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THE ASSOCIATION BETWEEN ABNORMAL DEVELOPMENTAL MILESTONES OF BABIES AND THE PREVALENCE OF SPINAL DEFORMITIES IN ADOLESCENCE

by

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DECLARATION

I, René Alberts hereby declare that this dissertation is my own, unaided work under the guidance of my mentors, Ms AJ van Rooijen and Ms M Eisenberg. . It has not been submitted before for any degree or examination at any other University. This dissertation is being submitted for the degree of Master of Physiotherapy at the University of Pretoria

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Witness

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ABSTRACT

The purpose of this study was to investigate whether there is an association between developmental milestones of babies and the prevalence of spinal deformities in adolescents in Middelburg, Mpumalanga. The relationship between spinal deformities in a cross-sectional group of adolescents and parental recall was the focus of the study. One hundred and four adolescents were evaluated to determine if a spinal deformity was present. The subjects were then allocated to either the case (those with spinal deformities) or the control (subjects without spinal deformities) groups. The mothers of the subjects were then interviewed with regard to some of the developmental milestones of their offspring, and other factors which may have had an influence on the development of adolescent spinal deformities.

The results showed that a perfectly "normal spine" was seldom found and that even in the control group some minor deviations, within normal limits, were present. Most of the mothers of subjects from the case group did not realise that their offspring had a deformity. There was a non-significant trend for more crawlers to be present in the control group. Subjects who did not crawl, and who were also late walkers appeared to have an increased tendency to develop adolescent spinal deformities. Despite the fact that the schools approached were multi-racial, only white parents responded to the request for participation in this trial. The possible reasons for this should be investigated and a trial comparing the prevalence of spinal deformities amongst adolescents from all ethnic groups in South Africa should be conducted.

Due to the possible recall bias of this study, it is recommended that a longitudinal study, commencing with the babies attending baby clinics in South Africa (representative of the South Africa population), be conducted to determine the influence of developmental milestones on the prevalence of spinal deformities in adolescence.

Key words: Developmental milestones, spinal deformities, adolescent idiopathic scoliosis, Scheuermann's kyphosis, aetiology.



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CHAPTER 1

INTRODUCTION AND PROBLEM STATEMENT

1.1. INTRODUCTION

Spinal deformities, whether congenital or idiopathic, are multifactorial diseases. The arthroskeletal biomechanics within the spine and the dynamic neuromuscular mechanics are important factors.¹ There are numerous causes of spinal deformities in the paediatric population world-wide. Idiopathic scoliosis, Scheuermann's kyphosis and the postural round back are the most common of these conditions.^{2,3} Although there are a variety of aetiological factors, there is no evidence of one specific causative factor.⁴

Adolescent idiopathic scoliosis tends to develop and progress during the adolescent growth spurt.^{1,3,5,6} Carr *et al* (1993)⁵ showed that growth alone is not the primary cause of an idiopathic scoliosis. A spinal curve can progress after skeletal maturity, indicating that growth alone cannot be responsible for this progression.⁶ Curve progression could rather be caused by forces of an asymmetrical posture and asymmetrical muscle contraction.⁵ Any factor independently influencing body symmetry, posture and growth, may lead to the development of idiopathic scoliosis.⁷ There is also a strong genetic basis for the development of idiopathic scoliosis.^{1,2,5,8}

Scoliosis can be defined as a lateral deviation of the vertebral column, with a consequent rotation of the spinous processes of a few vertebrae away from the midline position of the normal axis towards the concavity of the curve. The deformity is three-dimensional and progression of a curve leads to a permanent change in the orientation of the vertebrae.^{2,8,9} The thoracic vertebral rotation causes a deformity of the rib cage. This will lead to a distortion in the

relationship or capacity of the thoracic and abdominal contents.^{2,9} Thus a scoliosis is not only a deformity of the vertebral column, but also a deformity of the whole trunk.⁹

A kyphosis is an excessive curvature or angulation of the spine in which the concavity faces anteriorly.² The exact aetiology is also unknown. The increase of a thoracic kyphosis is due to gravity, muscle imbalance and loss of bony integrity. In the standing and sitting postures, the spine is subject to the force of gravity. The amount of stress on any vertebral segment is related to the body mass of the individual and the spinal level.¹⁰ The treatment of kyphosis would mainly include the reduction of body mass, postural control and hyperextension exercises of the thoracic spine.¹¹

There is a relatively low prevalence of spinal deformities in the general population. However, the deformities can lead to more serious problems such as lung restriction and neurological involvement.^{2,8,9} Conservative treatment consists of regular follow-up radiographs in mild cases, braces when the curves progress and regular exercise.^{8,12} Physiotherapy is part of the conservative treatment of spinal deformities and is mainly prescribed to retain spinal mobility, but has little effect in the prevention of the progression of a curve.^{9,13} Lehnert-Schroth (1992)¹⁴ has achieved some decrease in scoliotic curves with her exercise programme, but curves were not totally corrected. This presents physiotherapists with a problem of credibility with regard to the treatment of scoliosis.

Braces are the benchmark of conservative treatment but their value is now disputed,^{8, 15} especially in idiopathic scoliosis.² Bracing during adolescence can have a negative psychological impact on the patients because of concerns about their appearance. This may then result in non-compliance with regard to wearing the brace.² Modern brace treatment has proven effective in controlling the progression of spinal deformities in skeletally immature patients,^{8, 15} but correction rarely occurs.^{2, 12} Better results are obtained with kyphosis, except where a rigid structural deformity was present before treatment.^{8, 10, 14, 16}

Poor posture may very easily develop into a postural disorder such as kyphosis, lordosis and / or scoliosis.^{14,17} The spine is the main axis of posture and is maintained by activities of the trunk muscles. The tone of the trunk muscles is automatically regulated by a postural reflex mechanism between the peripheral proprioceptors and the brainstem centre. Functions of equilibrium are gradually acquired during the growing period, keeping pace with physical growth. Spinal deformities can be regarded as a manifestation of postural failure, associated with disharmony in the postural control system.¹⁸ Patients with idiopathic scoliosis demonstrate impairments in the control of equilibrium, but it is not possible to determine if idiopathic scoliosis is the cause or the result of these impairments.^{1,8,19,20,21,22,23}

Specific developmental phases seem to be a prerequisite for well-organized psychomotor development and its absence may lead to deficits.²⁴ Certain motor skills or milestones, during the development of a baby, may occur late. This will lead to shorter intervals between the acquiring of motor skills, or could cause children to miss out on some developmental stages due to short lived hypotonia.²¹ Bottos *et al* (1989)²⁴ found that long-term neurodevelopmental evolution was not influenced by missing the stages of crawling or creeping locomotor strategies. The children in this study were only followed up until the age of five years. Creeping is considered a hypotonic crawl variant,²⁵ while the process of crawling provides the opportunity for the development of eye-hand co-ordination, vestibular processing, improvement of balance and equilibrium, spatial awareness, tactile input, kinaesthetic awareness and social maturation. The ability to cross the midline presents the child with the ability to integrate the two symmetrical halves into a composite whole.²⁶

Boachie-Adjei & Lonner (1996)² hypothesised that abnormal developmental milestones in young children may suggest a neuromuscular cause of a spinal deformity. However, in the literature review that was conducted, no evidence was found of any study to determine a correlation between certain developmental milestones and other factors (see the following

paragraph) that may affect the neuromusculoskeletal system and the development of spinal deformities during adolescent years.

Due to the current unsuccessful treatment of spinal deformities by physiotherapists, it was decided to investigate the association between certain developmental milestones, namely sitting, crawling and walking, and spinal deformities. The possible role of other factors, such as position of lying, use of aids (sit chairs, walking rings and jolly jumpers), visual and auditory impairments, family history and sudden growth spurts, in the development of spinal deformities, was also investigated. The position of lying, visual and auditory impairments, family history and sudden growth spurts have previously been referred to in the literature as factors that could influence spinal curves.^{1,2,3,5,6} The use of developmental aids is a fairly modern trend that may affect the normal developmental stages of babies. If this study shows that there is a relationship between developmental milestones and certain other factors (as given above), and the development of spinal deformities, physiotherapists could help to instruct young mothers in the stimulation of gross motor skills and the stimulation of hypotonic muscles in their offspring. This intervention should minimise the risk factors in the development of spinal deformities, thus leading to an important area of preventative treatment at a primary health care level by the physiotherapist. The high cost of medical services in South Africa is a problem. The estimated cost for a spinal fusion in the Pretoria Academic Hospital is between ten and fifteen thousand rand. This study may highlight the importance of giving mothers relevant advice on the care of their offspring, in order to minimise the risk of the development of spinal deformities. Early intervention at primary health care level may lead to an important reduction in medical costs, as well as a decrease in the concomitant problems associated with spinal deformities.

1.2. PROBLEM STATEMENT:

There is no single specific aetiological factor in the development of spinal deformities.⁴ Postural failure and disharmony in the postural control system can influence spinal deformities.¹⁸ Motor development and muscle tone are dependent on the specific developmental phases of a baby.²⁴ Late milestones or omission of certain developmental stages in babies may lead to low trunk muscle tone, which in turn may lead to postural problems and spinal deformities in adolescents. The position of lying, visual and auditory impairments and sudden growth spurts could add to body asymmetry, while the use of developmental aids could add to the omission of developmental stages or altered developmental phases.

Physiotherapy has little effect in preventing the progression of a curve, therefore other ways of treatment should be researched. The risk factors in the development of spinal deformities could be minimised by intervention during the developmental stages of babies.

1.3. RESEARCH QUESTION

Do abnormal developmental milestones and certain other factors of neurologically intact babies have an influence on the prevalence of spinal deformities in adolescents in Middelburg, Mpumalanga?

1.4. AIM OF STUDY

1.4.1. MAIN AIM

To investigate the association between certain developmental milestones, namely sitting, crawling and walking, and the development of spinal deformities in adolescents aged between twelve and seventeen years, in Middelburg, Mpumalanga.

1.4.2. SUB AIMS

1.4.2.1. To determine if a literature review shows any correlation between the developmental milestones of a baby and the development of spinal deformities in adolescents.

1.4.2.2. To determine if the following factors have any influence on the prevalence of spinal deformities:

Developmental factors:

- age at which the babies sat independently
- whether the babies crawled
- age at which the babies crawled
- age at which the babies walked independently

Other factors:

- family history of deformities
- period of gestation
- preference of lying position
- other ways of locomotion before the babies walked
- the use of aids such as a walking ring, a sit chair or a " jolly jumper "



- any auditory impairment
- visual impairment
- growth spurts
- height
- gender
- menarche in girls
- hip flexor tightness
- decreased hamstring muscle flexibility

1.5. HYPOTHESIS

Deviations of certain normal developmental milestones namely sitting, crawling and walking, as well as certain other factors, in neurologically intact babies, may influence the development of spinal deformities in adolescence.

1.6. TERMINOLOGY

- **Spinal deformity:** Any deviation from the normal kyphotic and lordotic curves in the sagittal plane, or deviation of the vertebrae in the coronal plane.²
- **Idiopathic adolescent scoliosis:** A spinal curvature presenting at, or about the onset of puberty and before maturity for which no specific cause is established.²⁷ This is a lateral deviation of the spine in the coronal plane.²
- **Kyphosis:** A change in the alignment of a segment of the spine in the sagittal plane that increases the posterior convex angulation.²⁷
- **Kyphoscoliosis:** A spine with a scoliosis and a true hyperkyphosis.²⁷

- **Abnormal developmental milestones:** Average ages for normal developmental milestones have been established.²⁸ In this study any deviation from the normal average was considered as “abnormal”, although not pathological. Abnormal in this study can be described as “not within the normal averages”.
- **Postural control:** The spine, the main axis of posture, is maintained by activities of the trunk muscles. The tone of these muscles are regulated by a postural reflex mechanism between the peripheral proprioceptors and the brain.^{18,20}
- **Postural failure:** Disharmony in the postural control systems namely the postural reflex mechanism controlling the muscle tone.^{18,20}
- **Muscle tone:** Although not an active contraction, muscle tone determines the body posture, range of movement of the joints and the feel of the muscle. Muscle tone is determined by physical, chemical and neural influences.²⁸

1.7. SUMMARY

Although there are a variety of aetiological factors that could influence the development of a spinal deformity⁴, a spinal deformity can be regarded as a manifestation of postural failure.¹⁸ Physiotherapy has little effect in the prevention of the progression of a curve^{9,13}, therefore other ways of treatment should be researched. Abnormal developmental milestones and certain other developmental factors suggest a possible neuromuscular cause of a deformity².

