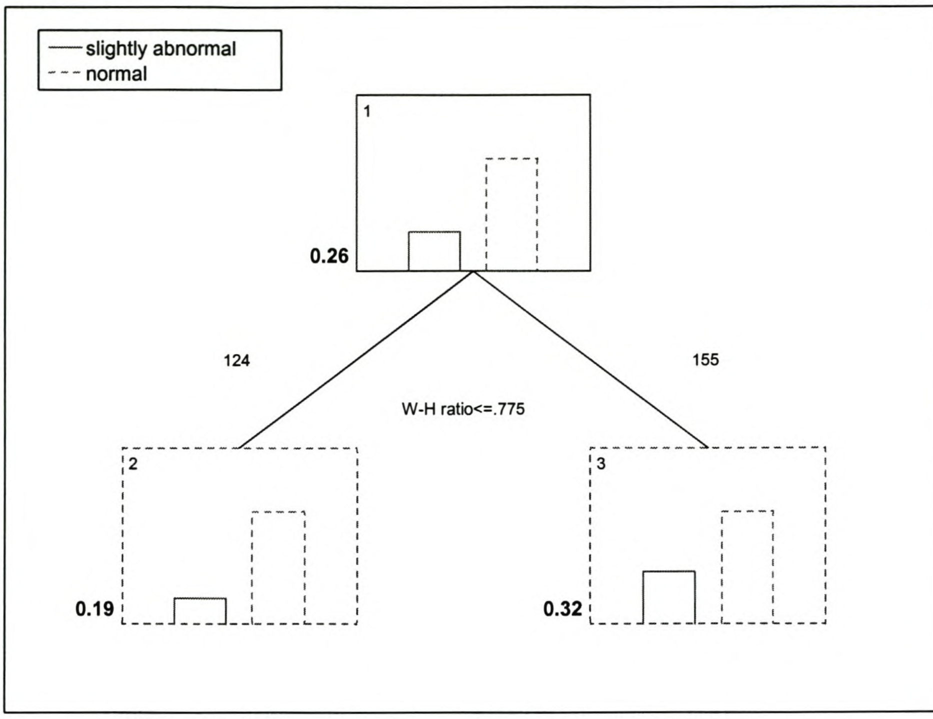


FIGURE 50: CLASSIFICATION TREE FOR PROTRUDING ABDOMEN AND W-H RATIO

4.3.7 LORDOSIS

The overall rate for the prevalence of lordosis was 66%.

a) Gender

The prevalence rate was higher in boys (71%) compared to girls that had a rate of 60% (Figure 51).

b) BMI

Subjects with a greater BMI (>20.35) had a higher prevalence rate (74%) compared to those subjects with a lower BMI (≤ 20.35), who had a rate of 61% (Figure 52).

c) Fat %

With a fat% ≤ 22.9% the prevalence rate was 59%, which is lower than the prevalence rate for subjects with a fat% > 22.9% (77%). However, with a fat% between 14.6% and 22.9% the prevalence rate is 49% compared to a 72% rate for a fat% ≤ 14.6%. The reason why the rest of the tree was not considered for discussion is because of the few number of subjects in the lower nodes of the tree (Figure 53).

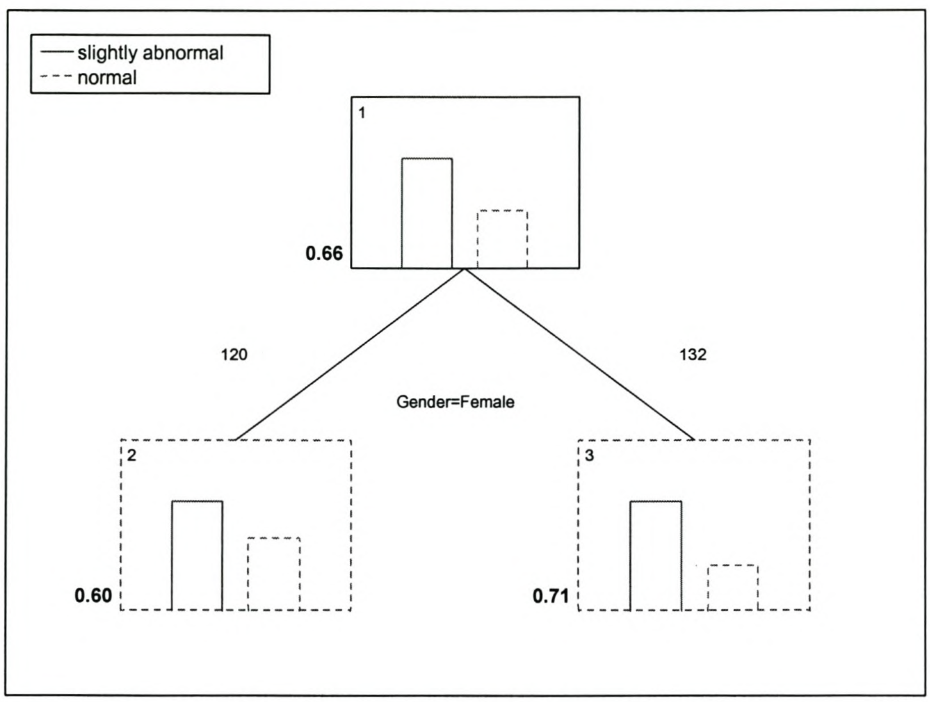


FIGURE 51: CLASSIFICATION TREE FOR LORDOSIS AND GENDER

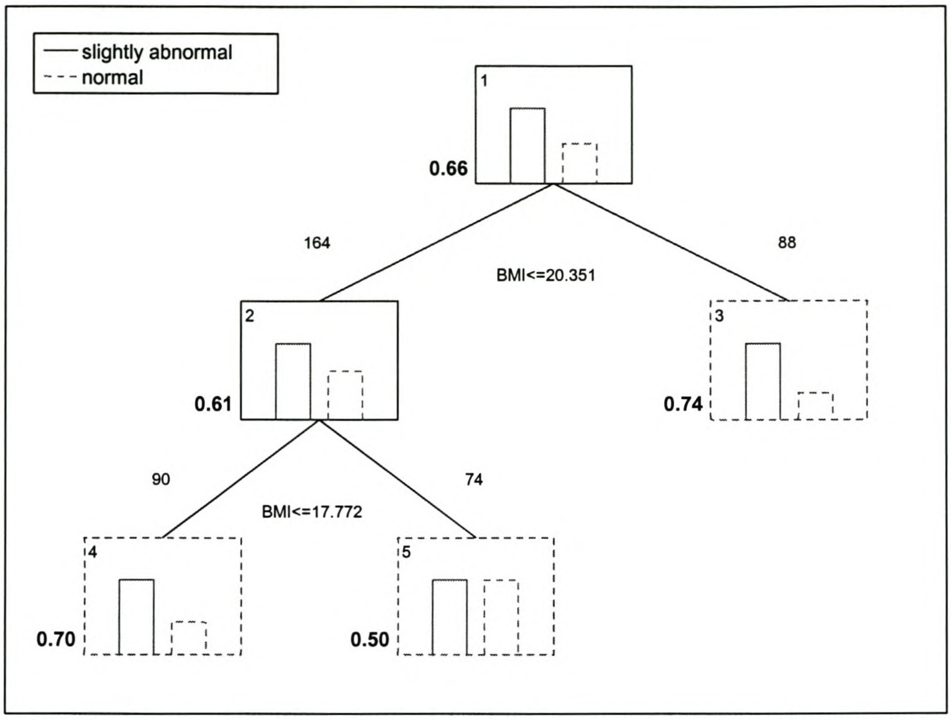


FIGURE 52: CLASSIFICATION TREE FOR LORDOSIS AND BMI

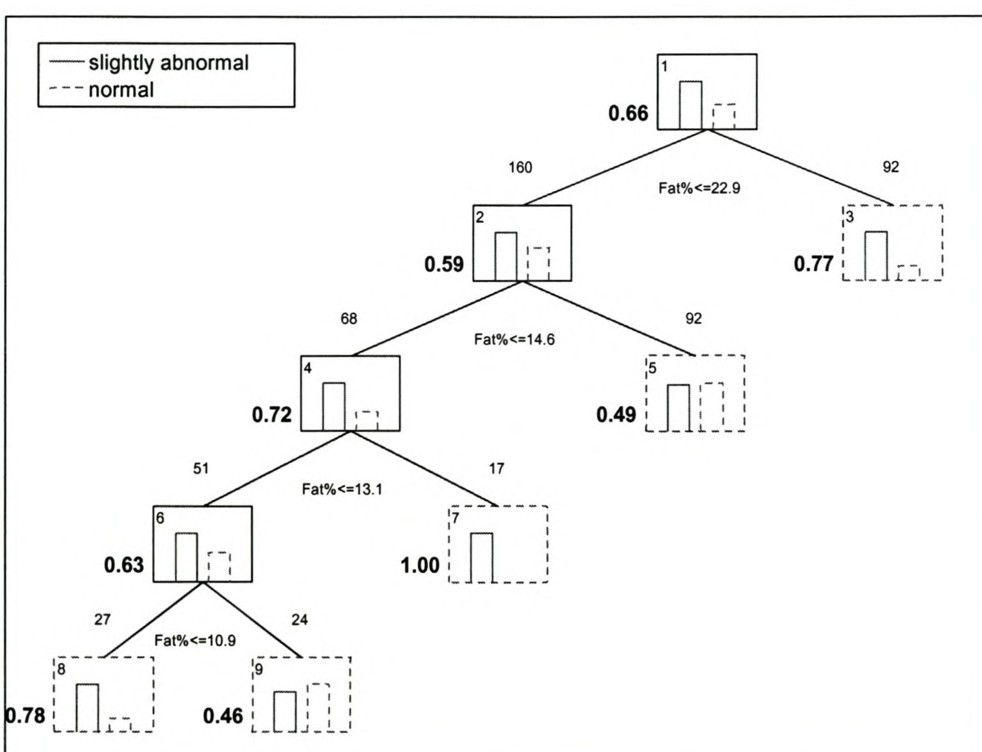


FIGURE 53: CLASSIFICATION TREE FOR LORDOSIS AND FAT %

4.3.8 UNEVEN SHOULDERS

The overall prevalence for uneven shoulders was 51%.

a) School

Mikro and Stellenbosch Primary had a higher prevalence rate (57%) compared to the rate for De Kuilen and Lochnerhoff with a rate of 42% (Figure 54).

b) Age

Younger subjects (≤ 11.5 years) seemed to have a lower prevalence rate (35%) compared to older subjects (>11.5 years), who had a rate of 55%. The rate for younger subjects is also lower than the overall rate of 51% (Figure 55).