The motivation, problem statement, research question, hypothesis, aims of the study and definitions of relevant terminology were given in this chapter. In the following chapter, chapter two, the literature review will cover all the aetiological factors of spinal deformities as well as the background for postural control and normal developmental milestones. Studies investigating the association between the presence of adolescent spinal deformities and developmental

milestones, as well as certain other factors (which may influence posture), will also be discussed. Chapter three explains the research methodology. Chapter four will give an explanation of all the results and relevant diagrams, histograms and tables. A thorough discussion of the results will be included in chapter five, while chapter six concludes with shortcomings and recommendations.

CHAPTER 2

LITERATURE REVIEW

2.1. INTRODUCTION

The literature review will cover the pathology and aetiology of idiopathic scoliosis, Scheuermann's kyphosis and the postural round back as these are the conditions most commonly seen in the general population. The methods of evaluation and various evaluation instruments that are currently used during the evaluation of these spinal deformities, will be discussed. An overview of the basic principles and effectiveness of treatment of the aforementioned spinal deformities will also be given. Due to the fact that poor posture of an adolescent can lead to a spinal deformity, and because an adolescent with a spinal deformity usually has poor posture, the influences of posture will also be discussed. Normal developmental milestones as well as developmental aspects of babies that may influence the spine, will also be included in the literature review. The literature review was conducted by using the database MEDLINE from 1981 to 1998 and CINAHL from 1982 to 1987. A Cochrane search was conducted to determine if any similar studies have been registered. The reference list of each article was also screened for relevant articles. Only articles published in Afrikaans and English were considered. Keywords used were: spinal deformities, idiopathic scoliosis, Scheuermann's kyphosis, adolescent kyphosis, aetiology, postural control, developmental milestones, motor development, muscle imbalance, exercises.

2.2. SPINAL DEFORMITIES

There are numerous kinds of spinal deformities in the paediatric population. The causes of these spinal deformities could be idiopathic (80 % of cases)¹⁴, congenital, neuropathic or myopathic.^{9,29} Scoliosis is also seen in association with spondylolisthesis, but may be solely idiopathic and unrelated to the spondylolisthesis. The hypoplasia of the articular facet may allow an asymmetrical forward displacement and rotational shift of the vertebral body, or the scoliosis may be due to muscle spasm, and therefore be of a “sciatic” type.³⁵

2.2.1. PATHOLOGY

What are the important pathological factors associated with idiopathic scoliosis, the postural round back and Scheuermann's kyphosis ?

2.2.1.1. IDIOPATHIC SCOLIOSIS

- **Definition of idiopathic scoliosis:**

An idiopathic scoliosis can be defined as a lateral deviation of the vertebral column in the coronal plane.^{2,9,14,30,31,32} A “normal” spine is supposed to appear vertical but this is seldom the case.^{2,31} Some researchers state that a curve deviating laterally from the vertical by five degrees can be considered abnormal^{29,33}, whereas others^{2,9,34} consider ten degrees as abnormal. This lateral deviation results in a rotation of a few vertebrae away from the midline position around the axial plane, with the spinous processes rotated towards the side of the concavity, causing a three-dimensional deformity.^{2,9,30,31,32} The shifting of the centre of gravity leads to a static imbalance.¹⁴

- **Structural changes:**

Rotation of the thoracic vertebrae causes a deformity of the rib cage because the ribs are displaced posteriorly on the convex side of the curve, thereby causing a rib hump.^{11,14,29,30} A costal depression or rib valley appears on the concave side, and a gibbus or rib hump develops on the convex side.¹⁴ This rotation can also take place in the lumbar area, but is less apparent.³² The vertebral rotation is related to the length and severity of the curve, with the most rotation taking place at the apex of the curve.³⁰

Slight dorsal asymmetries become evident when a patient bends forward to touch his toes. The greater the rib prominence, the greater the torsion of corresponding vertebrae as ribs and musculature move with the rotation and develop dorsal elevations. If nothing is done to counteract the hump, one lateral half of the back may quickly enlarge due to the gibbus that develops as a result of an imbalance of muscles and biomechanical forces.¹⁴ The shoulder girdle is drawn posteriorly above the rib valley and anteriorly above the costal convexity.¹⁴ In a right thoracic scoliosis, for example, the right scapula is higher and is forcibly lifted by the rib hump.³²

There is a distortion of the contents of the thorax and the abdomen.⁹ Respiratory restraint is one of the main complications of chest distortion due to a structural scoliosis.^{9,14} An idiopathic scoliosis is thus not only a deformity of the spinal column, but could also affect the viscera and respiratory function.^{9,31} The presence of a hump may also lead to numerous psychological problems.¹⁴

- **Types of idiopathic scoliosis:**

A scoliosis is described according to the side of the convexity, either left or right sided. The position of the apex of the curve determines whether it is a thoracic, lumbar or thoraco-lumbar curve.^{2,29}

A scoliotic curve can be structural or postural.^{2,9,31} A structural curve leads to decreased normal flexibility of the spine and is seen in cases of idiopathic scolioses.²⁷ On forward bending, a postural deformity will straighten out, but in the case of a structural scoliosis a rib hump would be observed on the convex side of the deformity.^{9,11,29} This is due to the fact that there is no vertebral rotation and a rib hump does not develop in the case of a postural scoliosis.³⁴ A postural scoliosis could be the initiating cause of a structural scoliosis, and usually has a single long thoraco-lumbar curve with a predominantly left convexity.³⁴ Postural scoliosis is attributable to compensatory lower limb growth or pelvic adjustments affecting the lumbo-sacral junction and poor posture.^{9,32,34} Lower limb length discrepancy should be corrected by means of an orthosis.⁹

Idiopathic scoliosis may be divided into three groups:

- the infantile idiopathic scoliosis which develops between birth and three years
- the juvenile idiopathic scoliosis which develops from four to ten years
- and adolescent scoliosis which develops after the age of ten.^{1,9}

The current trend is to describe scoliosis as either of early or of late onset, coinciding with the two peaks of rapid growth.^{9,29}

- **Clinical features:**

Clinical features that the parents or patient may notice are an elevated shoulder, a prominent shoulder blade or breast, a high prominent hip, asymmetric flank or trunk shape, poor posture or the curve itself.⁹ Backache is rare. If present, it is usually

associated with a secondary problem such as Scheuermann's disease or spondylolisthesis.^{9,35}

Different curve patterns can occur in idiopathic scoliosis.¹¹ In a thoracic spinal curve the entire thoracic spine is contained in the curve, and in 80 % of cases, the curve is convex to the right.^{11,32,33} Two curves could develop in the thoracic area, causing a double thoracic curve, which is usually convex to the left in the upper thoracic spine, and convex to the right in the lower thoracic spine.^{11,32} The primary curve could also appear in the thoracolumbar area or in the lumbar area. In the lumbar area the spinal curve is to the left in 90 % of cases. A double primary curve may develop in any two spinal areas.^{11,32}

In almost all cases of idiopathic scolioses there is a postural disorder in the sagittal plane with an anterior protrusion of the pelvis. The trunk deviates posteriorly from the lumbar region. The body adapts to the imbalance of the body equilibrium and finally adapts to the scoliotic state.¹⁴

The spine is mechanically less stable than other peripheral joints in the body and therefore requires good neuromuscular control to be correctly aligned. This makes the spine more sensitive to changes in muscle tone. Even a transitory difference in muscle tone could cause some structural changes.¹ The scoliotic curve changes the resting tension of some back muscle fibres due to alteration in the direction of pull of the back muscles.³⁶ Frequent illness episodes and reduced physical activity are found to be associated with trunk asymmetry.³⁷ An increased kyphosis of the thoracic spine was found to be a significant predictor of future scoliosis in girls.⁷ However, a loss of thoracic kyphosis with spinal stiffening may develop into a scoliosis in pre-adolescent girls.¹¹ When the scoliosis is already present, the thoracic kyphosis tends to be reduced.^{7,11,31} An increased lordosis of the lumbar spine can significantly predict scoliosis in boys, but not in girls.⁷ The normal sagittal alignment of the cervical spine is altered in adolescent

idiopathic scoliosis due to the diminished thoracic kyphosis, causing the cervical spine to be more flat or slightly kyphotic.³⁸

- **Prevalence:**

According to different studies the prevalence of idiopathic scoliosis varies in terms of severity of curves as well as age differences of onset . During a school screening the following was found:

- ◇ 1.8 per 1000 children from eight to eighteen years have idiopathic scoliosis
- ◇ 0,2 per 1000 have curves greater than 20 degrees.⁹
- ◇ curves greater than 20 degrees have a prevalence of 2-3 %⁹ in one or 0,3 - 13,6 % in another study³⁷
- ◇ in the general population the prevalence is 0,5 %, but is 1,5 % for boys with a family history of scoliosis, and 5 % for girls with a family history.⁹

- **Gender:**

Idiopathic scoliosis is found more frequently in females than in males,^{2,9,30,31} with a larger risk in girls from the age of nine to twelve years.⁹ Puberty of adolescents with idiopathic scoliosis is not significantly different from normal.⁵ However, in the literature the ratio of males to females varies.^{9,29,31}

According to a literature review by Bentley & Donell (1994)⁹ , researchers found that the female to male ratio was 3,5 to 1,0 , but increased to 7,2 to 1,0 for curves that require treatment.⁹ Other researchers show the ratio of boys is half that of girls³¹, and a five to one ratio is also reported.³⁴ Boys could be protected in some way.³¹ Perhaps this could be because muscle strength is approximately the same in boys and in girls until adolescence, but during the growth spurt boys show a greater increase in muscle strength than girls.¹

- **Skeletal maturity:**

Skeletal maturity is determined by means of radiographs of the iliac and ischial epiphyses.^{2,29} According to the Risser method, the development of the iliac epiphyses is divided into four stages.²⁹ The ilium is divided into four equal areas and the fusion of each area is a stage of the Risser sign.²⁹ These epiphyses fuse to the iliac crest over a period of several years, averaging twenty four months in males and thirty months in females.⁹ The fusion usually starts at the anterior superior iliac spine and progresses posteriorly to the posterior iliac spine.^{9,29} The average age for fusion of the epiphysis to the iliac crest is fourteen years in girls and sixteen years in boys, but it may vary from ten to eighteen years in girls and thirteen to twenty years in boys.⁹ Dhar *et al* (1993)⁹ felt that Risser did not take the actual fusion process of the epiphysis to the iliac crest into consideration, and therefore developed their own ten stages of skeletal maturity.⁹ However, the four stages of Risser, namely the Risser's sign, is most commonly used.^{2,29}

Radiographs taken to determine skeletal maturity are risky due to the adverse effects of radiation to the pelvic organs,^{2,9} but the determination of skeletal maturity is important owing to its relevance to curve progression.²⁹ Skeletal maturity is difficult to determine due to the wide age range at which youths reach sexual maturity.²⁹

- **Risks for progression of the curve:**

Scoliotic curve progression is more common in girls than in boys,^{2,9,29,39} with a prevalence of 2 to 3 times more²⁹ or 5 to 8 times more in girls.² Risk factors for the progression of curves are periods of rapid growth, a Risser sign of nil to two, pre-menarche detection, a curve of more than 30 degrees, a double curve (especially in the thoracic area), a rib-vertebral angle of more than 20 degrees, females and where there is a family history.^{2,9,11,14,29,40,41} A young patient with a low Risser sign and later onset of menarche has a greater risk of curve progression.⁹ Progression of curvature in boys with idiopathic scoliosis of more than 25 degrees and a Risser sign of four, occurred in 15 % of cases.¹⁵

Curves can progress after skeletal maturity when the vertebral epiphyses have already fused. This means that an asymmetrical posture and muscle activity can lead to intervertebral joint and disc degeneration.^{5,11,29} Minor curves sometimes have the tendency to resolve spontaneously.⁴¹

The dynamic mechanics of the human body have an influence on the curve progression as well as regression.¹ In girls the period of rapid progression is the time from the first signs of puberty and menarche.^{3,29} During the period of rapid growth (ten to fifteen years) the progression of idiopathic scoliosis takes place^{11,34,40}, and it may increase by as much as one degree per month.³⁴ The more years of growth left after detection of a curve, the greater the progression.²⁹ Lonstein & Carlson (1984)⁴⁰ showed a curve progression of 23,2 %. A spontaneous improvement took place in 10,7 % of these cases. These patients were less mature and had curves of less than 15 degrees.⁴⁰ The flexibility of a curve is important in determining the curve prognosis as well as the response to treatment. Progression may lead to pulmonary and spinal dysfunction.¹¹