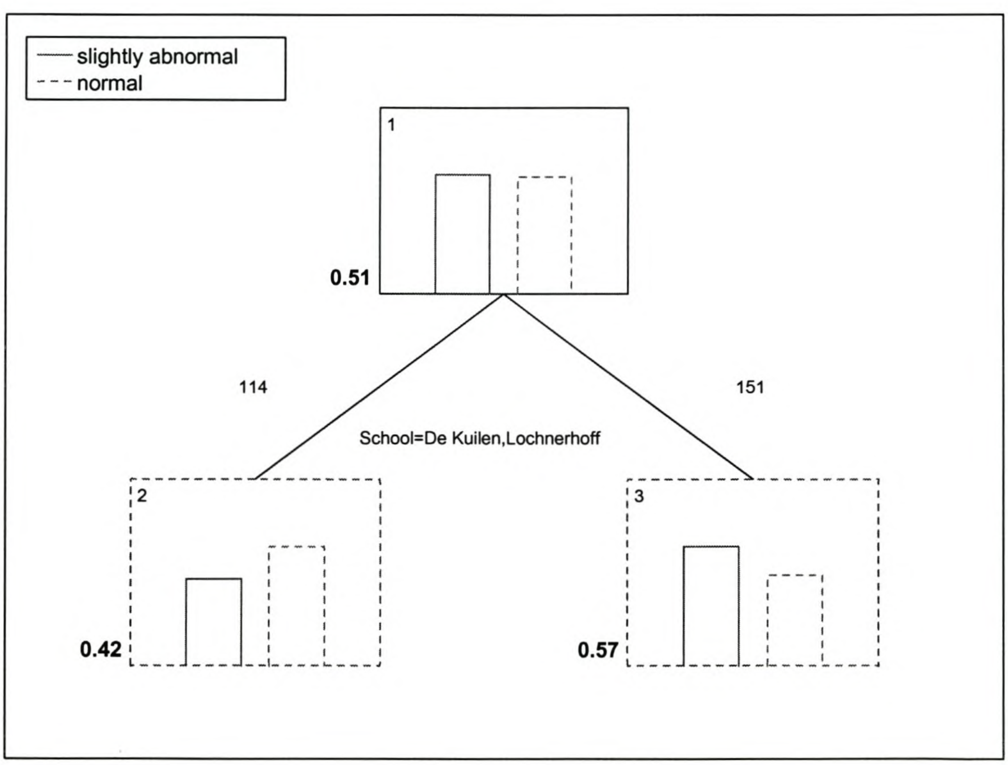


FIGURE 54: CLASSIFICATION TREE FOR UNEVEN SHOULDERS AND SCHOOL

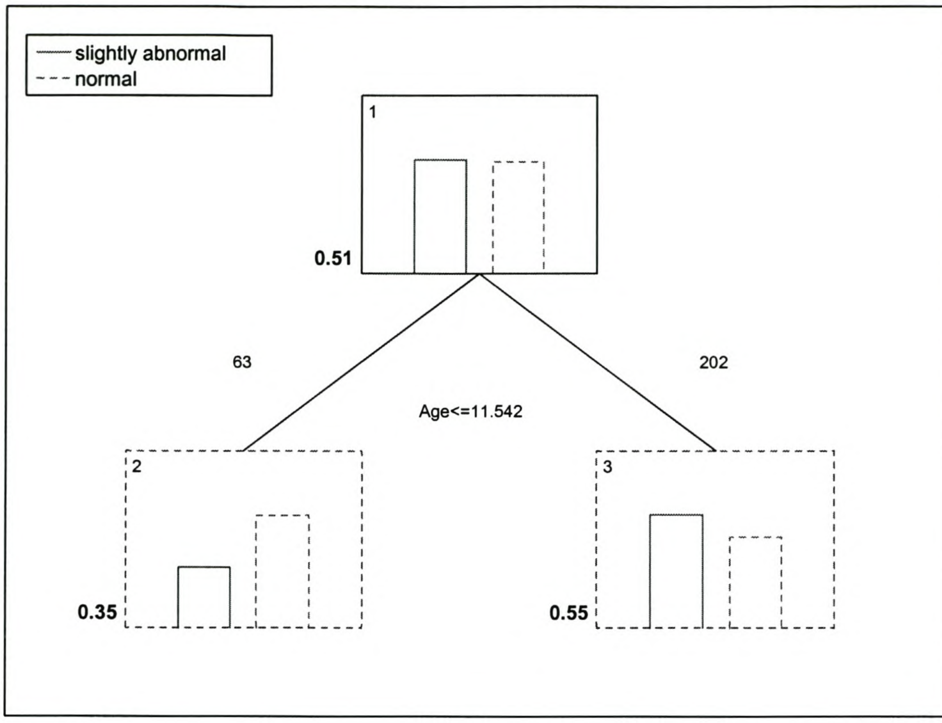


FIGURE 55: CLASSIFICATION TREE FOR UNEVEN SHOULDERS AND AGE

4.3.9 PRONATED FEET

The overall prevalence rate for pronated feet was 29%.

a) Gender

The prevalence rate for boys (37%) was higher than the 20% rate for girls (Figure 56).

b) School

Lochnerhoff and De Kuilen had a higher prevalence rate (35%) than the other two schools that had a rate of 25% (Figure 57).

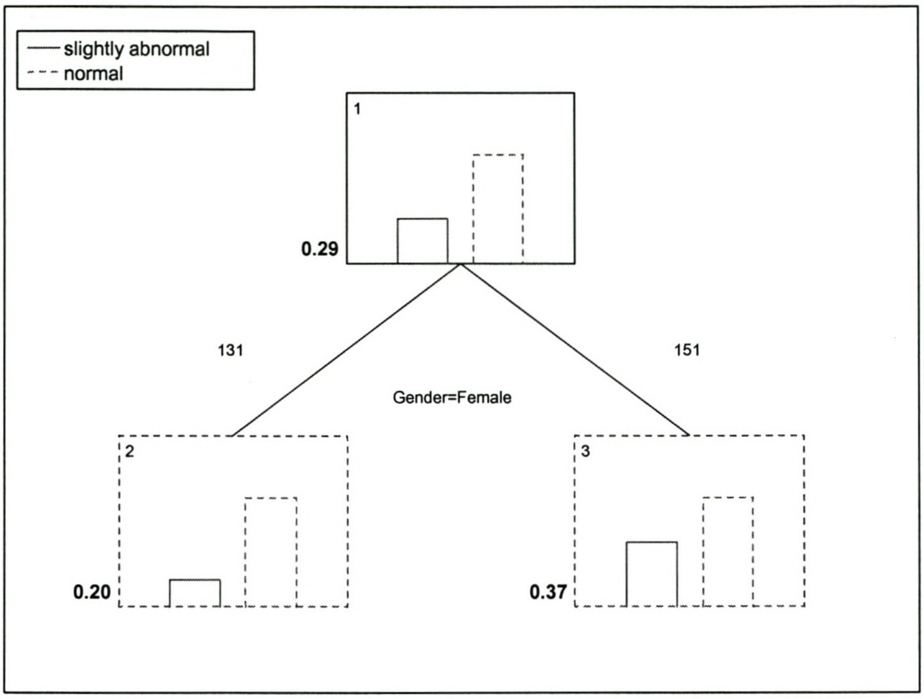


FIGURE 56: CLASSIFICATION TREE FOR PRONATED FEET AND GENDER

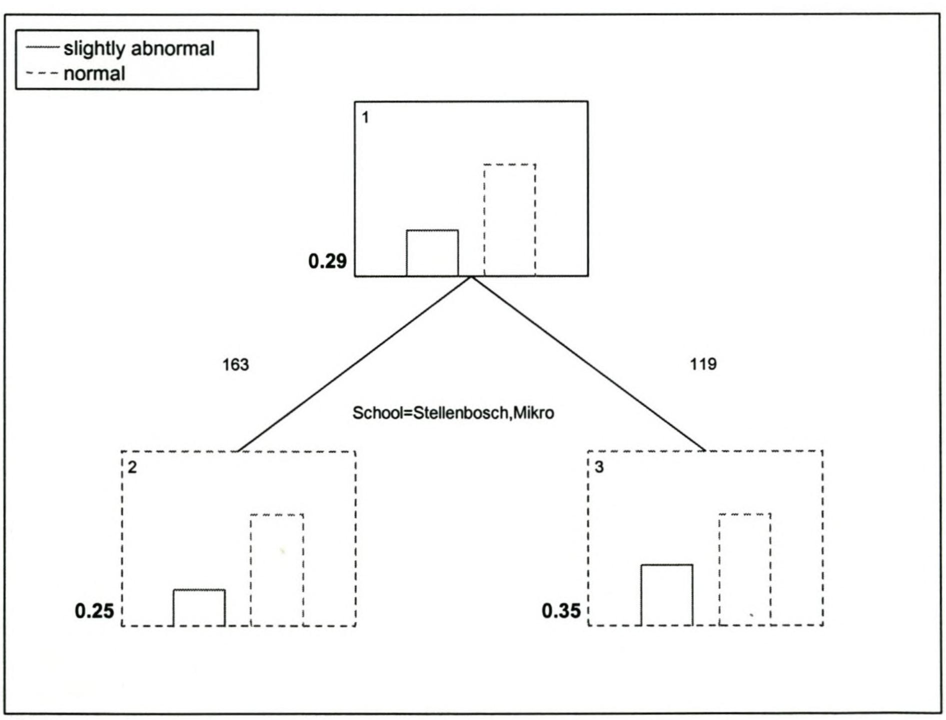


FIGURE 57: CLASSIFICATION TREE FOR PRONATED FEET AND SCHOOL

4.3.10 FLAT FEET

The overall prevalence rate for flat feet was 28%.

a) Body weight

Flat feet was more prevalent in subjects with a weight > 41.3kg (36%) than those subjects with a smaller weight (≤ 41.3kg) which had a prevalence rate of 11% (Figure 58).

b) Fat %

The prevalence rate was higher in subjects with a fat% > 29.7% (48%), compared to those subjects with a fat% ≤ 29.7%, which had a prevalence rate of 23% (Figure 59).

c) BMI

Subjects with a greater BMI (>22.38) had a higher prevalence rate (51%), compared to those subjects with a lower BMI (≤ 22.38), which had a prevalence rate of 22% (Figure 60).

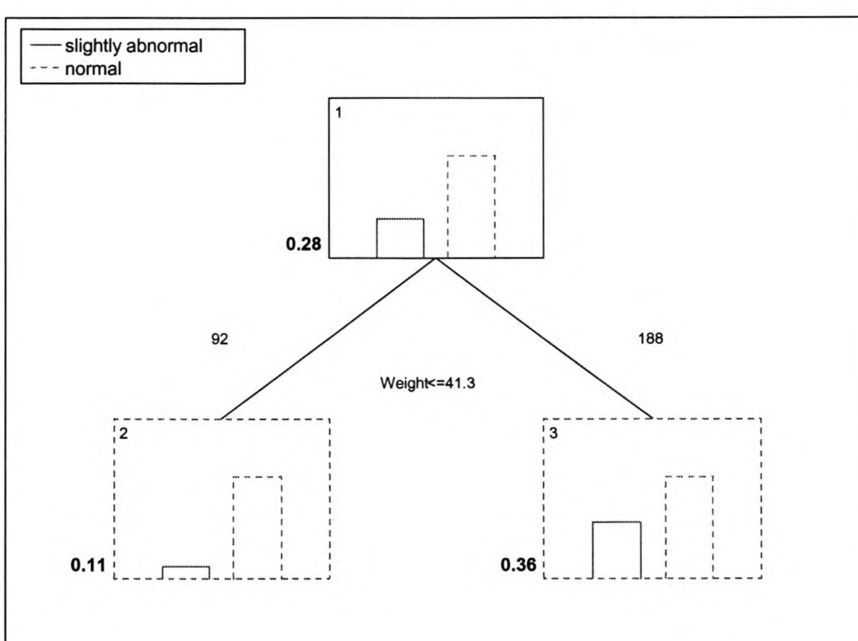


FIGURE 58: CLASSIFICATION TREE FOR FLAT FEET AND BODY WEIGHT

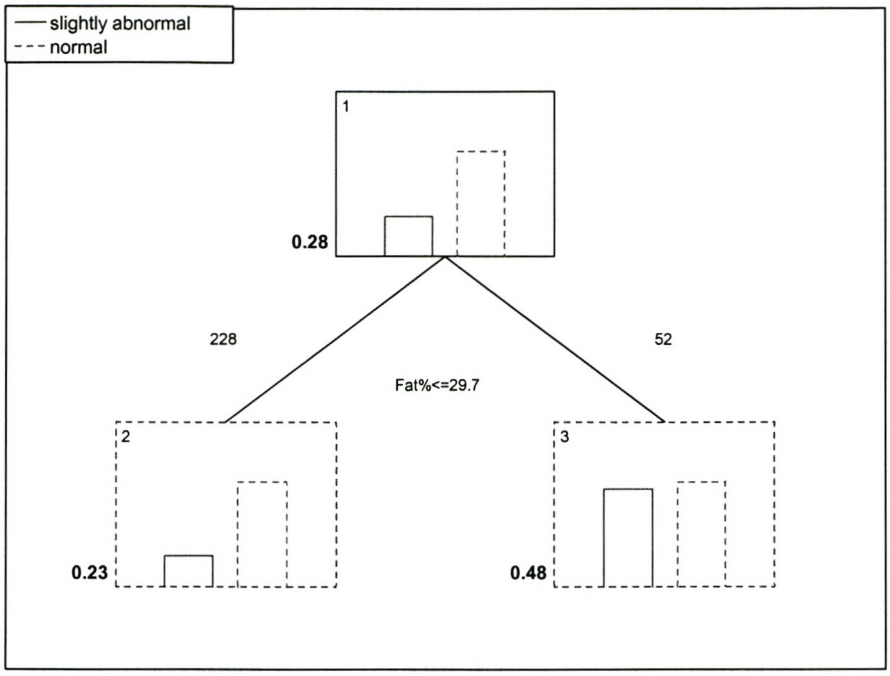


FIGURE 59: CLASSIFICATION TREE FOR FLAT FEET AND FAT %

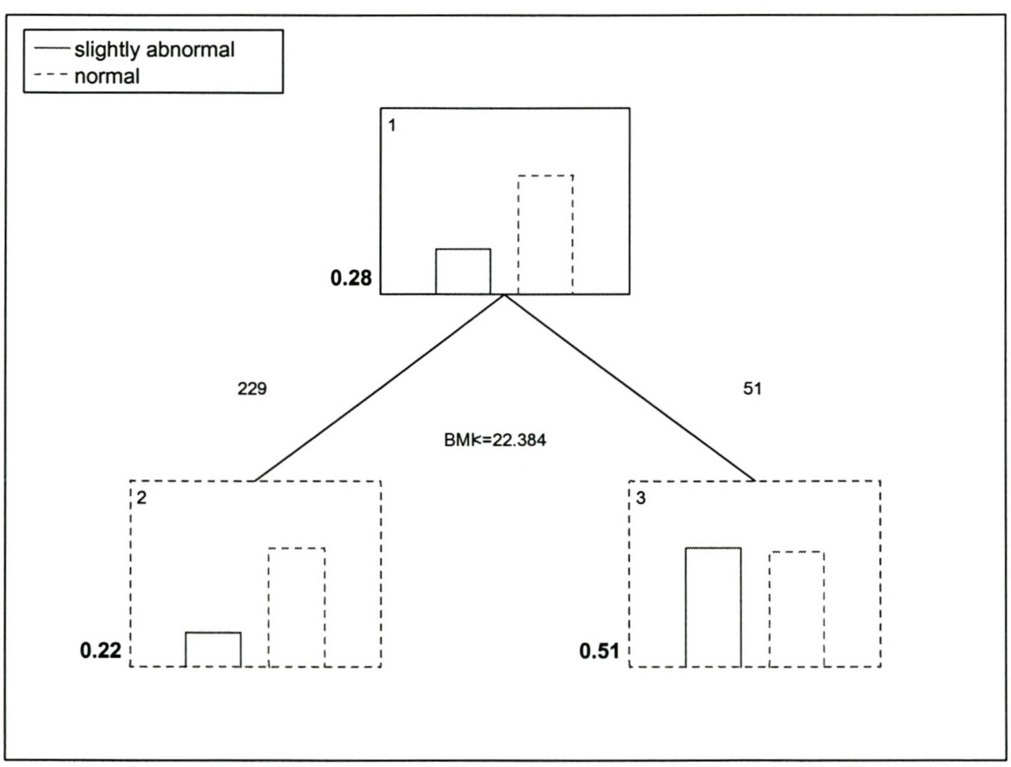


FIGURE 60: CLASSIFICATION TREE FOR FLAT FEET AND BMI

4.3.11 DISCUSSION

According to the researcher's knowledge there is limited comparative research conducted in the broad spectrum of postural deformities. As mentioned before, Francis and Bryce (1987) reviewed 43 published articles dating back to 1970 and found only one article by Maloney and Hildebrand (as cited in Francis & Bryce, 1987) that screened for other deformities. The following was concluded from the factors evaluated:

BMI, fat% and body weight influenced the prevalence of deformities the most. In all deformities, except winged scapulae and inclined trunk an increase in these three factors resulted in a higher prevalence rate.

Of further interest is the similarity between winged scapulae and inclined trunk. It was only winged scapulae and inclined trunk that were most prevalent in leaner subjects (smaller weight, BMI and fat%). Both deformities were more prevalent in subjects with a greater w-h ratio and the overall prevalence rate was also very similar (Winged scapulae, 39%; Inclined trunk, 42%). There is no current research that supports a close association between these two deformities, but it is still worth mentioning.

Lordosis, winged scapulae, inclined trunk, and pronated feet were more prevalent in boys than in girls. It is clear that if gender were a deciding factor, boys would have been more likely to suffer from the deformity. This finding is supported by the study of Francis and Bryce (1987) that found a higher prevalence rate for lordosis, pronated feet and winged scapulae among boys.

Forward head and flat chest were more prevalent in subjects with a low level of physical activity. Winged scapulae were more prevalent in physically active individuals. This finding is supported by the fact that winged scapulae were more prevalent in leaner subjects, because one would expect physically active individuals to be leaner. It should be noted that physical activity was measured more in terms of aerobic capacity (e.g. the further the distance from school and the longer the duration of a exercise session, the higher marks were scored). Shoulder or trunk strength was not measured, so one cannot make the conclusion that physical active individuals will have a higher prevalence rate for winged scapulae. Leaner subjects would exhibit a smaller subscapular skinfold thickness and therefore winged scapulae will be more visible in leaner subjects compared to those with a higher fat% around the subscapular region.

Uneven shoulders were more prevalent in subjects from Mikro- and Stellenbosch Primary, and De Kuilen, together with Lochnerhoff had the highest rate for pronated feet. Although Lochnerhoff seemed to have the most deformities, when factors such as gender was brought into consideration this finding lost validity. It is evident that not one of the four schools could be pointed out as having the most deformities, thus school district could not be a deciding factor in the present study. This finding differs from those described in the study by Francis and Bryce (1987). In their study school district was important in predicting the prevalence rates for pronated feet, protruding abdomen and kyphosis.

W-h ratio, age and subscap skinfold were found to have the least effect on the prevalence rate of postural deformities. Height was not a deciding factor, but it must be noted that it forms parts of BMI, and BMI was the factor that influenced the prevalence of postural deformities the most.

Fat% and BMI are used internationally as measurement of body composition and identifying overweight individuals. BMI in children and adolescents compare well to measurements of body fat (Pietrobelli, 1998). In the present study BMI and fat% had a significant correlation of 0.77.

A South African study conducted in 1950 (Postma, 1950) found the average weight of children aged 11 years to 13 years to be 38.65kg. The average weight found in the present study (47.48kg) is almost 10kg more (increased by 23%) than it was in 1950. Also, the average BMI in the 1950 study was 17.49, which is also lower than the average BMI of 19.75 in the present study. The study by Tremblay and Willms (2000) has shown a clear secular trend towards an increase in BMI in Canadian children. A recent editorial published in *JOPERD* stated the following:

> Sedentary lifestyle (watching television, using computers, playing video games) and poor nutrition (too much "junk food") are among the reasons given for this sudden increase in childhood overweight (Sherman, 2002:9).

The editorial revealed that the percentage of overweight (BMI > 95% of peers) Hispanic children rose from 10 to 22% from 1986 to 1998, while the percentage of non-Hispanic white children rose from 8 to 12%. The percentage of overweight, at-risk (BMI > 85% of peers) white children rose from 20% in 1986 to 29% in 1998. These findings can be the cause of great concern as a greater BMI, weight and fat% resulted in a higher prevalence rate in most deformities.

4.4 CONCLUSION

The prevalence rates in this study are considerably high. Differences in prevalence rates can be attributed to the manner in which deformities were evaluated. The "posture grid" made evaluation of certain deformities very easy, but some deformities were difficult to identify. The number of false negative tests could for instance attribute to the differences in prevalence rates.

Scoliosis was difficult to identify through the "posture grid". The same person administered the forward bending test, which reduced the degree of subjectivity. If radiographic tests (X-rays) would have been utilized the prevalence rate for scoliosis could have been higher. The high prevalence rate for uneven shoulder compared to a low prevalence rate for scoliosis supports the finding of a false negative test, as uneven shoulders are associated with scoliosis. The result for uneven hips would be the same, as this deformity was difficult to recognize through clothing (PT shorts).

Subjects with a higher fat% (especially subscap skinfold) can be missed, as it is difficult to identify winged scapulae through a thicker layer of fat. As reported previously, the prevalence rate for winged scapulae was higher in subjects with a lower subscap skinfold.

Postural deformities can be missed if a subject is not evaluated in a relaxed position. If one is consciously aware of being evaluated the first thing that comes to mind is "pull the shoulders back" and "tummy in". Protruding abdomen is a deformity easily overlooked, especially among girls, if subjects are not in a relaxed position.

Lordosis and kyphosis are deformities that are not easily missed through a "posture grid". These deformities are relatively easy to identify and this could explain the high prevalence rates for these two deformities (70% and 57% respectively).

Also, forward head, flat chest inclined trunk, twisted head, pronated feet, and flat feet are deformities that are easily recognized, thus the prevalence rates for these deformities were easily identified with great confidence.

It is clear that postural deformities, evaluated through a posture grid, would much rather result in false negative results than false positive. This finding is rather cumbersome, as the prevalence rate in this study was already very high, without the possible false negative evaluations.