- **Pulmonary complications:**

Restrictive lung disease in the presence of scoliosis occurs with a direct linear relationship to curve magnitude in patients with a thoracic deformity.^{2,42} This effect is increased in patients with hypokyphotic or lordotic thoracic spines.² Significant pulmonary restraint does not occur until a curve magnitude of 90 to 100 degrees or more is reached.² Other researchers claim that patients, with idiopathic scoliosis who have curves of under 40 degrees, have normal pulmonary functions and only if the curve exceeds 45 degrees should pulmonary functions be measured.¹¹ Adult scolioses with a Cobb angle of more than 60 degrees are threatened by pulmonary hypertension and restriction of cardiopulmonary performance.⁴² It is frequently assumed that respiratory impairment is negligible in scoliosis patients with a Cobb angle of less than 60 degrees. However, marked impairment of the respiratory mechanism and cardiopulmonary performance in

scoliosis patients with a Cobb angle of less than 35 degrees has been noted. The asymmetrical breathing pattern of a scoliotic patient leads to an increase of the curvature, particularly in rotation, and restricted rib mobility.⁴²

The lung work capacity and tidal volume are reduced in mild to moderate idiopathic scoliosis.⁴³ Hornstein, Inman & Ledsome (1987)⁴⁴ found a correlation between a decrease in vital capacity and other lung functions, and the severity of the curve, but Kearon, Viviani & Killian (1993)⁴⁵ found that the extent of this reduction depends on the severity of pulmonary impairment. Scoliotic patients adopt a low tidal volume and high frequency pattern of breathing, especially during exercise.^{43,44} Reduction in thoracic cage compliance results in a higher energy cost of breathing.⁴⁴ Growth impairment of the rib cage and lungs, and reduced inspiratory muscle strength have been reported in patients with idiopathic scoliosis.⁴² Pulmonary hypertension and cor pulmonale are seen in later stages of scoliosis, leading to cardio-respiratory failure in severe cases.^{2,44} In patients with adolescent idiopathic scoliosis the incidence of cor pulmonale is exceedingly low; it is more often seen in untreated infantile scoliosis or severe congenital deformity.²

- **Psychological aspects:** The cosmetic aspects of the deformity itself, as well as the psychological effects associated with the wearing of a brace, have a negative effect on the self-esteem of a patient with a spinal deformity. The patient feels insecure and different from the rest of the community.³²

2.2.1.2. KYPHOSIS:

- **Definition:**
A kyphosis can be described as an excessive curve, convex posteriorly occurring mainly in the thoracic spine.² Kyphoses occur in a single plane and the biomechanics

are therefore easier to understand than those of a scoliosis.¹⁰ The curve may be gradual, as in the cases of postural kyphoses, or it can have a sharper curve or gibbus, in the case of Scheuermann's kyphosis.²

- **Clinical features of Scheuermann's disease:**

Scheuermann's disease is recognised as a condition affecting the thoracic spine in two forms, the thoracic form and the thoraco-lumbar form. The apex of the thoracic form is localized between the seventh and ninth thoracic vertebrae, while the apex of the thoraco-lumbar form of Scheuermann's disease is between the tenth and twelfth thoracic vertebrae.⁴⁵ Classical Scheuermann's disease is diagnosed as a kyphosis that exceeds 45 degrees, with more than five degrees of wedging of the anterior vertebral bodies of at least three successive vertebrae.^{2,10,11,45,46,47} This wedging is caused by damaged growth centres in the anterior portions of the vertebral bodies.^{11,46,48}

Associated findings include Schmorl's nodes, vertebral endplate irregularity and narrowing of adjacent intervertebral discs.⁴⁸ The wedging of the three adjacent vertebrae observed on radiographs is used to differentiate between Scheuermann's kyphosis and a postural kyphosis. Patients who do not demonstrate these bony abnormalities and have a kyphosis exceeding 45 degrees, are considered to have a postural kyphosis or a postural round back.⁴⁷

Another form of Scheuermann's disease which occurs in the lumbar region, has been reported.^{45,46} Patients with this disease generally report low back pain and demonstrate vertebral endplate irregularity, anterior Schmorl's nodes and narrowing of the involved intervertebral discs on radiographs.⁴⁶ These patients are distinguished from those with the classic Scheuermann's disease by the location of involvement, the lack of thoracic kyphosis and marked wedging of the vertebral bodies.⁴⁶ Lumbar spondylolisthesis is frequently seen with hyperkyphosis.¹⁷

Scheuermann's kyphosis is a deformity that causes a painful back.^{10,11} A very slight scoliosis may exist in the area of maximum kyphotic deformity.^{11,45} This scoliosis can be on the level of the apex of the kyphosis, or above or below the kyphosis.⁴⁵ The forward bend test will show a typical dome when observed laterally.^{11,45}

- **Spinal stress:**

In standing or sitting the spine is subjected to the force of gravity. The amount of stress on any one mobile intervertebral segment is related to the weight of the individual and the level of the spine (for example the fifth thoracic vertebra carries less load than the fifth lumbar vertebra).¹⁰ There are other factors that add to this concept of spinal stress, namely motion stress, muscular forces and the position of a vertebra relative to the centre of gravity of the body.¹⁰ The extensor muscles, supraspinous and interspinous ligaments, the capsular ligaments and the ligamentum flavum should counteract the natural tendency of the thoracic spine to develop a kyphosis.¹⁰ The eighth thoracic vertebra lies most posterior to the central sagittal axis. This position is precarious as the extensor muscles are close to the vertebra causing a very short moment arm. In contrast, the flexor muscles lie in front of the eighth thoracic vertebra, and thus creating a strong moment arm. This is why the eighth thoracic vertebra is the most commonly involved vertebra in Scheuermann's disease.¹⁰

- **Gender**

Thoracic kyphosis develops more frequently in boys than in girls.¹⁷ There is a wide range of normal thoracic curve values with a mean of 35 degrees.⁸ The mean thoracic kyphosis tends to increase during growth and the mean lumbar lordosis seems to decrease in both sexes.¹⁷ Nissinen (1995)¹⁷ found that the most pronounced kyphosis was observed at a



mean age of 12.8 years, and the least pronounced lumbar lordosis a mean age of 13.8 years in both genders.

- **Prevalence:**

Scheuermann's kyphosis is seen in 0,5 - 8 % of the general population.²⁰ The prevalence rate increases between the ages of twelve and thirteen years.³¹ Hyperkyphosis of more than 35 degrees was found in 13,5 % of adolescents and a thoracic kyphosis exceeding 45 degrees was found in 3,1 % of adolescents.¹⁷

- **Complications:**

A neurological evaluation is essential in children with thoracic Scheuermann's disease. Although rare, cord compression due to stretching of the dural contents and a herniated thoracic intervertebral disc can occur.⁴⁸

SUMMARY:

Idiopathic scoliosis and Scheuermann's kyphosis are both conditions that cause a structural deformity of the spine. These deformities could have a negative psychological effect on the adolescent, and also lead to complications influencing his/her quality of life.

2.2.2. AETIOLOGY

Are there any specific aetiological factors which cause idiopathic scoliosis and Scheuermann's kyphosis ?

IDIOPATHIC SCOLIOSIS:

Idiopathic scoliosis should be regarded as a multifactorial disease. No single factor has been demonstrated to cause scoliosis.¹ In 80 % of idiopathic scolioses the causes are unknown.^{9,14,30} Posture, growth and factors leading to trunk asymmetry, independent of one another, may lead to the development of idiopathic scoliosis.⁷ One out of four children is reported to have trunk asymmetry at the age of ten years.⁴⁹ Biomechanically, the axial skeleton might be more unstable in individuals with increased height and accelerated growth spurts of the spine.¹

- **Growth:**

Idiopathic scoliosis has the tendency to develop and progress during adolescent growth.^{5,6,7} Taller children are more prone to develop adolescent idiopathic scoliosis.^{3,5} Growth alone, especially growth velocity *per se*, is not a primary cause of adolescent idiopathic scoliosis.^{4,5,7,31} Compared to girls with normal spines, an increased level of growth hormones has been found in girls with adolescent idiopathic scoliosis.¹ In patients with a strong genetic susceptibility to the condition growth appears to be less important.⁵ Growth velocity *per se* is unimportant, but adolescents with idiopathic scoliosis are taller than average.³¹ The curve in adolescent idiopathic scoliosis can increase after skeletal maturity. This means that growth cannot be responsible for the increase, but rather that the spine is subjected to asymmetrical posture and muscle activity.⁶ Other researchers claim that increased height should be regarded as a poor prognosis rather than an aetiological factor.³ Carr *et al* (1993)⁵ found no clinical evidence of generalized growth abnormalities that would account for the increased stature. Skeletal bone age was not

significantly different from the chronological age, nor were the puberty ages significantly different from normal.⁵ Curves progress rapidly during the adolescent growth spurt, which occurs in girls around twelve years and in boys two years later.¹ During the adolescent growth spurt the trunk increases more than the limbs in length.¹ Girls with adolescent idiopathic scoliosis are significantly taller than normal girls, but this is not the case with boys.¹ These girls start their growth spurt earlier, continue to grow for a longer period of time, but the age of menarche does not differ from normal girls.¹⁴ The risk of trunk abnormalities is at its highest in the period between onset of adolescent growth and the onset of menarche.³

- **Family history:**

Adolescent idiopathic scoliosis appears to have a genetic basis.^{1,2,5,9,11,20,32} Girls of mothers with scoliosis are more at risk to develop a scoliosis.⁹ The prevalence rises from 0,5 to 5 % in girls and 0,5 to 1,5 % in boys with a family history of scoliosis.⁹ Maternal age was found to be older in mothers of children with adolescent idiopathic scoliosis.³⁹ The genetic determination is regarded as dominant and is sex-linked to the X - chromosome, but is also influenced by maternal age.¹ Up to 33 % of parents and siblings of patients with adolescent idiopathic scoliosis have a scoliosis.¹ It has been calculated that if both parents have an idiopathic scoliosis, the chances for their off-spring to acquire a curve requiring treatment, can be fifty times that of the normal population.^{1,11} Fathers transmit the disease to their daughters, and mothers transmit the disease to both genders.¹ Several familial cases with clinical combinations of lateral gaze palsy and progressive scoliosis have suggested an autosomal recessive hereditary trait.²²

- **Posture and equilibrium: (also refer to 2.2)**

The importance of spinal posture of pubertal children is poorly documented.¹⁷ Postural disequilibrium and abnormality of the vestibular functions, defective proprioceptive functions and ocular motor disturbances have been observed in association with

adolescent idiopathic scoliosis.^{17,18,22,32,36} Equilibrium functions are gradually acquired during the growth period, keeping pace with physical growth. If equilibrium development does not keep pace with growth, postural failure will result. Scoliosis is regarded as a manifestation of postural failure associated with disharmony in the postural control system.¹⁸

Information from skin sensation, ligaments and muscles combine together with signals from the optical apparatus and semicircular canals. All these signals are integrated and co-ordinated to control equilibrium by means of the muscles.³² A vestibular imbalance can influence the tonicity of skeletal muscles via the vestibulo-spinal tracts in such a way that the individual leans and rotates away from sound side.¹ The spine demonstrates a lateral deviation and rotation leading to a functional asymmetry or scoliosis.¹ A vestibular imbalance exists in a high proportion of patients with idiopathic scoliosis, but it is difficult to determine whether it is a cause or an effect.¹ Asymmetric posture in children is very common.³⁷ Several postural stresses are experienced in daily living, schools and the use of computers.⁵⁰ An asymmetrical posture may be an early sign of the predisposition to develop scoliosis.³⁷ The spine is considered to be the main axis of posture and is maintained by activities of the trunk muscles. The tone of these muscles is automatically regulated by a postural reflex mechanism.¹⁸

Trunk asymmetry is a stage without axial rotation or with very little rotation.³⁷ In about 10 % of the adult population, a slight rotation of the fourth lumbar vertebra on the fifth lumbar vertebra is seen.³² This is so common that it may be regarded as a manifestation of the anatomical and functional asymmetry of the human body.³² In time this can become permanent due to the result of changes in the disc.³² Reduced physical activity or hypokinesia may be affected by lifestyle and passivity during illness. Muscle power as well as static and dynamic endurance, and muscle tone decrease.³⁷ Physical activity is

one of the factors that may affect posture quality.³⁷ Juskeliene *et al* (1996)³⁷ found an asymmetrical posture in 46-49 % of the 791 children in their study.

- **Developmental milestones:** (also refer to 2.4.)