CHAPTER 5

SUMMARY AND RECOMMENDATIONS

5.1 SUMMARY

Previous studies have tended to evaluate the prevalence of postural deformities among children. However most of these studies included only spinal deformities (Baker & Zangger, 1970; Kane & Moe, 1970; Grant *et al*., 1973; Segil, 1974; Sells & May, 1974; Lonstein, 1977). The present study reports the results of a prevalence evaluation of 13 postural deformities.

After two months of evaluating school children aged 11 to 13 years in the selected Western Cape Schools the findings demonstrated a high prevalence rate of postural deformities. Of the 13 postural deformities evaluated, 10 were considered for statistical analysis.

Lordosis, kyphosis, uneven shoulders, inclined trunk, winged scapulae, pronated feet, flat feet, flat chest, forward head and protruding abdomen were the deformities seen most often. Uneven hips, scoliosis and twisted head were excluded from the data analysis because of the low incidence compared to the other deformities. Lordosis, kyphosis and uneven shoulders had prevalence rates as high as 70%, 57% and 55% respectively. Although the prevalence rate for scoliosis was low compared to the other deformities the rate was still higher than the average rates reported in literature.

The findings in this study supports the researcher's statements in Chapter 1 in that physical activity and overweight may be factors that are closely associated with the prevalence of postural deformities. BMI and fat% affected the prevalence rates the most as an increase in these two factors caused a higher prevalence rate in most deformities. Physical activity was found to have a lesser effect on the prevalence rate, but still, a lower level of physical activity caused a higher prevalence rate in forward head and flat chest. Findings in this study concluded that the modern lifestyle of television, video entertainment, motorized transportation, fast food and a lack of regular exercise could be posing a threat to the healthy living of society.

Advances in technology continue to remove habitual physical activity from everyday life. The mechanization of the workplace and the development of labor saving devices in the home have been followed by advances in technology, which further reduced daily energy expenditure. But more of a concern is the suggestion that these levels of inactivity among children are the consequence of an inactive adult society, where inactive role models increasingly restrict young people's freedom.

Postural deformities among children could have detrimental consequences for the health of a child. The following are possible side effects resulting from postural deformities:

Kyphosis, especially if associated with round shoulders, tends to flatten the chest (flat chest) and this could interfere with breathing that could further lead to lung diseases. The incorrect postural alignment associated with kyphosis can lead to serious neck and back pain (Schrecker, 1971:22).

Lordosis interferes with the working of the abdominal organs. The displaced intestines being in part compressed may lead to constipation, which again may lead to a general poisoning of the internal organs. Lordosis, together with an inclined trunk, puts undue strain on the lumbar vertebrae, which in turn could result in lower back pain (Schrecker, 1971:29).

Scoliosis is a progressive condition and could have enormous side effects in future life if not treated or controlled. The effects of scoliosis on the internal organs are similar to those of kyphosis and lordosis, as the contents of the thoracic and abdominal cavities are partly compressed. The "unequable" use of the limbs and the formation of scoliosis constitute a viscous circle as it supports further progression of this deformity. The person is inclined to assume a skew posture, resulting in pain in many parts of the body, as there is an enormous muscle imbalance (Schrecker, 1971:41).

Protruding abdomen is the result of not only bad posture, but also abdominal muscle weakness. This creates a bad base of support concerning the body's core stability in which the abdominal muscles play an important role.

Shoulder instability is the result of weak muscular support. Winged scapulae are associated with fair as well as poor muscle development and could lead to injuries such as shoulder dislocations and shoulder impingement. Winged scapulae are also associated with round shoulders, which in turn tend to cramp and narrow the thorax in front that could impair normal pulmonary function.

Pronated feet could lead to compensatory knee pain and flat feet, which are associated with pronated feet and could result in stress fractures of the lower limb. Most of the stress fractures that occur are located at the tibial and metatarsal bones. Flat feet decrease shock absorption in the metatarsal region, which in turn creates stress fractures in the lower limb. Also, lowering of the skeletal arch of the foot exposes the nerves and blood vessels situated underneath to pressure with every step a person takes, which in the long run could result in considerable pain. This hinders activities such as walking, running and jumping.

These are few of many complications that could result from postural deformities. A postural deviation occurring in any part of the body creates pain or strain in another part. Postural deformities could dramatically decrease functional activity later in life. Simple activities, such as sitting at a table eating or reading a book in bed could create considerable pain. The normal daily activities like standing, walking, picking up an object, opening a door, and sitting in a chair, could become a terrible pain if the body is functionally impaired by a muscle imbalance caused by bad postural habits.

The overall screening of children for postural deformities with the use of a simple test like the ones used in the present study (New York Posture Test, Forward Bending Test) proves to be an effective and inexpensive method of detecting deformities. The data collected in this study generated invaluable data regarding, not only the prevalence of postural deformities, but also identifying factors such as overweight that were found to have a close association with the prevalence rate of postural deformities.

The results of the present study have shown a considerably high prevalence of postural deformities. The study also reported a higher prevalence of postural deformities among children who lead sedentary lifestyles after factors such as physical activity, BMI and fat% had been brought into consideration.

Again, to the researcher's knowledge there is not many comparative research available, but if the study of Francis and Bryce (1987) is brought into discussion the present study's results shows a clear trend to the increasing of the prevalence of postural deformities.

The study has demonstrated that postural deformities do exist among children in public schools. The lack of awareness and the results of this study should support the development of more responsible educational and screening programs in the schools. Furthermore, the total number of children detected with postural deformities and the high level of bad posture that was reported in this study, demonstrates the need for a uniform, nationwide screening program for postural deformities in South Africa.

5.2 RECOMMENDATIONS

Parents should not only worry about "bad backs" but also look at the child's posture and health in general and realize the effects of postural deformities on the body as a whole. Children's muscular development used to be kept in tact by activities such as "rope climbing", "tree climbing" and many leisure activities that are unfamiliar to most of today's children.

Parents and teachers should be made more aware of the consequences of bad posture and be educated in terms of the identification of postural problems and what corrective measures to take in order to correct these problems.

Parents can help children reduce time spent in sedentary behaviors, by, for instance, allowing sedentary recreation only after doing 60 minutes of physical activity, and by setting and consistently following family rules that limit television, computer, and video game time.

Parents should encourage healthy eating habits by limiting "snacking" (chips and chocolates) while watching television or playing on a computer.

Physical education should be brought back into the school curriculum. Physicians can also be effective advocates for improved school physical education, community recreation programs, playgrounds, cycling trails, and other community resources that will promote youth physical activity.

Children should be encouraged to walk bare foot more often, especially during the first six years of their lives as studies have shown that walking bare foot promotes good foot mechanics and prevents postural deformities such as flat feet and pronated feet.

Make children aware of their posture while working with a computer, watching television and sitting at a table during meal times.

Make use of full-size mirrors in rooms in order for one to always be aware of possible problems.

Not concentrating only on activities that increases aerobic capacity but also including muscular strength (e.g. trunk strength) activities.

5.3 REMAINING CHALLENGES

In dealing with anthropometric methods, attention should be directed to improving and/or developing new techniques for describing the human body and evaluating postural deformities.

Further studies must be conducted to evaluate not only the prevalence of postural deformities, but also to evaluate treatment protocols and preventive measures for children with postural deformities.

School-based programs have been successful at improving physical education and using classroom curricula to increase physical activity and decrease television viewing, but intervention in other settings needs to be evaluated for instance, focusing on outdoor recreation activities rather than organized sport. In Europe children stay after school until 15:30 in the afternoons to participate in voluntary outdoor activities that focus on the adventure aspect of physical activity (e.g. rock climbing, hiking trials, canoeing, etc.) rather than playing sport. Although voluntary, children are more likely to participate in these "recreational" activities than organized sport. Encouraging schools to present programs such as those in Europe will encourage children to stay after school and engage in leisure activities that are beneficial to their health.

The Healthy People 2000 Health Objectives for the Nation clearly spells out a variety of goals to achieve by the year 2000 to improve the health and well being of all Americans (Powers & Howley, 1996:7). Examples of objectives include:

- Increase to at least 10 percent the proportion of people aged 18 and older and to at least 60 percent the proportion of children and adolescents aged 6 through 17 who engage in vigorous physical activity that promotes the development and maintenance of cardiorespiratory fitness 3 or more days per week for 20 or more minutes per occasion.

- Reduce dietary fat intake to an average of 25 percent of calories or less and average saturated fat intake to less than10 percent of calories among people aged 3 and older.

- Reduce the prevalence rate of flat feet, lordosis etc. by 5% in the following year, by conducting routine postural evaluation programs.

- Decrease the fat% in overweight girls and boys between ages 12 and 14 years by 6%.

This process of setting long-term goals, evaluating progress toward the goals, and redefining the goals provide direction for use of scarce "health-care rands". The process also helps to identify the future needs for health-care providers to deliver the services.

Providing medical aid subsidies for the treatment of postural deformities could lead to better effective treatment. Treatment could reduce conditions such as back pain and as a result decrease the economic burden caused by this condition. Not only does parents spend a large amount of money on medical treatment, but also, it costs the government millions of rands. By tackling this problem effectively it would result in enormous savings and less pressure on health budgets.

5.4 LIMITATIONS

- There is a lack of clarity attending definitions of what is "normal" posture. It has taken researchers many years to come to a unified understanding of what is "normal" and several attempts have been made to develop the optimal criteria, but to date there is still controversy concerning the correct criteria for what seems to be "optimal or normal" posture (Solberg, 1993). Thus it is unlikely that the researcher is now in a position to define a generalized normal posture that is applicable to a wide variety of children.

- Only white children were considered for statistical purposes, as there were too few children from other races. Thus, comparisons between different races were not possible.

- The children selected, were limited to a small geographic location (+/- 30km radius).

LIST OF REFERENCES

ALEXANDER, C.B. (1999). "The American Academy of Orthopaedic Surgeons". *The American Academy of Orthopaedic Surgeons Bulletin News*. [Hyperlink http://www.aaos.org/wordhtml/bulletin/dec99/acdnws8.htm]. 10 April 2002.

AMENDT, L.E.; AUSE-ELLIAS, K.L.; EYBERS, J.L.; WADSWORTH, C.T.; NIELSEN, D.H. & WEINSTEIN, S.L. (1990). Validity and reliability testing of the scoliometer. *Physical Therapy*, 70(2):108–117.

ANON. (1998a). "National Institute of Arthritis and musculoskeletal- and skin diseases." *Questions and answers about scoliosis in children and adolescents*. 22 September. [Hyperlink http://www.nih.gov/niams/healthinfo/scochild.htm]. 27 February 2001.

ANON. (1998b). "World Book Medical Encyclopedia". *Lordosis*. 13 October. [Hyperlink http://www.rush.edu/worldbook/articles/012000a/012000109.html]. 22 January 2002.

ANON. (1999a). "Lucile Packard Children's Hospital". *Kyphosis*. 22 February. [Hyperlink. http://www.packardchildrenshospital.org/health/orthopaedics/kyphosis.htm] 26 May 2001.

ANON. (2000a). "National Library of Medicine". *Fact sheet: lordosis*. 2 January. [Hyperlink http://www.nlm.nih.gov/medlineplus/ency/imagepage/9583.htm]. 13 March 2002.

ANON. (2000b). "Health Services / Technology Assessment Text". *Screening for Adolescent Idiopathic Scoliosis*. 5 February. [Hyperlink http://text.nlm.nih.gov/cps/www/cps.53.html]. 27 February 2001.

ANON. (2000c). "The Children's Hospital at Westmead". *Fact sheet: flat feet*. 18 August. [Hyperlink http://www.nch.edu.au/parents/factsheets/flatfetj.htm]. 19 April 2001.

ANON. (2000d). "Your Orthopaedic Connection". *Spine: Scoliosis*. 30 December. [Hyperlink http://orthoinfo.aaos.org/fact/thr_report.cfm?Thread_ID=14&topcategory=Spine]. 4 April 2000.

ANON. (2000e). "Your Orthopaedic Connection". *Kyphosis: Curvature of the spine*. 30 December.[Hyperlink http://orthoinfo.aaos.org/fact/thr_report.cfm?Thread_ID=247&topcategory=Spine]. 19 April 2000.

ARNHEIM, D.D. & PRENTICE W.E. (2000). *Principles of athletic training* (10th ed.). Singapore: McGraw-Hill.

ASCANI, E.; BARTOLOZZI, P.; LOGROSCINO, C.A.; MARCHETTI, P.G.; PONTE, A.; SAVINI, R.; TRAVAGLINI, F.; BINAZZI, R. & DI SILVESTRE, M. (1986). Natural history of untreated idiopathic scoliosis after skeletal maturity. *Spine*, 11(8):785-789.

BAKER, E. A. & ZANGGER, B. (1970). School screening for idiopathic scoliosis. *American Journal of Nursing*, 70(4):766-767.

BALADY, G.J.; BERRA, K.A.; GOLDING, L.A.; GORDON, N.F.; MAHLER, D.A.; MYERS, J.N. & SHELDAHL, L.M. (2000). *ACSM'S guidelines for exercise testing and prescription* (6th ed.). London: Williams & Wilkins.

BALAQUE, B. (1999). Non specific low back pain in children and adolescents: Risk factors. *European Spine Journal*, 8:429-438.

BARRACK, R.; WHITECLOUD, T.S.; BURKE, S.W.; COOK, S.D. & HARDING, A.F. (1984). Proprioception in idiopathic scoliosis. *Spine,* 9(7):681-685.

BASS, S.L. & KERR, D.A. (2000). "Medical Journal of Australia". *Factors that influence healthy bone development in children*. [Hyperlink http://www.mja.com.au/public/nutrition/question12.htm]. 18 April 2001.

BENETTI, G.L. & PODESTA, F. (1991). Scoliosis: ten years experience of screening. *Paediatric Medicine*, 13(4):379–385.

BERNHARDT, M. & BRIDWELL, K.H. (1989). Segmental analysis of the sagittal plane alignment of the normal thoracic and lumbar spines and thoracolumbar junction. *Spine,* 14(7):717-721.

BLOOMFIELD, J.; ACKLAND, T.R. & ELLIOTT, B.C. (1994). *Applied anatomy and biomechanics in sport*. Melbourne: Blackwell Scientific Publications.

BLOUNT, W.P. & BOLINKE, J. (1967). Physical therapy in nonoperative treatment of scoliosis, *Physical Therapy*, 47(1):919-925.

BOACHIE-ADJEI, O. & LONNER, B. (1996). Spinal Deformity. *Pediatric Clinics of North America,* 43(3):883-897.

BOWMAN, B. (2001). "Connecticut Children's Medical Centre". *Scoliosis*. [Hyperlink http://www.ccmckids.org/departments/Orthopaedics/orthoed21.htm]. 13 March 2002.

BRADFORD, D.S. (1977). Juvenile kyphosis. *Clinical Orthopaedics*, 128(10):45-55.

BREIMAN, L.; FRIEDMAN, J.H.; OLSHEN, R.A. & STONE, C.J. (1993). *Classification and Regression trees*. New York: Chapman & Hall.

BROOKS, H.L.; AZEN, E.G.; BROOKS, R. & CHAN, L. (1975). Scoliosis: A prospective epidemiological study. *Journal of Bone and Joint Surgery*, 57(A):968-972.

BURWELL, R.G.; JAMES, N.J.; JOHNSON, J.F. & WEBB, J.K. (1982). The rib humpscore: a guide to referral and prognosis? *The Journal of Bone and Joint Surgery*, 64(B):248

CAILLIET, R. (1975). *Scoliosis: diagnosis and management*. Philadelphia: FA Davis.

CANALE, S.T. (1998). *Cambell's operative orthopaedics* (9^{th} ed.). St. Louis: Mosby.

CHANSIRINUKOR, W.; WILSON, D.; GRIMMER, K. & DANSIE, B. (1999). Effects of backpacks on students: Measurement of cervical and shoulder posture. *Australian Journal of Physiotherapy*, 47(2):110-116.

CHRISTENSEN, K.D. (n.d.). “Children and scoliosis.” *Adjunctive therapies to the adjustment*. 25 April. Hyperlink http://www.ccptr.org/KDC/children_and_scoliosis.htm. 4 April 2001.

CHUKUKA, S.; ENWEMEKA, I; BONET, M.I.; JAYANTI, A.I.; PRUDHITHUMRONG, S. & OGBAHON, E.F. (1986). Postural correction in persons with neck pain. *The Journal of Orthopaedic and Sports Physical Therapy,* 8(5):235-238.

COBB, J.R. (1958). Scoliosis. *Journal of Bone and Joint Surgery*, 40(A):510-512.

CONNOR, P.M.; YAMAGUCHI, K.; MANIFOLD, S.G.; POLLOCK, R.G.; FLATOW, E.L. & BIGLIANI, L.U. (1997). Split pectoralis major transfer for serratus anterior palsy. *Clinical Orthopaedics,* 341:134-142.

DAVIS, D.; KIMMET, T. & AUTY, M. (1986). *Physical Education: Theory and Practice*. South Melbourne: Macmillan.

DELISLE, D. (1995). "DPDC: Muscle Balance and Function Development". *Assessing and correcting poor posture*. [Hyperlink http://www.dpdc-mbf.com/AsessPos.htm]. 3 August 2001.

DELPORT, B.M.; STRYDOM, G.L.; VAN DER WALT, T.S.P.; MOUTON, A.J. & THEUNISSEN, C.J. (1985). A qualitative analysis of the physical activity profile of executives in the South African motor industry and the effect of a 24-week training programme on it. *S.A. Journal for Research in Sport, Physical Education and Recreation,* 8(2):105-118.

DOMMISSE, G.F. (1998). Scheuermann's disease and postural kyphosis. *South African Journal of Bone and Joint Surgery*, 8(3):48-51.

DRUMMOND, D.S.; ROGALA, E. & GURR, J. (1979). Spinal Deformity: Natural history and the role of school screening. *Orthopedic Clinics of North America*, 10(4):751-759.

EMANS, J.B.; KAELIN, A.; BANCEL, P.; HALL, J.E. & MILLER, M.E. (1986). The Boston bracing system for idiopathic scoliosis: follow-up results in 295 patients. *Spine*, 11(8):792-801.

FARADY, J.A. (1983). Current principles in the nonoperative management of structural adolescent idiopathic scoliosis. *Physical Therapy*, 63(4):512-523.

FOO, C.L. & SWANN, M. (1983). Isolated paralysis of the serratus anterior: A report of 20 cases. *Journal of Bone and Joint Surgery*, 65(B):552-556.

FRANCIS, R.S. & BRYCE, G.R. (1987). Screening for musculoskeletal deviation – A challenge for the physical therapist. *Physical Therapy*, 67(8):1221-1225.

FROMM, S. (2002). "Virgin". *The winging scapula*. 28 February. [Hyperlink http://freespace.virgin.net/steven.fromm/index.htm]. 18 March 2002

FULLARTON, S. & EMMERSON, C. (1999). "Health in schools". *How to stop computers becoming a pain.* [Hyperlink http://www.public.health.wa.gov.au/SCHOOLS/july99.pdf]. 8 March 2001.

FYSH, P. (2001). "ChiroWeb". *Kids need Chiropractic too.* 6 October. [Hyperlink http://www.chiroweb.com/archives/13/06/19.html]. 19 April 2001.

GEISSELE, M.E.; KRANSDORF, M.J.; GEYER, C.A.; JELINKWK, J.S. & VAN DAM, B.E. (1991). Magnetic resonance imaging of the brain stem in adolescent idiopathic scoliosis. *Spine*, 16(7):761–763.

GIAKAS, G.; BALTZOPOULOS, V.; DANGERFIELD, P.H.; DORGAN, C.J. & DALMIRO, S. (1996). Comparison of gait patterns between healthy and scoliotic patients using time and frequency domain analysis of ground reaction forces. *Spine*, 21(9):2235-2242.

GLEICK, E. (1999). Land of the fat. *Time*, 25(39):50-58.

GLUCKMAN, M.S. (1995). "DPDC: Muscle Balance and Functional Development". *Muscle Balance and Functional Development Article*. [Hyperlink http://www.dpdc-mbf.com/MBDFArtl.htm]. 3 August 2001.

GRANT, W.W.; FEARNOW, R.G.; HEBERTSON, L.M. & HENDERSON, A.L. (1973). Health screening in school-age children. *American Journal of Diseases of Children*, 125(4):520-522.

GRATZ, R.R. & PAPALIA-FINLAY, D. (1984). Psychosocial adaptation to wearing the Milwaukee brace for scoliosis. *Journal of Adolescent Health Care*, 5:237-242.

GREGG, R.R.; LABOSKY, D.; HARTY, M.; LOTKE, P.; ECKER, M.; DISTEFANO, V. & DAS,M. (1979). Serratus anterior paralsy in the young athlete. *Journal of Bone and Joint Surgery*, 61(A):825-831.

HARGIS, C. (1998). "Dr. Calvin Hargis". *Conditions we treat*: *Hips*. [Hyperlink http://www.drhargis.com.htm]. 4 April 2001.

HARRINGTON, P.R. (1977). The etiology of idiopathic scoliosis. *Clinical Orthopaedics*, 126:17-25.

HAYWOOD, K.M. (1993). *Lifespan motor development* (2^{nd} ed.). Champaign: Human Kinetic Publishers.

HELFET, A.J. & GRUEBEL LEE, D.M. (1978*). Disorders of the lumbar spine*. Philadelphia: J.B. Lippincott.

HELLEBRANDT, F.A. (1938). Standing – a geotropic reflex, the mechanism of the asychronous relation of motor units. *American Journal of Physiology,* 8(3): 471-474.

HILLIBRAND, A.; BLAKEMORE, M.D.; LADER, R.T.; GREENFIELD, M.L.; FARLEY, F.A.; HENSINGER, R.N. & HARIHARAN, M. (1996). The role of melatonin in the pathogenisis of adolescent idiopathic scoliosis. *Spine*, 21(10): 1140–1146.