At birth the entire spine is kyphotic. When a child develops head control, the neck extension produces a cervical curvature convex anteriorly. This is the development of the cervical lordosis. A similar lumbar lordosis develops when the child begins to sit and stand.³¹

There is a higher prevalence of scoliosis in Scotland than America. This could be due to the fact that babies in Scotland are positioned more often in supine than in prone during their first two years. Americans use the prone position for their babies in preference to supine.¹ Babies who are nursed in prone develop neck and spinal muscle control earlier than babies nursed in supine.¹ Prone positions may enhance the development of righting reflexes that develop later to keep the body in an upright position.¹

- **Other:**

Total lateral gaze palsy, the most severe type of visual disequilibrium, has been reported in association with progressive scoliosis.²² It is not clear if this is a cause or a result of idiopathic scoliosis.

Latissimus dorsi, muscles of the lateral abdominal wall, the intercostalis and the iliopsoas are important muscles in the development of scoliosis.¹ Histochemically more type I (slow-twitch) muscle fibres are found on the convex side of idiopathic scoliosis.^{1,29,31,51} It is not clear if these changes are secondary to the curve, or whether they existed prior to the development of scoliosis. Higher postural tone was noted in muscles on the concave side of a curve compared to the convex side.¹ Early involvement of children in intensive

swimming programmes exposes them to types of stress that can affect the growth and development of their musculo-skeletal systems in an adverse way, producing a disruption of normal growth patterns.³⁴ Structural idiopathic scoliosis was found in 6,9 %, and functional scoliosis with lateral curvature to the hand-dominant side of the body in 16 % of swimmers.³⁴ The presence of scoliosis in pre-adolescent and adolescent swimmers may indicate that motor developmental patterns could have a direct relationship on the skeletal growth of vertebrae and the spine.³⁴ An assumption is made that the repetitive motions required in swimming could produce a physiological adaptation, and thus a muscular adaptation, which leads to a contracted spinal curve.³⁴

Malnutrition has been found to be associated with idiopathic scoliosis in South America, Europe and the United States of America. It was noted that too much carbohydrates and too little protein were consumed. In the Soviet Union the incidence of idiopathic scoliosis was four times higher in undernourished children.⁵²

KYPHOSIS:

The aetiology of Scheuermann's disease is unknown but mechanical strain, such as strenuous labour and sports activity, repetitive trauma and tight hamstrings have been implicated.⁴⁸ Scheuermann's kyphosis shows an autosomal dominant hereditary pattern.^{2,48} There is a positive family history in 15 - 20 % of patients with a Scheuermann's kyphosis.¹¹

Left handedness, independent of gender, was also found to be a predictor of future hyperkyphosis due to the pronounced kyphotic posture needed for writing.⁵⁰

SUMMARY: Evidence of a specific aetiological factor could not be found in the literature. It is clear that idiopathic scoliosis and kyphosis are multifactorial diseases. Growth, hereditary factors, gender and posture are clearly the most important aetiological factors.

2.2.3. EVALUATION AND INSTRUMENTS

Is there consensus with regard to the evaluation methods of spinal deformities?

A variety of evaluation methods and instruments are described in the literature.

The validity and reliability of these instruments differ. The most relevant methods will be reviewed in the following section:

School screening is important for the detection of deformities.^{2,30} Screening is defined as the presumptive identification of unrecognised disease or defect by the application of tests, examinations or other procedures that can be applied rapidly.³¹ A comprehensive history is necessary in order to elicit information about the deformity and other associated problems. Family history with regard to spinal deformities may suggest a genetic factor.^{2,30} Relevant injuries and illnesses should be evaluated to determine the possible cause of any deformity. Skin pigmentation such as café-au-lait spots may indicate a diagnosis of neurofibromatosis.² The child and parents should be questioned as to how the deformity was discovered. The age at which the deformity was first noticed is important to determine the potential for further progression. The onset of menarche is important to assess the relative maturity and growth potential in female adolescents.^{2,30} Boachie & Lonner (1996)² recommend a review of birth history, developmental history and childhood illnesses as important, and suggest that abnormal developmental milestones in young children may lead to spinal deformities. However, whether any of these factors indeed play a role has not been verified. Some

authors suggest that hand dominance should be evaluated, but no correlation between hand dominance and idiopathic scoliosis could be found.^{33,48}

Structural scoliosis is diagnosed by the presence of at least one positive physical sign: rib-hump, lumbar hump, spinal muscle imbalance, discrepancy of shoulder height or radiographic evidence of a curve.³³ A kyphosis is diagnosed by an increased kyphotic posture or a structural dome in the spine on lateral views of radiographs.¹⁷

- **Height:**

Serial height measurements are useful in assessing growth and progression of deformity.^{2,32} Height may decrease or remain static in growing children in whom curve progression has already occurred.²

- **Leg length discrepancy:**

Leg length discrepancy has a high prevalence in the general population, but the level of significant leg length discrepancy is generally accepted as ten millimetres or more. This difference in leg length can cause asymmetry of the spine.⁵³ Leg length inequality causes pelvic obliquity and secondary scoliosis.² A postural deformity due to leg length discrepancy will straighten during forward bending.⁹ Such a deformity can be corrected by means of a shoe lift.² Leg length inequality can be determined by means of a tape measure: the distance from the superior anterior iliac spines to the tip of the medial malleoli is measured.⁵³ Another method to determine leg length inequality is by placing boards of known thickness under the short leg until horizontal symmetry of the iliac crests or superior posterior iliac spines is obtained.^{33,48,55} A palpation meter has also been used to determine leg length discrepancy. The iliac crests were used as landmarks and any difference in height was determined. The validity of the palpation meter has not yet been tested.⁵⁶

Relative iliac crest height measurement is a standard evaluation technique in the structural examination of patients to determine pelvic girdle asymmetries and leg length discrepancy. Radiographic imaging is generally accepted as the most reliable method of leg length discrepancy measurement.⁵⁴ However, unnecessary exposure to X-rays should be avoided.

- **Passive straight leg raise:**

Tight hamstring muscles have been implicated in the aetiology of Scheuermann's kyphosis.⁴⁸ A passive straight leg raise is used to determine the flexibility of the hamstring muscles. The extent to which the leg can be lifted without discomfort, varies. Different averages of straight leg raise have been documented (80 degrees⁵³, 75 degrees⁵⁷, 83,4 degrees⁵⁸ of hip flexion). Normal range of movement in healthy individuals can vary from 50 degrees to 120 degrees.⁵⁸ The passive straight leg raise is performed to the onset of tightness or to the onset of symptoms, and is measured as an angle formed between the bed and the leg.^{53,58,59} Other authors advocate raising the leg to a point where the contralateral thigh begins to move.⁵⁶

- **Thomas test:**

The Thomas test is a specific test to detect flexion contractures of the hip and to evaluate range of hip flexion. The patient is supine, and as the one leg is moved passively into hip and knee flexion, the other leg should remain flat on the examination table.⁵³ The psoas muscle is draped over the anterior rim of the pelvis, which provides it with the ability to alter the position of the pelvis. Upward and downward pelvic tilting is related directly to the degree of respective flexion and hyperextension of the lumbar spine. Tightness of the psoas muscle will pull the anterior rim of the pelvis downward, causing an anterior tilt. Such a tilt will cause the sacrum to incline forward, resulting in a lumbar lordosis.⁵¹

- **Plumbline:**

A plumbline is dropped to determine the deviation of the spine from the vertical line.^{2,32, 60} A vertical plumbline from the seventh cervical spinous process usually passes straight to the natal cleft.^{2,38} Any deviation of spinous processes from the plumbline is measured in millimetres.² A distance of less than 10 millimetres between the cleft and the string is considered normal.³⁶

In the sagittal plane the tragus of the ear or the earlobe is transected by the theoretical plumbline.^{61,62} The plumbline passes anterior to the seventh cervical vertebra in the sagittal plane, through the shoulder joint, midway between the back and abdomen, anterior to the first sacral segment and through the greater trochanter of the femur.^{62,63}

- **Postural observations:**

Clinical evaluation of posture and the estimation of the range of kyphosis and lordosis are subjective and vary among different examiners.⁶⁴ Minor asymmetry of the trunk in school children is common and cannot be regarded as abnormal.^{31,55} Trunk asymmetry may be considered a risk factor for adolescent idiopathic scoliosis,⁴⁹ and is more prevalent in girls.⁷ Posture is assessed by visual assessment of shoulder or pelvic asymmetry or abnormal flank creases.^{2,30,33,61,65} During assessment of posture, the patient should stand in his/her normal relaxed posture and should not be corrected.^{32,56}

- **Forward head posture:**

The natural head position is a standardised and reproducible position of the head in an upright posture, the eyes focused on a point in the distance at eye level, implying that the visual axis is horizontal. Natural head posture is subject to individual variations.⁶⁷ Forward

head posture implies that the head is in an anterior position in relation to the theoretical plumbline.^{60,61,62,68} Postural changes associated with forward head posture are a forward glide of the lower cervical vertebrae with the upper cervical complex extended, alteration of the upper thoracic kyphosis, protraction and elevation with rotation of the scapulae and elevation of the first and second ribs.^{68,69,70}

Cervical inclination has also been determined by means of a lateral photograph.⁷¹ The forward position of the head relative to the cervico-thoracic spine was determined by the position of the second cervical vertebra relative to the seventh cervical vertebra. An angle was calculated by means of a horizontal line through the seventh vertebra intersected by a line drawn between the second and seventh vertebrae.⁷¹

- **Hump size:**

Hump size is the most powerful predictor of scoliosis, and together with the angle of thoracic inclination, is useful for the screening of scoliosis.^{7,72} Hump size is determined by means of the Adam forward bending test.^{2,7,8,31,55,72} Symmetry of the ribs are assessed from anterior and posterior. Even minor deformities can be detected by this technique.⁸ To quantify the transverse plane asymmetry, the height of the rotational prominence can be measured by means of a ruler and spirit level.^{31,49,55,72} During screening, patients are referred for radiographs in cases where the hump size is six millimetres or more.^{7,55} In a cohort study by Nissinen *et al* (1993)⁷, boys with a hump of six millimetres had a five-fold risk of developing scoliosis.

Accurate measurement of the vertebral rotation is important in scoliosis assessment.⁷² The rotational prominence, or angle of trunk rotation, is measured by means of a scoliometer or inclinometer.^{2,31,49,55,72} The thoracic hump measured at the curve apex using the scoliometer, correlates with the Cobb angle and apical vertebral rotation in thoracic

scoliosis.^{48,55,72} A hump size of six millimetres has been found to correlate with a Cobb angle of 10 degrees.⁴⁹ Some researchers consider five degrees of trunk rotation as an indication for referral for treatment,³¹ while others consider an angle of trunk rotation of seven degrees or more to be associated with scoliosis, and this should prompt the physician to obtain radiographs of the spine.²

Symmetrical spines are seldom found (22 %).⁵⁵ Right sided thoracic humps and left sided lumbar humps are seen most frequently.^{33,55} Girls are more inclined have a hump size of more than six millimetres.^{33,49}

A kyphotic deformity and its region within the spine, can be evaluated by viewing the patient laterally during the forward bending test.²

- **Radiographs:**

Radiographs should include standing antero-posterior and lateral views of the spine from the occiput to the sacrum. The pelvis must be visualised so that skeletal maturity can be assessed.² Supine, right and left lateral bending films show curve flexibility and are important in the planning of surgery. The flexibility of the kyphotic curve is revealed by means of a lateral view with a hyperextended back.² Rotation of the vertebrae is seen by viewing the pedicles on an antero-posterior radiograph. In a normal spine no rotation should be present and the pedicles should be on the lateral border of the vertebrae.^{2,72}

The measurement of Cobb angles on radiographs is the most effective way of determining the angle of deformity.^{6,31,72} Radiographs are two dimensional and cannot reveal the true three-dimensional nature of scoliotic curves.^{30,72} However, the Cobb angle can be affected by variations of the patient's position relative to the radiographic equipment.⁷²

The vertebrae are defined on radiographs. Neutral vertebrae are those vertebrae which have no rotation. End vertebrae are those which are most inclined in relation to the horizontal in a standing position, while an intermediate vertebra is an end vertebra which is common to two adjacent curves.³²

During the measurement of Cobb angles some researchers show an inter-observer agreement in the measurements of Cobb angles and skeletal maturity.⁷³ These researchers did not differ in determining the upper and lower end vertebrae, but they were, however, all associated with the same scoliotic clinic.⁷³

In smaller curves the variability in the assessment was larger.⁷³ Other researchers found variability in selection of the end vertebrae, and this could result in inter-observer error and unreliability in the measurement of scoliotic curves, as well as in the measurement of the sagittal contours.^{74,75} During the measurements of the sagittal contours, some investigators used the superior endplate of the fifth thoracic^{47,76}, or the fourth thoracic⁷⁷ or third⁷⁸ thoracic vertebrae as the upper line and the inferior endplate of the twelfth thoracic vertebra as the lower line of the Cobb angle. Other researchers used the superior endplate of the first thoracic vertebra to the inferior endplate of the twelfth thoracic vertebra for the measurements of the Cobb angles.³⁸ The vertebral endplates above the fifth thoracic vertebra are difficult to see on the radiographs due to the scapula that is superimposed on a lateral radiograph. Lateral radiographs are therefore considered to be unreliable for the level above the fifth vertebra.^{47,76} The lumbar sagittal contour is measured from the superior endplate of the first lumbar segment,^{76,79} (or other vertebrae that can be considered as an intermediate vertebra⁷⁸), to the superior endplate of the first sacral vertebra^{38,77,79} (or inferior endplate of the fifth lumbar vertebra⁷⁶).