ICETON, J. & HARRIS, W.R. (1987). Treatment of winged scapula by pectoralis major transfer. *Journal of Bone and Joint Surgery*, 69(B):108-110.

INMAN, V.T.; SAUNDERS, J.B. & ABBOTT, L.C. (1944). Observations on the function of the shoulder joint. *Journal of Bone and Joint Surgery*, 26(A):1-30.

JANZ, K.F.; BURNS, T.L.; TOMER, J.C.; LEVY, S.M.; PAULOS, R.; WILLING, M.C. & WARREN, J.J. (2001). Physical activity and bone measures in young children: The Iowa bone development study. *Pediatrics,* 107(6):1387-1393.

JONASSON-RAJALA, E.; JOSEFSSON, E.; LUNDBERG, B. & NILSSON, H. (1984). Boston thoracic brace in the treatment of idiopathic scoliosis: initial correction. *Clinical Orthopedics*, 183(3):37-41.

JUNGHANNS, H. (1986*). Clinical implications of normal biomechanical stresses on spinal function* (English language ed.). Philadelphia: Aspen Publishers.

KANE, W.J. & MOE, J.H. (1970). A scoliosis prevalence survey in Minnesota. *Clinical Orthopaedics,* 69(1):216-218.

KEMPER, H.C.G.; VERSCHUUR, R.; RAS, K.G.A.; SNEL, J.; SPLINTER, P.G. & TAVECCHIO, W.C. (1976). Effect of 5- versus 3-lessons-a-week physical education program upon the physical development of 12 and 13 year old schoolboys. *The Journal of Sports Medicine and Physical Fitness,* 16(4):319-326.

KENDALL, H.O.; KENDALL, F.P. & BOYNTON, D.A. (1977). *Posture and pain* (9th ed.). New York: Williams & Wilkins.

KENDALL, F.P.; McCREARY, E.K. & PROVANCE, P.G. (1993). *Muscles testing and Function* (4th ed.). Baltimore: Williams & Wilkins.

LAVENTURE, B. (2000). Physical education and the challenge of public health. *The British Journal of Teaching Physical Education*, 2:6-8.

LEDOUX, W.R. & HILLSTROM, H.J. (2002). The distributed plantar vertical force of neutrally aligned and pes planus feet. *Gait posture*, 15(1):1-9.

LEVINE, D.; WHITTLE, M.W. & HOOD, K.F. (1996). Static and dynamic relationship between pelvic tilt, lumbar lordosis and abdominal muscle performance. *Physical Therapy,* 76(5):74.

LLOYED, T.; CHINCHILLI, V.M.; JOHNSON-ROLLINGS, R.N.; KIESELHORST, R.D.; EGGLI, D.F. & MARCUS, R. (2000). Adult female hip-bone density reflects teenage sports-exercise patterns but not teenage calcium intake. *Pediatrics*, 106(1):40-44.

LOHMAN, T.G. (1987). The use of skinfolds to estimate body fatness on children and youth. *Journal of Physical Education, Research and Dance*, 58(9):98-102.

LONSTEIN, J.E. (1977). Screening for spinal deformities in Minnesota schools. *Clinical Orthopaedics,* 126(1):33-42.

LONSTEIN, J.E. (1988). Why school screening for scolosis should be continued. *Spine*, 13(2):1198-1199.

LOVELESS, M.D. (1999). Pediatric spinal deformity. *Jacksonville Medicine*, 6:227-229.

MAGEE, J.D. (1987). *Orthopedic physical assessment* (4th ed.). Philadelphia: W.B. Saunders.

MANIADAKIS, A. & GRAY, A. (2000). The economic burden of back pain in the UK. *Pain*, 84:95-103.

MARTINI, F.H. (1995). *Fundamentals of anatomy and physiology* (3rd ed.). New Jersey: Prentice-Hall.

McCOY, A. & DICKENS, B. (1997). "Victorian Government Department of Human Services". *Understanding normal variations in childhood gait and posture*. 17 April. [Hyperlink http://hna.ffh.vic.gov.au/yafs/cis]. 11 February 2002.

MEIRING, J.H.; LOOTS, G.P.; COETZEE, H.L.; LIEBENBERG, S.W.; VAN HEERDEN, L. & JACOBS, C.J. (1994). *Anatomie vir medies-verwante studierigtings*. Pretoria: J.L. van Schaik Uitgewers.

MERTZ, J.A. (2000). School-Based Scoliosis Screening. *Journal of the American Medical Association*, 283(13):1689.

MOE, J.H.; WINTER, R.B.; BRADFORD, D.S. & LONSTEIN, J.E. (1978). *Scoliosis and other spinal deformities*. Philadelphia: W.B. Saunders.

MORRISSY, R.T.; GOLDSMITH, G.S.; HALL, E.C.; KEHL, D. & COWIE, G.H. (1990). Measurement of the Cobb angle on radiographs of patients who have scoliosis: Evaluation of intrinsic error. *American Journal of Bone and Joint Surgery*, 72(3):320–327.

MURRAY, P.M.; WEINSTEIN, S.L. & SPRATT, K.F. (1993). The natural history of long-term follow-up of Scheuermann Kyphosis. *The Journal of Bone and Joint Surgery,* 75(A):236-247.

NACHEMSON, A.L. & PETERSON, L.E. (1995). Effectiveness of treatment with a brace in girls who have adolescent idiopathic scoliosis. *American Journal of Bone and Joint Surgery,* 77(A):815-822.

NASH, C.L. & MOE, J.H. (1969). A study of vertebral rotation. *American Journal of Bone and Joint Surgery*, 51:223-229.

NEGRINI. S.; CARABALONA, R. & SIBILLA, P. (1999). Backpacks as a daily load for school children. *The Lancet*, 354:1974.

NEWBOUND, D. (2002). "Families Online". *The importance of good posture*. [Hyperlink http://www.familiesonline.co.uk/topics/health/health_posture.htm]. 10 April 2002.

NORTON, K. & OLDS, T. (1996). *Anthropometrica: A textbook of body measurements for sports and health courses*. Sydney: UNSW Press.

O'DONNELL, C.S.; BUNNELL, W.P.; BETZ, R.R.; BOWEN, J.R. & TIPPING, C.R. (1988). Electrical stimulation in the treatment of idiopathic scoliosis. *Clinical Orthopaedics*, 229(4):107-113.

OZONOFF, M.G. (1992). *Pediatric Orthopedic Radiology* (3rd ed.). Philadelphia: W.B. Saunders.

PASCOE, D.D.; PASCOE, D.E.; WANG, Y.T.; SHIM, D.M. & KIM, C.K. (1997). Influence of carrying book bags on gait and posture of youths. *Ergonomics*, 40(6):631-641.

PHELPS, W.M.; KIPHUTH, R.J.H. & GOFF, C.W. (1956). *The diagnosis and treatment of postural defects.* Illinois: Charles C Thomas Publisher.

PIETROBELLI, A. (1998). Body Mass Index as a measure of adiposity among children and adolescents: A validation study. *Pediatrics*, 132:204-210.

POSTMA, J.W. (1950). Die groei van Suid Afrikaanse kinders van 6 to 16 jaar. *Vigor*, 3(2):30-33.

POWERS, S.K. & HOWLEY, E.T. (1996). *Exercise Physiology: Theory and Application to Fitness and Performance* (3rd ed.). New York: McGraw Hill.

RAO, U.B. & JOSEPH, B. (1992). The influence of footwear on the prevalence of flat foot. *The Journal of Bone and Joint Surgery*, 74(B):525:527.

REEDCO INC. (2001, 14 April). [info@ccmi-reedco.com]. "Anatomical measuring devices". Private e-mail message to Suzanne Stroebel, [13463993@sun.ac.za].

RENSHAW, T.S. (1988). Screening school children for scoliosis. *Clinical Orthopaedics*, 229:26–33.

ROAF, R. (1956). Paralytic Scoliosis. *Journal of Bone and Joint Surgery*, 38(B): 640-659.

ROAF, R. (1977). *Posture*. London: Academic press.

RODRIGUES, J.I.; GARCIA-ALIX, A.; PALACIOS, J. & PANIAGUA, R. (1988). Changes in long bones due to fetal immobility caused by neuromuscular disease. *Journal of Bone and Joint Surgery*, 70(A):1052-1060.

SALLIS, J.F. (2000). Overcoming inactivity in young people. *The Physician and Sportsmedicine*, 28(10):31-32.

SCHAFER, R.C. (1999). "Chiro.org". Upper back and thoracic spine trauma. [Hyperlink http://www.chiro.org/placrs/RC_SCAFER/mono-23.htm]. 24 January 2002.

SCHER, D.M. (2001). "Medline Plus Medical Encyclopedia". *Pes Planus*. 23 May. [Hyperlink http://www.nlm.gov/medlineplus/ency/article/001262.htm]. 24 January 2002.

SCHMORL, G. & JUNGHANNS, H. (1971). *The human spine in health and disease* (2nd ed.). New York: Grune & Stratton.

SEGIL, C.M. (1974). The incidence of idiopathic scoliosis in the Bantu and white population groups in Johannesburg. *South African Journal of Bone and Joint Surgery,* 56(B):393.

SELLS, C.J. & MAY, E.A. (1974). Scoliosis screening in public schools. *American Journal of Nursing,* 74(1):60-62.

SHERMAN, N.W. (2002). Minority children have highest overweight rate and lowest fitness rate. *Journal of Physical Education, Research and Dance*, 73(2):8-11.

SHERRILL, C. (1993). *Adapted physical activity, recreation and sport* (4th ed.). Dubuque: Brown & Benchmark.

SHRECKER, K.A. (1971). *Corrective gymnastics for schools* (3rd ed.). Cape Town: Balkema Academic and Technical Publications.

SHTERN, M. (1975). Screening adolescent school children for scoliosis. *The Medical Journal of Australia,* 6:761-762.

SOLBERG, G. (1993). Plastic changes in spinal function of pre-pubscent scoliotic children engaged in an exercise therapy programme. Unpublished M. thesis. (Human Movement Studies). Grahamstown: Rhodes University.

SOUCACOS, P.N.; SOUCACOS, P.K.; ZACHARIS, K.C.; BERIS, A.E. & XENAKIS, T.A. (1997). School-screening for scoliosis. A prospective epidemiological study in Northwestern and Central Greece. *The Journal of bone and Joint Surgery*, 79(A):1498-1503.

SPAN, Y.; ROBIN, G. & MAKIN, M. (1976). Incidence of scoliosis in school children in Jerusalem. *Journal of Bone and Joint Surgery*, 58(B):379.

STATSOFT (2001). STATISTICA: Data-analysis software system (version 6).

STEDMAN, T.L. (1990). *Stedman's Medical Dictionary* (25th ed.). Baltimore: Williams & Wilkins.

STEELE, F.G. & BRAMBLETT, C.A. (1988). *The anatomy and biology of the human skeleton*. Texas: A & M University Press.

STONE, B.; BECKMAN, C.; HALL, V.; GUESS, V. & BROOKS, L. (1979). The effect of an exercise program on change in curve in adolescents with minimal idiopathic scoliosis. *Physical Therapy*, 59(6):759-763.

SWAN, N. (2000). "The health report". *Flat feet in children*. 19 June. [Hyperlink http://www.abc.net.au/rn/talks/8.30/helthrpt/stories/s141954.htm]. 24 January 2002.

TREMBLAY, M.S. & WILLMS, J.D. (2000). The spread of the childhood obesity epidemic, *Canadian Medical Association Journal*, 163(11):1429-1433.

TWISK, J.W.R. (2001). Physical activity guidelines for children and adolescents: A critical review. *Sports Medicine*, 31(8):617-627.

VAUGHAN, J.J. (n.d.). "The Kentucky Spine Institute". *Patient education*. 22 January. [Hyperlink http://www.kyspine.com/HTML/hyperkyphosis.html]. 27 May 2001.

VEDANTAM, R.; LENKE, L.G.; KEENEY, J.A.; BRIDWELL, K.H. (1998). Comparison of standing sagittal spinal alignment in asymptomatic adolescents and adults. *Spine*, 23(2):211-215.

VIVIANI, G.R.; BUDGELL, L.; DOK, C. & TUGWELL, P. (1984). Assessment of accuracy of the scoliosis school screening examination. *American Journal of Public Health*, 74:497–498.

WALKER, A.R.P. (1972). Biological and disease patterns in South African inter-racial populations as modified by rise in privilege. *South African Medical Journal*, 46:1127-1134.

WARNER, J.P.P.; MICHELI, L.J.; ARSLANIAN, L.E.; KENNEDY, J. & KENNEDY, R. (1992). Scapulothoracic motion in normal shoulders and shoulders with glenohumeral instability and impingement syndrome. *Clinical Orthopaedics*, 285:191-199.

WARNER, J.J.P. & NAVARRO, R.A. (1998). Recognition and treatment. *Clinical Orthopaedics*, 349:139-148.

WASYLENKO, M.; SKINNER, S.R.; PERRY, J. & ANTONELLI, D.J. (1983). An analysis of posture and gait following spinal-fusion with Harrington instrumentation. *Spine*, 8(8):840-845.

WATSON, E.H. & LOWREY, G.H. (1962). *Growth and development of children* (4th ed.). Chicago: Year Book Medical Publishers

WATSON, A.W.S. (1983). Posture and participation in sport. *The Journal of Sports Medicine and Physical Fitness*, 23(3):231-239.

WEINSTEIN, S.L. (2001). "Virtual Hospital". *Adolescent Idiopathic Scoliosis*. 23 February. [Hyperlink http://www.vh.org/Providers/Textbooks/AIS/01AIS.html]. 8 March 2001.

WEISZ, I.; JEFFERSON, R.J.; CARR, A.J.; TURNER-SMITH, A.R.; PHIL, D.; MCINERNEY, A. & HOUGHTON, M.A. (1989). Back shape in brace treatment of idiopathic scoliosis. *Clinical Orthopedics*, 240(3):157-162.

WELLS, K.F. & LUTTGENS, K. (1976). *Kinesiology. Scientific basis of human motion* (6th ed.). Philadelphia: WB Saunders.

WELTON, D.C.; KEMPER, H.G.C.; POST, G.B.; BAN MECHELEN, W.; TWISK, J.; LIPS, P. & TEULE, G. (1994). Weight-bearing activity during youth is a more important factor for peak bone mass than calcium intake. *Journal of Bone Mineral Research*, 9:1089-1095.

WHITE, A.A.; PUNJABI, M.M. & THOMAS, C.L. (1977). The clinical biomechanics of kyphotic deformities. *Clinical Orthopedics*, 128:8-17.

WHITE, T.D. (1991). *Human Osteology*. San Diego: Academic press.

WILLNER, S. (1981). Spinal pantograph – a non-invasive technique for describing kyphosis and lordosis in the thoraco-lumbar spine. *Acta Paediatrica Scandinavica*, 52:525-529.

WILLNER, S. & JOHNSON, B. (1983). Thoracic kyphosis and lumbar lordosis during the growth period in children. *Acta Paediatrica Scandinavica*, 72:873-878.

WILLNER, S. & UDEN, A. (1982). A Prospective prevalence study of scoliosis in Southern Sweden. *Acta Orthopaedica Scandinavica*, 53:233-237.

WYNNE-DAVIES, R. (1968). Familial (idiopathic) scoliosis. *Journal of Bone and Joint Surgery,* 50(B):24-30.

YOUDAS, J.W.; GARRET, T.R.; EGAN, K.S. & THERNEAU, T. M. (2000). Lumbar lordosis and pelvic inclination in adults with chronic low back pain. *Physical Therapy*, 80(3):261-275.

APPENDIX A

INVITATION LETTER TO SCHOOLS

Department of Sport Science
University of Stellenbosch
Stellenbosch
Matieland
7602
14 June 2001

Dear Sir \ Madam

PERMISSION TO CONDUCT A RESEARCH PROJECT

During August 2001 the following research project is being conducted in some primary schools in your region in the Western Cape, supervised by the Department of Sport Science, University of Stellenbosch:

The prevalence of postural deformities in children ages 11-13, in the Western Cape.

Postural deformities are a commonly encountered problem among children. Most of the aches and pains of adults are the result, not of injuries, but of the long-term effects of distortions in posture or alignment that have their origins in childhood or adolescence. Television, video entertainment, motorised transportation, fast food and lack of regular physical activity contribute to the poor physical condition of children. School screening is mandated in schools in 26 states of the United States for children between 10 and 16 years of age. Previous studies conducted in the US found that 160 out of 1000 people have scoliosis (postural deformity). This means that scoliosis is as prevalent as hypertension or diabetes mellitus. Identification of postural deformities at an early stage makes early treatment possible, which may in the future prevent serious spinal abnormalities.

To be able to conduct these two studies, we need your co-operation.

We hereby ask permission to include your school in this study. If you require more information we will be happy to come and speak to you and your personnel to inform you about the contents and procedures of this study.

Participation in these studies will entail the following:

A team comprising of a Biokinetics intern and sport science students from the University of Stellenbosch will visit the school on a pre-arranged day during August/September 2001. This will be conducted at a time that will keep disruption of the normal school routine to a minimal. We will obtain permission from the children's parents/guardian prior to conducting the survey. Approximately 18 children can be tested in an hour.

Please return the enclosed form or contact us in this regard before 29 June 2001.

Thanking you in advance.

____

Suzanne Stroebel
(Biokinetics intern: University of Stellenbosch
Tel: (021) 808 4735
biokin@maties.sun.ac.za

____

Prof. J.G. Barnard
(Head of Biokinetics: University of Stellenbosch)
Tel: (021) 808 4718
jgb@maties.sun.ac.za

I, ……………………………………………………………………….(full name), the head master of ………………………………………………………………………...(name of school) hereby give permission for my school to be included in the research project discussed above. The school is willing to allocate……………………hours to you for this purpose. Children in all three age groups \ two of the age groups \ one of the age groups (please circle where applicable) can be tested.

Signed

…………………………………………………………. Date:………\………..\2001

The Head Master

Contact details of the person we need to contact for further arrangements:

……………………………………………………………………….

……………………………………………………………………….

……………………………………………………………………….

……………………………………………………………………….

……………………………………………………………………….

……………………………………………………………………….

……………………………………………………………………….

Address: Department of Sport Science
Private Bag x1
University of Stellenbosch
Matieland
7602

Fax: 808 4817

APPENDIX B
LETTER TO PARENTS

University of Stellenbosch

Department of Sport Science: Stellenbosch Biokinetics Center

The following study is being conducted in your region, under supervision of the University of Stellenbosch, Department of Sport Science:

The prevalence of postural deformities among children aged 11 to 13 years is some Western Cape Schools.

The purpose of the above study is the early identification of children with postural deformities (uneven shoulders, "skew" back, hollow back, etc.). The identification of postural deformities at this age is crucial, as intervention is still possible. Participation in this study will be to the benefit of the child and the results of the study will make a positive contribution to this field of research. Participation in the study is voluntarily and is left to the discretion of the parent/guardian.

Information is confidential and will be used for the purpose of research only.

Answer the following questions by making a cross (x) in the appropriate block or where required fill in the appropriate information.

PERSONAL DETAILS OF CHILD

Name and surname:____Date:_____/_____/2001

Date of birth: (dd/mm/yy)___/___/___ Gender:

Male	Female

Please answer the following questions:

1. Are you aware of any postural deformities in the immediate family? (e.g. "Skew back" (scoliosis), hollow back, flat feet, etc.) Yes_______No_________

   If yes, specify____

2. Have your child previously been diagnosed with a postural deformity? Yes_______No_________

   If yes, specify____

3. Does your child participate in any organized sport or strenuous exercise twice or more per week?

   Yes_______No_________

If yes, specify the type op sport or exercise and indicate how many times per week he/she participates in this sport or exercise____

____

4. Approximately, how many hours per day does your child spend in front of the television or computer?__________

____

PARENTAL CONCENT

Hereby, I (parent/guardian) of ________________________________(name and surname of child) give my consent to the participation in the mentioned study. I accept that the persons involved in this study are fully qualified and will protect the well being of the child at all times. I will not hold the University of Stellenbosch or the persons involved responsible for any unforeseen events.

Name of parent/guardian: ________________________________Date:_____/_____/2001

Signed: ____________________________ Witness: ________________________________

Should you require any information please contact the following persons:

Suzanne Stroebel (Biokinetics intern)

Tel: (021) 808 4735

biokin@maties.sun.ac.za

Prof. J.G. Barnard (Head: Biokinetics Center)

Tel: (021) 808 4718

jgb@maties.sun.ac.za

APPENDIX C

MEASUREMENT FORM

University of Stellenbosch Department of Sport Science: Stellenbosch Biokinetics Center

SECTION A: PERSONAL DETAILS

Name and surname:..

Date of test:......../........./2001 Date of birth:........../........./...........

Gender:

Male	Female

Home language:.........................

☐ Right handed ☐ Left handed

Name of school:...

Grade:..............................

Contact numbers of parents: (h)..

(w)..

(cell)...

Office use only:

W	S	K	I	A

Other :.......................................

SECTION B: ANTHROPOMETRIC MEASUREMENTS

Stature:................cm Weight:................kg

Leg lengths: Right leg:…………cm Left leg:…………cm

Skinfolds (mm): Tricep?......................... …………… ……………..

Supscapular?.............. ……………. ……………..

Circumferences (cm): Waist?.......................

Hip?.........................

Office use only:

Sum of skinfolds:.............mm

Fat percentage:…………..%

BMI:.......................................……….

W-H ratio:................................

SECTION C: PHYSICAL ACTIVITY PROFILE

1. Do you participate in any sport, exercise or strenuous activity? (2 x per week)

Yes..........No.........

2. If yes, name the type of sport, exercise or activity.................................

....

(*Please encircle the number next to your answer*)

3. What is the duration of one exercise session?

1 = ½ hour

2 = 1 hour

3 = 2 hours

4 = > 3 hours

4. How many times per week do you exercise?

1 = 1

2 = 2

3 = 3

4 = >4

5. How do you get to school?

2 = walk

2 = bicycle

0 = car/bus/train/taxi

Other, Specify:......................................