Tangential radiographic assessment of the lumbar lordosis showed less variability than the traditional Cobb method.^{76,80} The fact that some vertebrae in the lumbar area are wedge shaped could also affect the reliability of the Cobb angles.⁸⁰ The Cobb method shows changes between the end vertebrae and does not represent the actual arc.⁷⁹

The position of the arms during standing radiographs also varies. The arms are usually stretched out in front of the chest to 90 degrees.⁷⁶ This position can increase the thoracic kyphosis,³² while other radiologists⁷⁷ feel that the hands should rest on a horizontal support in front of the pelvis.⁷⁷ Radiographs are impractical in the assessment of posture during the research of large samples, and are also considered a health risk.⁶⁵ Therefore the use of non-invasive instruments offers safer and more practical methods of assessing spinal curves.

- **Non-invasive instruments:** Non-invasive methods of measurement of spinal mobility include the use of a tape measure, standard goniometer, inclinometers and other special instruments (kyphometer⁸¹, arcometer⁸²).⁷ The reproducibility of measurements by means of inclinometers have proven to be acceptable and indicative of spinal posture in the sagittal plane when compared to radiographic measurements.⁷⁵ Other researchers claim that apparent abnormalities in surface posture do not necessarily indicate that the underlying vertebral alignment is also abnormal.¹⁶ A variety of inclinometers are available.⁷⁵

As with the radiographs, a variety of spinal levels are used to measure the curves with instruments. Measurements with the Myrin inclinometer were done from the levels of the posterior superior iliac spines on the sacral level to the first lumbar spinous process for lumbar lordosis, and from the first lumbar spinous process to the first thoracic spinous process for kyphosis.⁷⁵ Measurements with the kyphometer for a kyphosis were done from

the interspinous space of the second and third thoracic vertebrae to the interspinous space of the eleventh and twelfth thoracic vertebrae. The lordosis was measured from the eleventh and twelfth interspinous space to a point between the first and second sacral segments.⁸¹ D'Oswaldo (1997)⁸² used any two spinous processes between the first and the twelfth thoracic vertebrae, which included the more evident kyphotic area, during measurements with an arcometer external method.

The precision of measurements using a kyphometer was found to be good.⁸¹ D'Oswaldo (1997)⁸² showed a correlation between the measurements with an arcometer and radiographs during clinical measurements. Posture and curve variability may influence the measurements. In the arcometer measurements, the patients were standing with their arms stretched out forwards, while the arms were hanging next to their sides during other non-invasive methods.^{86,85,83}

Spinal pantography is a method of evaluating the true sagittal curve by means of a low friction wheel which follows the contour line of the spinous processes, reflecting it onto a drawing board.⁸⁴ A photographic method with surface markings can also quantify the visible shape of a spinal curve and accurately measure the magnitude of the curve by means of a mathematical method.⁸⁵ These researchers compared their measurements to surface contours on the radiographs. Their measurements correlated reasonably well to radiographic measurements of the vertebral column. However, these researchers concluded that inclinometers, goniometers and flexible rulers quantify the relationship between the two end vertebrae but do not take the shape of the curve into consideration.⁸⁵ The use of a double inclinometer was found to be a valid method of evaluating spinal movement when compared to radiographs.⁸⁴ This study was only conducted on the spinal movements and not on static standing postures.

In two different studies, measurements by means of electro-magnetic devices were found to be accurate and reliable, when compared to previously validated and reliable methods using a double inclinometer. Radiographs were not used due to the fact that multiple films would have been needed, exposing the patients to too much radiation.^{84,86,87} Measurements by means of the Saunders Electronic Inclinometer are considered reliable if they are consistent, that is if they fall within approximately 10 % or five degrees of each other.⁸³ Measurements for standing posture have been tested by means of measurements at the interspinous spaces of the specific spinal junctions. This instrument is the most recent development in inclinometers.⁸³

During the determination of reliability of the above mentioned non-invasive studies, the standing posture of the subjects was mostly with the arms next to the sides, but the gold standard for radiographs is standing with the arms in front of the chest in 90 degrees of shoulder flexion, which could possibly influence the sagittal curve. This could account for some of the non-invasive measurements that did not correlate with the radiographs.

The lack of a universal reliable non-invasive evaluation method, and the dangers and high cost of radiographs, make it difficult to determine the angles of curves accurately.

- **Normal values of spinal curves:**

Due to variations in the methods of selection of end vertebrae, measurement and technique differences, it is difficult to determine the normal values of curves.

Guidelines established by the Scoliosis Research Society determine that the normal range for a thoracic kyphosis using the Cobb method is 20 - 40 degrees, but should not exceed 45 degrees.⁴⁷ The normal value for a thoracic kyphosis is 20 - 45 degrees,^{2,47,78,88} and for a normal lordosis 25 - 60 degrees² or 20 -60 degrees.⁷⁸ The latter was measured from the

top of the first lumbar vertebra to the bottom of the fifth lumbar vertebra.⁷⁸ There is no significant difference between the kyphotic curve of boys compared to girls.^{84,78} Others consider less than 20 degrees as a hypokyphotic curve and more than 40 degrees as a hyperkyphotic curve.³⁸ When using the landmarks of the fifth thoracic vertebra to the twelfth thoracic vertebra as a screening method, a measurement of more than 33 degrees can be considered a pathological kyphosis.⁴⁷ The mean for the lordotic curve for adults, measured from the first lumbar vertebra to the first sacral segment, varies from 72 degrees to 56 degrees, according to Stagnara (1988).³²

The spinal curve changes with growth. The normal lumbar lordosis average measurement at the age of one year is approximately 40 degrees. By the end of puberty it is 50 degrees.⁸⁰ The least pronounced kyphosis in both genders is at the age of 10 -12 years, due to the fact that the growth rate is at its slowest.⁸⁴ The mean kyphosis measurement at the age of 10 - 14 years is 37,5 degrees, and at the age of 15 - 20 years is 38,5 degrees, while the mean lordosis at the age of 10 - 14 years is 56,1 degrees, and at the age of 15 - 20 years is 56,6 degrees.⁷⁸

SUMMARY: It is evident that there are variations in the gold standards of evaluation methods for spinal deformities. Non-invasive methods are not as accurate as radiographs, but even the radiographs show variability. Non-invasive methods are sufficient to screen for spinal deformities.

2.2.4. TREATMENT OF SPINAL DEFORMITIES

The aim of treatment is to obtain a balanced and stable spine at skeletal maturity²⁴, but are spinal deformities currently being treated effectively ?

2.2.4.1. CONSERVATIVE TREATMENT

OBSERVATION: The key to successful treatment is early detection.² Certain factors, such as the patient's age, gender, presence of secondary sexual characteristics and the angle of the curve, should all be taken into consideration in planning the treatment of any spinal deformity.¹² The initial approach is always observation.^{15,30} Non-progressive curves require no specific treatment apart from regular follow-ups.⁹ The mainstay for the treatment of spinal deformities in the paediatric population is non - operative.² School screening, or non - invasive screening, is an important way of early detection of spinal deformities.^{2,30} Various approaches to treatment are seen in different parts of the world.¹ In the United States 0,5 % of patients were treated for scoliosis, while in Scotland 30 % of patients were treated.¹

Patients in early and late adolescence are considered differently, taking the maturity of the skeleton into consideration.¹² Skeletally immature patients with idiopathic scoliosis with a curvature of 10 - 20 degrees, merely need to be observed at four to six monthly intervals.^{2,12,15} This is done until vertebral maturity is reached and the deformity shows no progression.^{12,15} In the case of a non-progressive scoliotic curve of 20 - 29 degrees, no treatment is needed yet, but if this patient shows a five degree progression, a brace would be indicated.^{2,12,89} Other researchers feel that a five degree increase in angulation

would not need treatment, but if the progression persisted, intervention would be required to prevent severe curvature.¹⁵ Patients with more significant curvatures and those entering the rapid growth phase of development, should be seen every three to four months for observation and radiographs.^{2,15} Patients, with a scoliotic curvature greater than 20 degrees, need to be followed up for two to four years after skeletal maturity, to assess possible progression in adulthood.¹⁵ An increase in the curve occurred in 70 % of patients who were initially only under observation.⁹ As soon as a patient's curvature exceeds 30 degrees, conservative treatment such as bracing, exercises and postural retraining is introduced.⁸⁹ Results by means of conservative treatment are better in cases of patients with a Cobb angle of less than 30 degrees.⁸⁹ Opinion with regard to conservative treatment varies: some feel that it cannot stop curve progression, but that it can slow it.⁸⁹

The treatment of kyphosis varies with the cause of the deformity. A postural round back or a flexible kyphosis is treated by means of reassurance, observation, and extension exercises. In the case of Scheuermann's kyphosis, the treatment is different and bracing is used more often.^{2,10} Reports on long-term results of patients treated for Scheuermann's kyphosis, are rare.⁸⁸

BRACING : Orthoses are the most common method of conservative treatment in scoliotic and kyphotic curvatures, despite the fact that their value is disputed.^{2,9,15} They are used for progressive curves in the growing child, where the deformity is flexible and therefore correctable.^{9,15} Some consider bracing the only non-operative modality that can control the progression of the scoliotic and kyphotic curves.^{15,90} Orthotic devices are better at halting curvature progression than at reversing the deformity.^{2,12,15,30} Bracing fails to prevent curve progression in less than 40 % of scoliotic patients.⁵ The rib prominence,

as a result of the vertebral rotation in scoliosis, is not decreased by bracing.² High scoliotic curves above the mid thoracic area are difficult to control in a brace.^{9,15}

Although good results are seen with bracing, non-compliance remains a serious problem.^{9,15} Bracing of adolescents can have a psychological impact because of concerns about appearance.²⁹ This is despite the fact that many new braces have been developed to improve the aesthetic aspect.¹⁵ It has also been found that only 36 % of boys wear their braces.¹⁵

It is thought that bracing can affect the chest and abdominal mobility and thus cause respiratory dysfunction, but Refsum *et al* (1990)⁹¹ found no evidence to indicate that a brace worn for six months can be associated with deterioration of pulmonary functions in adolescent girls with idiopathic scolioses.

There is also no specific answer regarding the timing and efficacy of bracing.¹⁵ Bracing worn for 22 hours per day can prevent the progression of a deformity.¹² A 16 hour period of bracing is also suggested.¹⁵ Braces should be worn until skeletal maturity is reached.^{12,15} The weaning of boys at skeletal maturity should be delayed due to the fact that their curves increase more frequently than those of girls after discontinuation of bracing.¹⁵ Exercises are indicated for the period when the brace is removed.^{12,15,90} Contractures of soft-tissue around the spine progress during the period of bracing because of the immobilisation.³⁶ The final removal of the braces results in small losses of the correction in scoliotic curves, especially in the thoraco-lumbar and lumbar regions, and this may also become more severe in late adolescence.^{12,15} Night time bending braces, where the patients are held in a markedly reversed position to the curvature, show 83 % of satisfactory control of the scoliotic curvature.¹⁵ This is not yet proven in double major curves.¹⁵

If a skeletally immature patient presents with a scoliotic curvature of 30 degrees or more, bracing is indicated.^{2,12,15,30} Other researchers commence bracing as soon as the scoliotic curve exceeds 20 degrees.⁹⁰ In young patients with persistent progression, intervention by means of bracing is needed to prevent severe scoliotic curvatures.¹⁵ In unusual situations, where a young child with a significant genetic history presents with a scoliotic curvature of less than 20 degrees, in cases of boys with a progressive curve exceeding 25 degrees including those who have reached skeletal maturity, bracing will be considered for the patient.¹⁵ Regular follow-up clinical evaluations every three to four months are needed to evaluate the efficacy of the braces.¹⁵ Braces are contra-indicated when the scoliotic curve is greater than 45 degrees, when they are not tolerated by the patient, and at skeletal maturity.^{9,12} Other researchers consider bracing to be ineffective in controlling a scoliotic curve of more than 50 degrees.¹⁵ In cases where the patient presents with a flexible, well balanced spine and a scoliotic curve of 40 to 50 degrees, bracing is still considered.¹⁵ If significant hypokyphosis is present, orthosis may increase the hypokyphosis and then aggravate the scoliotic deformity.^{15,31} When patients have not benefited from an orthosis, surgery is necessary,¹² and this occurs in 10 % of patients treated in braces.¹⁵

Results with bracing for kyphosis are excellent, except when a rigid structural deformity is present before treatment commences.^{10,15,16} Kyphosis of more than 50 degrees can be treated successfully with a brace with a 40 % improvement.¹⁵ Unsuccessful treatment (failure to reduce the kyphosis to less than 45 degrees) is more likely in patients where wedging is more than 10 degrees in more than one vertebra, where the initial kyphosis is more than 65 degrees (74 degrees according to other researchers⁹⁰), and where initial treatment was started after the iliac epiphyses had closed.¹⁵ Since the apical vertebra in a typical case of Scheuermann's disease is the eighth thoracic vertebra, it is understandable why an underarm orthosis has minimal effect while the higher braces (cervico-thoraco-lumbo-sacral-orthoses) have better results.¹⁰ The brace should be worn until growth stops and then the child is gradually weaned from it.¹⁰ Excellent results can be

expected, provided the diagnosis is made promptly, the brace fits well and is worn faithfully, and treatment is continued for an adequate length of time.^{10,45} To maintain correction in Scheuermann's kyphosis, braces are worn until vertebral wedging decreases to five degrees.¹⁶ Although good initial results are obtained with braces in kyphosis, a five year follow-up study showed a significant loss of correction after the bracing was discontinued.⁸⁸

PHYSIOTHERAPY: Bentley *et al* (1994)¹² refers to previous research where it is stated that physiotherapy is ineffective to prevent progression of the scoliotic curve. Unfortunately the research articles that are referred to are old (1967 and 1979) and no mention is made of the method of research. Emphasis is on physical activity and spinal exercises to maintain flexibility of the spine.^{9,12,13}

Solberg (1996)⁹² suggests that the treatment rationale for idiopathic scoliosis should include appropriate mobilisation therapy, as well as improving imbalances between agonistic and antagonistic muscle groups associated with the spine and releasing the muscle contractures on the concave side of the spine.⁹² The lateral deviation of the spine may also reduce the ability of the intervertebral discs to distribute weight effectively and a decrease in disc height may occur. This could result in abnormal weight bearing by the facet joints and an alteration of the facet joint alignment. Therefore, one of the aims of treatment would be to encourage awareness of the use of the spine in everyday life, and to teach the application of mechanical principles of kinetic handling in activities of daily life.⁹² Individual supervision of an exercise programme for idiopathic scoliosis is recommended.⁹² Unfortunately, details of the exercise programme were not included. Only ten subjects were used, and although the researcher reports a significant improvement, no mention was made of the p value. No mention was made of the sampling method or the use of a blind researcher for the measurements of improvement. This study was done on black school children in South Africa and is difficult to compare to other international

studies due to the differences in ethnic background as well the lack of detail with regard to the trial.

According to Weiss (1992)⁴¹ the treatment of choice for idiopathic scoliosis in the United Kingdom is surgical correction, but in Germany physiotherapy is included in the treatment schedule. Exercise therapy is generally the sole treatment for patients with a Cobb angle of up to 20 degrees.^{41,93} If the angle increases, exercises are combined with an orthosis. Katharina Schroth, a physiotherapist from Germany who had a scoliosis, conceived a three-dimensional approach to the treatment of scolioses; initially to correct her own appearance, but also to apply the programme to patients later on. Currently it is the method of treatment for all patients at the Katharina Schroth Deformity Centre in Germany.^{14,41,93} Research done by Weiss (1992)⁴¹ showed that this exercise programme has improved the curvature, pain, vital capacity and poor posture.^{41,93} A retrospective study of 118 patients, making use of a sample of convenience, showed an improvement of 5 degrees or more in 43% of the patients. The researcher mentioned that significant results may have been observed if a randomised, controlled clinical trial were carried out with a control group who received no physiotherapy. The three-dimensional method is based on sensori-motor and kinaesthetic principles.⁴¹ The principle of treatment is to develop a new awareness of body image for an imbalanced posture as well as for a balanced posture, trying to develop an opposite appearance to what the scoliotic body shows.¹⁴

Weiss⁹³ hypothesises that these systematic exercises can reduce the extent of the scoliotic posture and thus have a corrective effect on spinal growth. According to a retrospective study, retrieving data from the records at the Katharina Schroth Centre multiple joint dysfunction which develops due to unilateral trunk tensioning, causes pain and can be reduced by means of the Schroth method of exercising.¹⁴ Approximately 1200 patients attend the Katherina Schroth Centre a year. Total pain relief in 85 % of the

patients was observed.¹⁴ The vital capacity increased was also improved by the exercise programme that was followed at Schroth Centre.¹⁴ A study done on 813 patients showed a significant improvement, in patients younger than 24 years, of the vital capacity and chest expansion with the help of the Schroth rotational breathing exercises. The torsion of the trunk could be reduced by means of rib movements.^{14,41,99} Rotational breathing leads to a significant increase in rib mobility and thus vital capacity; sagittal respiratory excursion is also improved and this may be of great importance in improving a flat back.^{14,42} During rotational breathing exercises, the patient learns to direct the air consciously to the concave side of the thorax and deliberately tenses the muscles on the convex regions.⁴² Unfortunately no control group was used in this study.

The laws (according to which Schroth worked) for the treatment of scoliotic curves are to assume a asymmetric starting position for exercises which could lead to reflex activation of the correcting portions of the postural muscles.⁹⁹ It is hypothesised that active side-shift of the trunk, away from the convexity of the curve, may provide an active correction of the curve by using the shift of the centre of gravity of the body.^{30,36} This movement may improve the dynamic equilibrium which is essential for a well balanced posture during locomotion.³⁶ It was found that the greater the curve, the more difficult it is to correct by means of the side-shift or asymmetrical posture.³⁶ A new movement pattern, aimed at achieving postural normality and mental re-education by means of conscious repetitive de-rotation exercises and muscle training, will later be carried out automatically and adapted into activities of daily life.¹⁴ Active stabilisation is necessary to develop a good body shape, and to avoid passive support by the spinal ligaments only.¹⁴ This is achieved by isometric exercises in the corrected posture.¹⁴ Each scoliotic person has to continue exercising throughout life. During the first period of treatment with the Schroth exercise programme the patients have to exercise for six to eight hours per day.^{41,42} Patients are educated in doing home exercises and are monitored at regular intervals.⁴¹ Passive corrections by means of cushions, achieved in a relaxed position are also used to assist in

the proprioceptive re-education.⁸³ Braces help to support the obtained corrections.^{14,41} These are evidence based outcomes.

According to the research done by Weiss (1992),⁴¹ curves of less than 19 degrees tended to progress less than curves of 20 - 29 degrees and those of more than 30 degrees when treated by means of the Schroth method. The curves of 20 to 29 degrees progressed most when treated only with exercises.⁴¹ Subjects were not randomly selected and there was no control. The researcher stated that it is unethical to withhold physiotherapy from scoliosis patients in Germany.⁴¹

Some researchers feel that early physical therapy could prevent severe progression and avoid surgery⁸⁹, while others show that the mean curve improvement between patients who followed an exercise programme, and those who did not exercise, is non significant.⁹⁰ These exercises were mainly pelvic tilt exercises in different positions, back extension and trunk lateral shift exercises.⁹⁰ Weiss (1992)⁹³ hypothesises that an exercise programme should be implemented to filter out patients who may benefit from rehabilitation programmes, before surgery is attempted.

In pre-adolescent children with kyphosis, exercises may be sufficient to correct the deformity.¹⁵ Other researchers state that exercises alone cannot improve the curve.⁴⁵ Back extensor muscle strength is important in the maintenance of good posture.⁹⁴ Sinaki *et al* (1996)⁹⁴ significantly proved in a study done on 65 volunteers that an increased strength of back extensors seems to decrease the thoracic kyphosis, but it could increase the lumbar lordosis. If the exercises commonly used for improving back extensor strength are not used in combination with exercises for decreasing lumbar lordosis, the increased lumbar lordosis will decrease the efficacy of extension exercises.⁹⁴ Unfortunately this was not a randomised controlled trial.

2.2.4.2. SURGERY:

Surgery for idiopathic scoliosis is indicated when conservative treatment, to control the curve progression in a growing child or in an adolescent with marked cosmetic deformity and trunk asymmetry, is unsuccessful. Surgery is also advocated if a curve, greater than 50 degrees before skeletal maturity, is present.^{9,30} Other researchers consider surgery when a 40 degrees curvature is reached in skeletally immature patients,^{2,15} and when a curvature of 50 degrees is reached in a skeletally mature patient.² A scoliotic deformity associated with pain is also considered for surgery.³⁰ The aim of surgery is to correct the deformity as much as possible, to stabilise the spine and to achieve alignment of the shoulders, upper trunk and pelvis.⁹ Complete correction of an asymmetric deformity, notably the ribs, is very difficult.⁹ The presence of severe thoracic lordosis prevents the use of braces and these patients are also treated surgically, regardless of the angular value of the scoliosis.¹² Mullaji *et al* (1994)⁹⁴ observed that a mean progression of 4 degrees of the Cobb angle (of the scoliotic curve) occurred after a successful posterior fusion, but there is little change in the kyphosis. This showed that there was a significant anterior vertebral growth in 30 skeletally immature patients, but the progression was not severe enough to warrant combined anterior and posterior fusions.⁹⁵ No randomised controlled trial was done and no mention was made of any blind researcher that was used to do the Cobb measurements.

Surgery is not needed in cases of flexible Scheuermann's disease, but it is indicated in late adolescence and young adults who have both pain and a significant deformity.¹⁰ About 5 % of patients with Scheuermann's disease, who receive conservative treatment after observation, will require surgical correction and stabilisation. Surgery is done in cases where the curve exceeds 75 degrees in adolescents.⁴⁵

SUMMARY: No evidence of a significant improvement with any of the conservative methods of treatment of a spinal deformity was found. In idiopathic scoliosis, increase of the curve is prevented by means of conservative treatment, but the curve is not reversed. Surgery is the last resort in cases of severe deformities, as it affects the quality of life negatively due to the rigidity of the spine after surgery.

2.3. POSTURE

What are the factors that influence normal posture and how does posture affect the spinal column?