6. If you are walking or cycling, how far do you live from school?

0 = Do not walk or cycle

1 = 0-1 km

2 = 1.1-2 km

3 = 2.1-3 km

4 = >3 km

7. How many hours per **day** do you spend in front of the computer or television?

4 = < ½ hour

3 = 1-2 hours

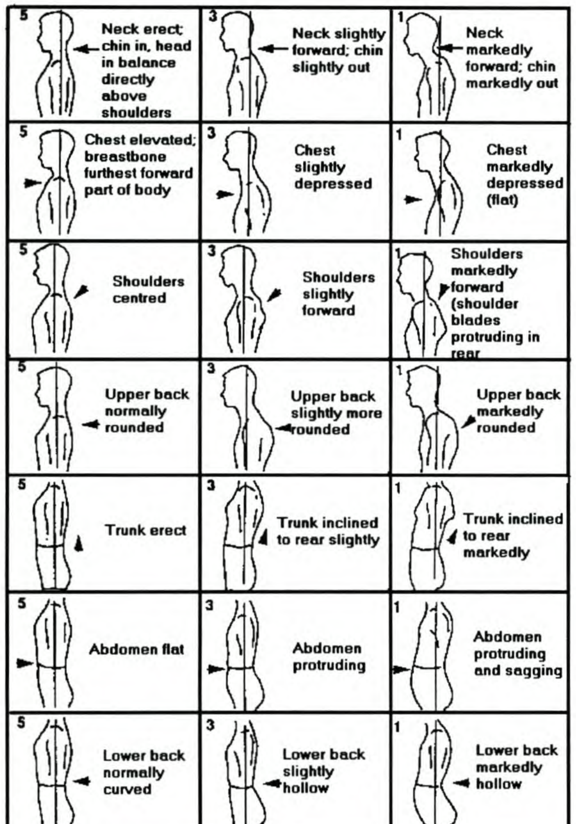
2 = 3-4 hours

1 = >4 hours

SECTION D: POSTURAL EVALUATION

POSTURE RATING CHART

SIDE VIEW POINTS



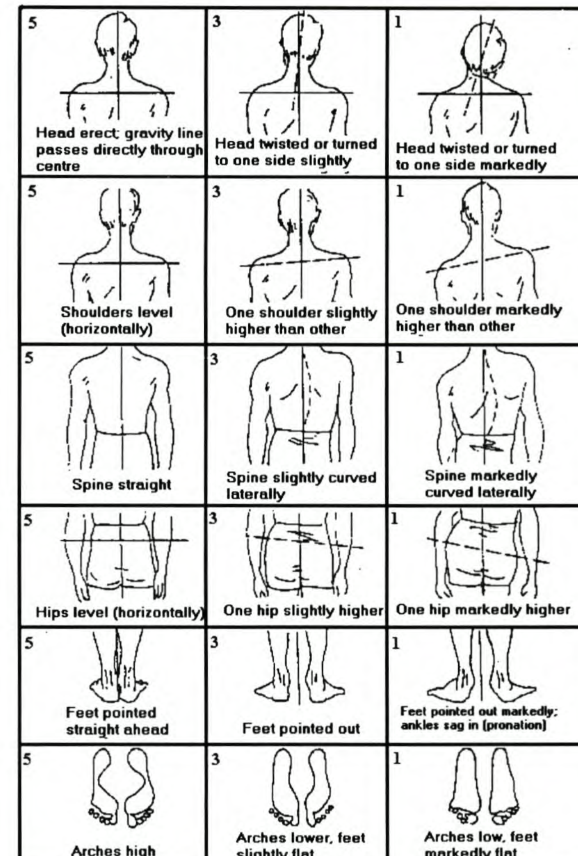
5	3	1	SCORE
Neck erect; chin in, head in balance directly above shoulders	Neck slightly forward; chin slightly out	Neck markedly forward; chin markedly out	____
Chest elevated; breastbone furthest forward part of body	Chest slightly depressed	Chest markedly depressed (flat)	____
Shoulders centred	Shoulders slightly forward	Shoulders markedly forward (shoulder blades protruding in rear	____
Upper back normally rounded	Upper back slightly more rounded	Upper back markedly rounded	____
Trunk erect	Trunk inclined to rear slightly	Trunk inclined to rear markedly	____
Abdomen flat	Abdomen protruding	Abdomen protruding and sagging	____
Lower back normally curved	Lower back slightly hollow	Lower back markedly hollow	____

Forward Bending Test (Y/N) ☐

L/R ☐

POSTURE RATING CHART

BACK VIEW POINTS



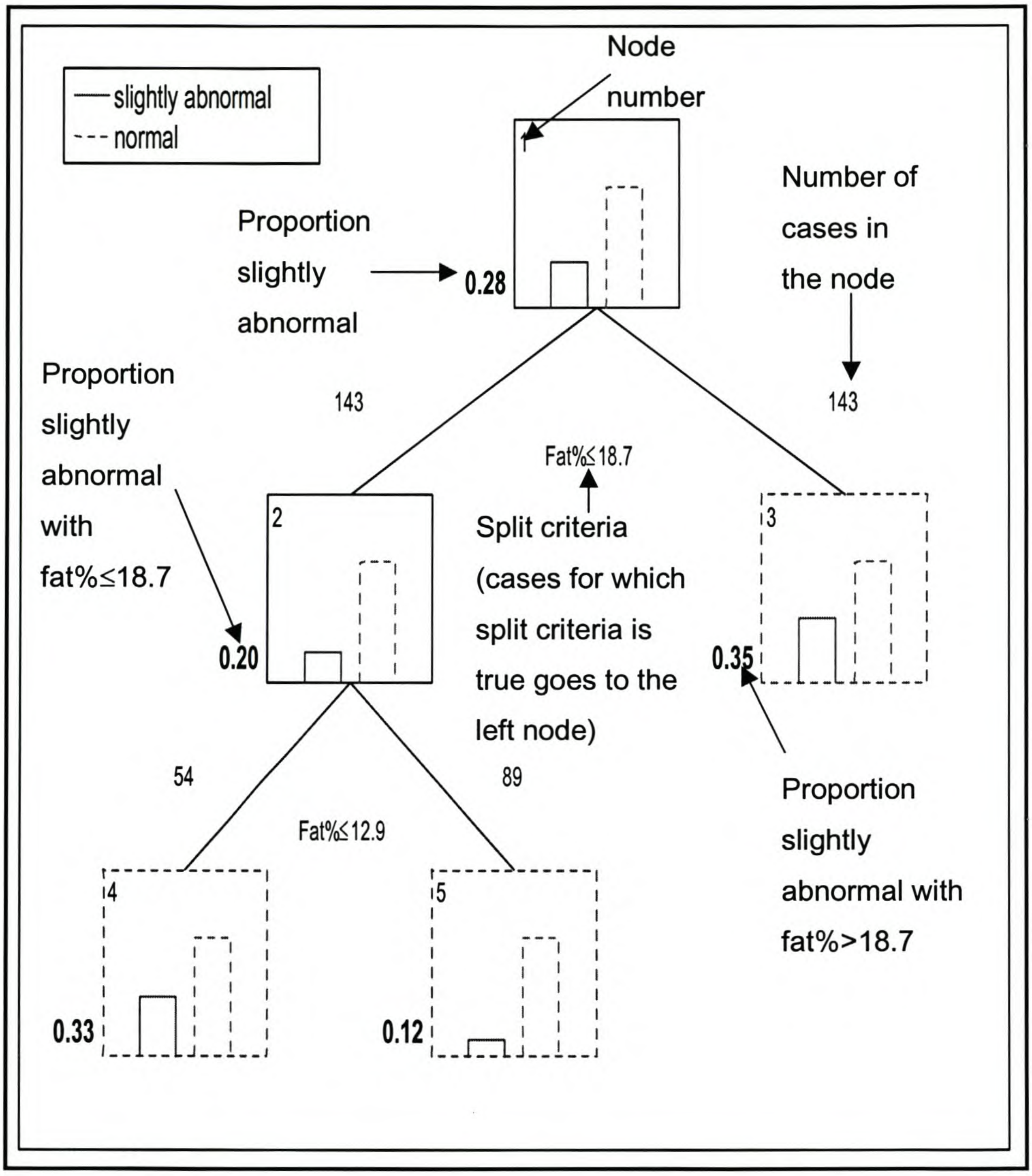
5	3	1	SCORE
Head erect; gravity line passes directly through centre	Head twisted or turned to one side slightly	Head twisted or turned to one side markedly	____
Shoulders level (horizontally)	One shoulder slightly higher than other	One shoulder markedly higher than other	____
Spine straight	Spine slightly curved laterally	Spine markedly curved laterally	____
Hips level (horizontally)	One hip slightly higher	One hip markedly higher	____
Feet pointed straight ahead	Feet pointed out	Feet pointed out markedly; ankles sag in (pronation)	____
Arches high	Arches lower, feet slightly flat	Arches low, feet markedly flat	____

Total: ☐

New York Posture Test

APPENDIX D

CLASSIFICATION TREE METHODOLOGY



Example: Classification tree for Forward head and Fat %.

Conclusion: Subjects with a lower fat% (≤18.7) had a lower prevalance rate (20%) compared to subjects with a higher fat% (>18.7), with a prevalence rate of 35%. However, in the fat% range between 12.9 and 18.7 there was a sharp decrease in prevalence rate to 12%.

* It is coincidental that the node splits into an equal number of cases (143).

Further explanation for Appendix D

0.28: The overall prevalence rate (28%) for this deformity. The overall rates included only slightly abnormal postures (scores of 3) and not abnormal postures (scores of 1).

Fat%: The splitting variable (e.g. gender, age, weight etc.). In this case the tree split at a fat% of 18.7%. This fat% is the % where the method found an optimum split.

The splitting criteria at which the tree split will always go to the left node (e.g. if the tree split on female, all females will go the left node and all the males will go the right node; if the tree split on fat%≤ 18.7, all the subjects with fat%≤ 18.7 will go to the left node and all the subjects with fat%> 18,7 will go to the right node.

143: Number of subjects that fell in that specific category. 143 subjects had a fat%≤ 18.7 (left node) and 143 subjects had a fat%> 18.7 (right node). *It is coincidental that this is an equal amount*.

0.20: The prevalence rate (20%) for the deformity (in this case forward head) in the category fat%≤ 18.7%. Thus, of the 143 subjects that had a fat%≤ 18.7, 20% had the deformity.

0.35: The prevalence rate (35%) for the deformity in the category fat%> 18.7%. Thus, of the 143 subjects that had a fat%> 18.7, 35% had the deformity.

The tree may only split once, but if the method finds another optimum split within a category, it may split again. (In this example the tree did split again).

54: The number of subjects that fell in the category fat%≤ 12.9%.

89: The number of subjects that fell in the category fat%> 12.9%.

0.33: The prevalence rate (33%)of the deformity in the category fat%≤ 12.9%.

0.12: The prevalence rate (12%) of the deformity in the category fat% between 12.9% and 18.7%.