Posture is the position or attitude of the body and the relative arrangement of body parts for specific activities.⁹⁶ The erect posture places a considerable strain on the structures of the vertebral column. The central nervous system maintains the postural equilibrium by means of a complex system of reflexes and muscular controls.⁹⁷ Postural tone depends largely on the stretch reflex in the extensor muscles of the trunk. The stretch reflex acts so that any external factor which brings the body out of equilibrium, will stretch the appropriate extensor muscles and their spindles, inducing a contraction in the stretched muscles and thus restoring the body to its position of equilibrium.⁹⁸ The integration of the sub-systems of the neuromusculo-skeletal system is important for the stability and the normal functioning of the lumbar spine. This involves stability under static and dynamic conditions.^{99,100} Dynamic stability requires muscular tension and co-ordination. A balance between agonistic and antagonistic muscle groups must exist and normal proprioception is essential for this muscular co-ordination.^{23,99} As muscular fatigue occurs, there is a decrease in control of primary movement (movement in the sagittal plane), leading to altered spinal kinematics and resulting in dysfunction.⁹⁹ Muscles of the trunk

are active whether an individual is sitting, standing, lifting or rolling.¹⁰¹ The infant must be able to maintain a static upright posture and compensate for sway associated with walking.¹⁰² A good posture consumes minimal energy and does not stress joints, musculature or connective tissue. A poor posture may very easily progress to a postural disorder such as kyphosis, lordosis or scoliosis.¹⁴

2.3.1. THE DEVELOPMENT OF POSTURE

The vertebral column of the new-born has primary thoracic and sacral curves which are concave to anterior. At about three months of age, the baby begins to hold its head up and, in association with this, a secondary curve appears in the cervical area which is convex to anterior.⁹⁷ Postural responses develop in a cephalo-caudal direction, with the neck muscle responses appearing first (four months), followed by trunk muscle responses (five to eight months) and leg muscle responses (ten to fourteen months), coinciding with the developmental stages of voluntary control.^{102,103} Postural control matures at an age of between seven to ten years.^{13,104}

As babies begin to sit they adopt a total kyphotic posture which is a normal phase of spinal development.³² As the ability to sit improves, the cervical and lumbar lordotic curves appear and these curves are controlled by the postural muscles of the vertebral column. These secondary curves may fail to develop at the expected time should there be any delay in the development of the postures of sitting and holding the head up.⁹⁷ During the creeping stage, the centre of gravity is supported in a very stable manner by this quadrupedal posture, but as soon as the infant rears him/herself, an unstable stance due to the higher centre of gravity occurs.⁹⁷ Many children from the age of one to five years go through a temporary period where they stand with a marked lordosis. This should cause no concern unless the lordosis persists or worsens, especially towards the pubertal growth

spurt; however, this lordosis usually resolves itself.^{32,97} Numerous children adopt a “bad” posture when sitting, usually a complete kyphosis. Some children adopt a lumbar lordosis during standing, others a thoracic kyphosis and some a combination.³² If poor posture persists or deteriorates and becomes less reducible, it becomes necessary to do special tests to identify the possible start of a structural kyphosis or lordosis.³²

A most important factor in posture is the tilt of the pelvis in relation to the horizontal. The pelvic tilt is determined by the postural pull of the muscles of the back, abdomen, and thighs, and these forces are in turn influenced by the way the individual habitually stands. An over exaggerated upright posture will increase the anterior tilt of the pelvis, carrying the lumbar spine forwards and with it, the centre of gravity.⁹⁷ If this posture is routinely held, the muscles which have pulled the pelvis out of position, may shorten and their antagonists lengthen. Theoretically in the case of a slack posture the pelvic tilt will decrease and the centre of gravity will pass backwards, increasing the thoracic kyphosis and causing neck extension with a poking chin.⁹⁷

All muscles contribute to postural control, but the deep muscles with attachments to the vertebrae appear to have a specific role for joint support.¹⁰⁵ The trunk extensor and the muscles of the abdominal wall muscles control trunk stability.^{93,106,107,108}

2.3.2. POSTURAL CONTROL

Postural control involves adjustments by means of voluntary movements to control the body in cases of equilibrium disturbances.^{109,110} Afferent inputs trigger a specific muscle activation pattern. This pattern is modulated by somato-sensory, visual and vestibular input.^{102,108} Training or motor learning can accelerate postural control.^{19,104,108} The position

of the trunk, specifically the lumbar spine, plays an important role in the central nervous system's control of posture.¹⁰ A stable posture is essential before the onset of locomotion.¹⁰²

The upright posture requires an elaborate extensor musculature to support the body against the forces of gravity. The vertebral column is exposed to new patterns of force by means of different weight distributions and muscle tension. A narrower base needs an intricate system of balance reactions, and the trunk is the foundation for such a mechanism.¹⁰⁶

The spinal stabilizing system consists of three sub-systems: the passive musculoskeletal sub-system (vertebrae, facet articulations, intervertebral discs, spinal ligaments and joint capsules), the active musculoskeletal sub-system (muscles and tendons surrounding the spinal column) and the neural and feedback sub-system.¹¹⁰ Dysfunction of the spinal stabilizing system occurs when there is malfunctioning in any of these sub-systems.¹¹⁰

Motions of the head, relative to the trunk, are primarily directed towards orientating and stabilizing the position of the eyes and head in space.¹¹¹ Tilting of the head and body would elicit the vestibular reflex and activate proprioceptors in the neck muscles to bring the head toward an upright position.¹¹¹ The activation of muscle patterns for motor control of the head is dependent on previous experience of the head-neck motor system.¹¹¹ Vision plays a more important role in novel situations of postural control, such as learning to stand, while vestibular inputs serve a referential function and are critical in resolving conflict between somatosensory and visual inputs.^{10,103,104} Removal of the visual cues could, however, increase the sensitivity of the proprioceptive and vestibular cues.¹⁰⁴

2.3.3. POSTURAL DYSFUNCTION

Panjabi (1992)⁹⁶ hypothesises that postural fault takes place when there is a deviation from the normal alignment but no structural changes have taken place. Postural dysfunction refers to an adaptive shortening of involved soft tissues and muscles.⁹⁶ The postural theory according to Soderberg (1986)⁵¹ notes that the spinal column is a matter of balance between the antero-posterior curvatures of various areas of the spine. The greater the lordosis, the greater the thoracic kyphosis and even the cervical lordosis, in order to balance the vertebrae. In a lordotic posture there is tightness of the hip flexor and lumbar extensor muscles, whilst a flat low back posture has tight trunk flexor and hip extensor muscles, and elongated and weakened lumbar extensors and hip flexors. According to this theory the postural round back or increased kyphosis has a tight anterior thorax and stretched or weak thoracic erector spinae and scapula retractor muscles. The development of a scoliosis shows a tendency towards tightness on the concave side, and a stretched and weak convex side.⁹⁶

The psoas muscle, extending from the upper lumbar spine to an insertion on the lesser trochanter of the femur, has a complex function due to multiple segmental attachments. The muscle is draped over the anterior rim of the pelvis, providing a mechanism to alter the position of the pelvis. Upward and downward tilting of the anterior rim of the pelvis is directly related to the degree of flexion and extension in the lumbar spine. Thus tightness of the psoas muscle pulls the anterior rim of the pelvis inferior, causing a downward or anterior tilt. The sacrum is now inclined further forward and the fifth lumbar vertebra is more anterior, thus increasing the lumbar lordosis.⁵¹ The sensory input received from the position of the trunk, specifically the lumbar spine, together with other sensory and proprioceptive motor systems, is important for the central nervous system during the control of posture.⁵¹ No explanation as to how these biomechanical and neural statements were arrived at was given.

Herman *et al* (1985)¹⁹ postulated that due to the organisational pattern of the descending motor pathways controlling the symmetrical actions of the musculature, it is conceivable that functional changes in vertebral alignment will be created. This is possible due to altered positive feedback of somato-sensory information to the brainstem or cortical structures, and/or by modified perceptual analysis of sensory data during the interpretation of erect vertebral alignment. Defective proprioceptive inputs from the joints, ligaments and tendons, to the neural mechanism, has been implicated as a possible aetiological factor of idiopathic scoliosis.^{20,21,23} Other researchers¹¹² postulated that the neurotransmitters or neurohormonal systems in the pineal body, are major contributing factors for the balanced and symmetrical development of proprioception and paraspinal muscles. The unbalanced proprioception between left and right sides will lead to inappropriate and asymmetrical contraction of multifidus. This asymmetry will eventually cause the spinous processes to rotate towards the unaffected side.¹¹² Altered perception of proprioceptive signals from the axial motor system is a likely feature of idiopathic scoliosis and may contribute to postural instability during dynamic activities.¹⁹ Visual and vestibular information also converge upon the brainstem and cortical structures, causing impaired integration and disturbance in the orientation of the vertebral spine and in postural stability.¹⁹ Researchers²⁰ determined that idiopathic scoliosis may therefore represent a specific impairment of the higher cortical functions. This study was conducted on 26 female patients with idiopathic scoliosis and showed that there was a statistical positive correlation between brainstem function and curve progression.²⁰ The trial was not randomised and there was no control group. Yekutieli *et al* (1981)²¹ also suggest that the muscle spindle system may be at fault in adolescent idiopathic scoliosis, and support the hypothesis that equilibrium reactions may be abnormal.

SUMMARY: There are a variety of factors which influence normal posture. The central nervous system and the musculature work together to obtain postural stability. Postural control and normal spinal curvature develop, and voluntary control matures during normal developmental milestones of a baby and child. Malfunction of the postural control system can lead to the development of spinal deformities.

2.4. NEUROMOTOR DEVELOPMENT

Normal new-born babies have considerable sensory capabilities with which to experience the world. Primitive reflexes form the basis for future learned behaviour. The proper sequencing of motor events is required, so that primitive reflexes disappear before voluntary activities begin. At the age of four months, reflexes disappear and actions become more voluntary.¹¹³

The literature review of neuromotor developmental theories is limited to possible factors that may influence spinal deformities.

2.4.1. NORMAL DEVELOPMENTAL MILESTONES

What are the specific neuromotor developmental milestones which babies should achieve at certain ages?

Certain age ranges at which a specific skill is attained, have been indicated from studies of normal development. The later some skills appear, the shorter the interval between two subsequent developmental stages. Normal developmental skills are attained over a wide age range.²⁵ The passage through specific developmental phases seems to be a prerequisite for well organized psychomotor development, and its absence could lead to deficits.²⁴

The spine is relatively straight in the new-born except for two flexion curves; a shallow thoracic curve with its apex located at the fourth to sixth thoracic levels and gently sloping to the seventh cervical vertebra, and a flexed sacro-coccygeal area. In the spine, extension as well as lateral and rotational ranges of motion are limited. Spinal mobility increases rapidly during the first six months of life. Limited hamstring length and hip capsule tightness are also present.¹¹⁴

2.4.1.1. SITTING

Head righting develops gradually from birth and is only fully complete by the end of the fifth month. Until then, when a baby is pulled up into the sitting position, the head remains unstable and lateral head control cannot develop.¹¹⁴ Lateral flexion righting of the trunk can be elicited by five months.¹¹⁴ By six months of age a baby has sufficient postural tone to maintain many postures against gravity.¹¹⁴ A great variety of sitting postures can be observed as each baby is unique with regard to postural control, control of balance and preferred patterns of postural alignment. Some babies tend to keep their centre of gravity forwards over their hips, while others have a more flexed spine resulting in the centre of gravity to be displaced posteriorly behind the pelvis.¹¹⁴

Complex postural responses are necessary before a baby can sit independently.^{108,115} Although a baby can sit independently by the age of six to nine months, total postural control in sitting continues to develop. In the normal development of postural adjustments during sitting, three phases can be distinguished. The first phase is the primary variability phase, which is characterised by a large variation in direction-specific postural responses, and cannot be adapted to task-specific conditions. This phase starts at a pre-sitting age

and lasts until nine to ten months.¹¹⁸ The posterior muscles for postural control mature earlier than the anterior muscles. This leads to a temporary solution for balance problems by using a fixed extensor synergy when starting to stand and walk.¹¹⁵ The second or transient toddling phase is typified by the invariant use of complete direction-specific response patterns and a relative high level of antagonist activation. The focus of adaptation lies close to the support surface and affects the caudally located muscles most. This phase extends from nine to ten months until two and a half to three years. During the third or the secondary variability phase, variations in the direction-specific response patterns return. The postural adjustments are less energy-demanding and consist of variable activation of agonistic and antagonistic postural muscles. The focus of adaptation is now located in the neck muscles. This phase starts at two and a half to three years and continues into adulthood.¹¹⁶

At the age of six months babies sit without assistance, but are not yet independently mobile.^{102,113} This is also the age at which babies reach across the midline.¹¹³ This ability, to cross the midline, enables the infant to integrate the two symmetrical halves into a composite whole.²⁸

Postural synergies active in controlling the sitting position, include the erector spinae, abdominals, hip extensors and sometimes the hip flexors. At the age of seven months babies can sit independently with their hands free to play. They can maintain a more erect trunk for longer periods, with a more stable pelvis and improved control of weight shift.^{25,114} Although lumbar extension has developed in prone, the lumbar spine is not held in extension during sitting until much later, when the baby develops the ability to control the entire trunk in an upright position.¹¹⁴

2.4.1.2. CRAWLING

The quadruped position can be attempted by seven months. By eight months the baby develops sufficient shoulder girdle, trunk and pelvic control to rotate from sitting to quadruped. During the next few months postural control and co-ordination will improve. Some babies will crawl at nine months, but most are ready to crawl by ten to eleven months.¹¹⁴

During this stage there are five locomotor sequences that may develop. Eighty two percent of infants are crawlers. Other ways of locomotion observed by Robson (1984)²⁵ are shufflers (9 %), creepers (1 %), rollers (1 %), while 7 % of the infants stood up and walked without any other preceding form of locomotion.²⁵ Some infants have short lived hypotonia which prevents them from being standard crawlers, and they use other methods of locomotion. They also achieve their other milestones at a later stage than normal crawlers. This hypotonia usually resolves at an age of two to three years.^{24,25,117}

Crawling on hands and knees is the major pre-standing locomotion activity, appearing after a short period of creeping or rolling.²⁵ There is a large variability of normality, and consequently the possibility exists that infants with motor strategies other than creeping and crawling, may also develop normally.²⁴

Bottos et al²⁴ found that at an age of five years there was no asymmetry in motor activity of children who crawled as babies. Children who shuffled or just stood up and walked did show asymmetry in their motor activities. Hypotonia in the central trunk is related to the choice of locomotion before walking.

The process of crawling provides a state of eye-hand co-ordination, vestibular processing, improvement of balance and equilibrium, spatial awareness, tactile input and kinaesthetic awareness.²⁸

2.4.1.3. WALKING

The most fundamental motor skill in humans is the maintenance of upright posture and bipedal locomotion. Humans do not acquire sufficient postural control to stand upright and walk until the last month of their first year.¹⁰²

The child's ability to maintain an upright posture becomes more efficient and functional during the last trimester of the first year. The lumbar spine extends through a greater range and the normal curve of the spine is seen more consistently, providing mechanical and muscular stability for postural alignment.¹¹⁴ Standing, while holding onto something stable, starts at nine months, but children demonstrate the ability to walk unsupported at about one year.^{113,118}

The ten to twelve month old baby explores the surroundings in more upright positions.¹¹⁴ Although some babies walk as early as nine months and others as late as seventeen months, most babies walk by the end of their first year.^{114,118} Children who do not walk by eighteen months are usually evaluated for possible causes of developmental delays.¹¹⁸ During the first year of life the centre of weight moves closer to the legs, and this increases the efficiency of locomotion. Strength of the limb and trunk muscles increase for support, and a balance between flexor and extensor muscle groups develops. Control of posture and balance are important factors in the process of learning to walk.¹¹⁸ From three years onwards, once the child has mastered walking skills, the fixed extensor synergy is discarded, and postural adjustments affect anterior muscles more than posterior muscles.¹¹⁵

2.4.2. OTHER FACTORS THAT INFLUENCE DEVELOPMENT

Abnormal balance, the presence of a motor problem and abnormal minor neurological problems are more significant in low birthweight babies.^{113,120} Boys are more frequently affected than girls.¹²⁰ Impaired balance may inhibit children's play activities and consequently their development.¹²⁰ Negative environmental influences such as poverty, abuse and neglect place infants at risk for developmental delays.¹¹³

2.4.2.1. LYING POSITIONS

An infant is born with mechanisms which provide some motor control in the early months. One of these mechanisms is an imbalance between flexor and extensor muscle tone, so that flexor tone dominates, contributing to an overall flexed posture of the new-born infant.¹¹⁴ Voluntary kicking movements of infants in the supine position are associated with simultaneous activation of agonist and antagonist muscles.¹¹⁹ The movements of a baby are related to its level of arousal, gestation age and position in which it is nursed. Babies are more active when in supine than in prone.^{114,121} Babies who lie supine are rarely symmetrical, but slightly tilted to one side.^{114,121} By the end of the fifth month movements in supine become more symmetrical.¹¹⁴ Weggemann *et al* (1987)¹²¹ found that babies moved their heads more frequently to a preferred side when in supine than in prone, and showed a tendency towards asymmetry and a possible risk of positional deformity. Posterior pelvic tilting and an increase in the length of the hamstrings were also observed by the fifth month as the baby began to reach for his/her feet¹¹⁴.

Prone encourages symmetrical positioning. The low incidence of idiopathic infantile scoliosis in North America, and the higher incidence in Britain, has been attributed to the increased use of the prone sleeping position in North America.¹²¹ Even in prone,

asymmetrical extension is used to turn the head to one side in the early stages (one to two months). By the end of the second month the infant can lift the head symmetrically.¹¹⁴ In prone the pelvis of the baby is lifted off the surface due to the flexed posture, causing the centre of gravity to be more cephalic.¹¹⁴ The contour of the low back also changes from relatively flat at birth, to concave posterior by the end of the fifth month, with increased activity of the erector spinae and multifidus muscles in prone.¹¹⁴

Lying on the right or left sides is also likely to cause trunk asymmetry, but is the best position for open airways.^{114,121}

Other researchers found that sleeping positions significantly influence the age of achieving the gross motor developmental milestone of rolling over. Infants who sleep in the side or supine position, roll over later than infants who sleep in the prone position.¹²² At about four months the baby plays with his/her feet, but can lose control over the symmetry, causing him/her to roll over. Soon the baby will begin to use abdominal muscles, including the obliquus abdominus, to control some of the pelvic movements.¹²²

2.4.2.2. FREEDOM TO MOVE

Over protective parental behaviour leads to limited freedom of movement granted to the child, with consequent conditioning of locomotor choices of the parent and limitation of locomotion experience of the child. The infants have to move according to the choice of the parent.²⁴ Bottos et al (1989)²⁴ feel that babies should be allowed to move freely on the ground during the first year of life, so that they may choose their own locomotor strategies.

2.4.2.3. DEVELOPMENTAL COORDINATION DISORDERS

The terms “clumsy” or developmental co-ordination disorder, are often used to indicate that a child’s performance of daily activities which require basic motor co-ordination, is below the expected age and intelligence levels; but the child is otherwise normal. It is hypothesised that these motor-control difficulties may be related to subtle central nervous system dysfunction and not to developmental delays.^{123,124} Previous findings suggest that the subtle central nervous system dysfunction most often manifests itself as an inability to organise and execute voluntary movements consistently. This motor-control deficit is frequently observed in tasks that require functional asymmetry, both gross motor as well as fine motor skills.^{123,124,125}

SUMMARY: Although there is a wide age range in which to achieve certain developmental skills, it is important that these skills must develop before a certain age. The developmental skills or milestones have an influence on the development of a normal spine. Asymmetry in the development of skills may also influence the development of spinal deformities.

2.5. SUMMARY OF LITERATURE REVIEW

Idiopathic scoliosis and Scheuermann’s kyphosis are both conditions which cause a structural deformity of the spine. Evidence of one specific aetiological factor could not be found in the literature. It is clear that idiopathic scoliosis and Scheuermann’s kyphosis are multifactorial diseases. Growth, hereditary factors, gender and posture appear to be the most important aetiological factors.^{1,2,5,7,8}

The central nervous system and the musculature work together to obtain postural stability.¹⁸ Postural control, normal spinal curvature and voluntary movements occur during the normal developmental milestones of a baby and child. Although specific developmental skills can be attained within a wide age range it is important that these skills must develop before a certain age. Asymmetry in the development of motor skills could also influence the development of spinal deformities.²⁴

Current treatment methods do not result in the correction of deformities, but reduce the progression of the deformities.

There are various gold standards for the evaluation of spinal deformities. Non-invasive methods are not as accurate as radiographs, but are effective for the screening of deformities. Boachie & Lonner (1996)² recommend a review of the birth history, developmental history and childhood illnesses. Although not researched, they suggest that abnormal developmental milestones may lead to spinal deformities. The above mentioned statement motivates the necessity for this study. In the following chapter the research methodology for this study will be described.

CHAPTER 3

RESEARCH METHODOLOGY

3.1. INTRODUCTION

It was clear from the literature review that it would be unethical to use radiographs for this study due to the inherent dangers. A variety of methods for the evaluation of deformities were found in the literature. However, even the gold standard methods showed variations from one researcher to another. Therefore it was decided to make use of non-invasive methods, found to be effective for the screening of deformities, in this study.

ETHICAL CONSIDERATIONS: The protocol was submitted to and approved by the Ethics Committee of the Faculty of Health Science of the University of Pretoria.

3.2. STUDY DESIGN

A case-control study was conducted in Middelburg, Mpumalanga. Adolescents with spinal deformities were compared to adolescents without spinal deformities, with regard to their developmental milestones as babies and other variables which may have contributed towards the development of spinal deformities.

3.3. STUDY POPULATION

All adolescents, male and female, between the ages of twelve and seventeen years, who attended any of the schools in Middelburg, Mpumalanga, were considered part of the total population. The schools were:-

- Dennesig Primary School
- Kanonkop Primary School
- Middelburg Primary School
- CR Swart Primary School
- Kanonkop High School
- Steelcrest High School
- Middelburg High School
- Middelburg Technical High School

3.4. SAMPLING

The sampling frame was pupils from the community who complied with the criteria and volunteered to participate in the study. The sampling was done in the following way:

The school principals in the town of Middelburg, Mpumalanga, were approached for permission to give a lecture on back deformities at each relevant school. This lecture was given to all scholars, aged between twelve and seventeen years, at the specific schools (Appendix A).

Permission was also obtained to hand out an information letter on common spinal deformities (Appendix B) to this group of scholars. The letter had to be given to the scholars' parents. They were also informed about the research study being undertaken in Middelburg, Mpumalanga, in which they could voluntarily participate. No costs would be incurred. The fact that this research

would not harm the children in any way, was also explained. The parents were asked to either return the completed volunteer form to the school, or to telephone the researcher. A form granting consent to allow their children to participate in the study, was also attached. Unfortunately two schools did not have the available time for a lecture, but permission was granted to hand out the information letter. Three thousand five hundred letters were distributed to the schools.

All the volunteer forms were collected from the schools by the researcher. Appointments were made by the researcher to meet with the volunteer and his/her mother. All volunteers were included in the study if they complied with the inclusion criteria. A sample size of one hundred and four subjects was obtained. There were sixty one who complied with the inclusion criteria for the cases, and forty three who complied with the inclusion criteria for the controls.

3.5. SAMPLE CRITERIA

EXCLUSION CRITERIA

- Any congenital deformities of the lower limbs, chest or vertebrae
- Any abnormal locomotion such as the permanent use of crutches or a wheel chair
- Any leg length discrepancy of more than ten millimetres⁴
- Previous fractures of vertebrae
- Any spinal deformity of neurological origin
- Any chronic lung disease such as cystic fibrosis, or tuberculosis
- Previous thoracic surgery

INCLUSION CRITERIA FOR CASES

All adolescents who were diagnosed with a spinal deformity by means of postural observation and the physical evaluation (refer to 3.6.2.) of hump size, angle of rotation, deviation from the midline, and kyphosis/lordosis measurements.

INCLUSION CRITERIA FOR CONTROLS

All adolescents who did not present with a spinal deformity according to postural observations and the physical evaluation (refer to 3.6.2.) of hump size, angle of rotation, deviation from the midline and kyphosis/lordosis measurements.

3.6. RESEARCH PROCEDURE

When the subjects and their mothers arrived for their appointments at the physiotherapy practice, they were informed of the research procedures. The informed consent form (Appendix C) was handed to the mothers. Time was allocated for the mothers and subjects to read the informed consent form. Any questions were answered by the researcher. The subjects and their mothers were then asked to sign the informed consent form, if they agreed to participate. Each of the subjects was provided with a pair of shorts to wear. The females also wore halter-neck tops with thin straps, so that the back would be bare. (Figure 1). The physical examination was then started.



Figure 1: Subject dressed in a pair of shorts and halter-neck top

3.6.1. DESCRIPTION OF INSTRUMENTS

- **EXAMINATION ROOM:**

The same examination room was used for all subjects. The examination couch was solid with hard upholstery. Good overhead lights were available to ensure accurate readings.

- **INCLINOMETER:**

(Baseline digital inclinometer / Saunders electronic inclinometer)

The digital inclinometer (Figure 2) is a portable, hand-held inclinometer designed to measure posture and mobility of the spine. The inclinometer has a liquid crystal screen that shows a digital display of its position. All readings are displayed in degrees and no calibration is needed. There are three buttons on the face of the inclinometer: ON/OFF, ALTERNATE ZERO and HOLD. The inclinometer has two sides, a long base and a short base. The inclinometer can be zeroed in any position by pressing the alternate zero ("Alt Zero") button. The digital display then shows a zero. The reading in the following position will be a reading relative to the zero. The hold button can be pressed to show the reading of the inclinometer in the new position. The inclinometer is powered by a standard nine volt battery, and is not affected by the time of day, normal temperatures or general humidity.



Figure 2: Baseline digital inclinometer

- **MEASURING CANE:**

A metal measuring cane was fixed to the wall. Care was taken that the height was exactly correct. The measuring cane was graduated in centimetres and millimetres.

- **TAPE MEASURE:(Figure 3)**

A new standard, flexible tape measure graduated in centimetres and millimetres was

used. The length of the tape measure was one hundred and fifty centimetres.



Figure 3: Measuring tape, spirit level and metal ruler

- **SKIN MARKER:**

A black Artline superfine point marker was used.

- **SPIRIT LEVEL:(Figure 3)**

A plastic spirit level of twenty five centimetres length, was used.

- **PLUMBLINE:(Figure 4)**

A thin string with a lead weight was fixed to an overhead arch.

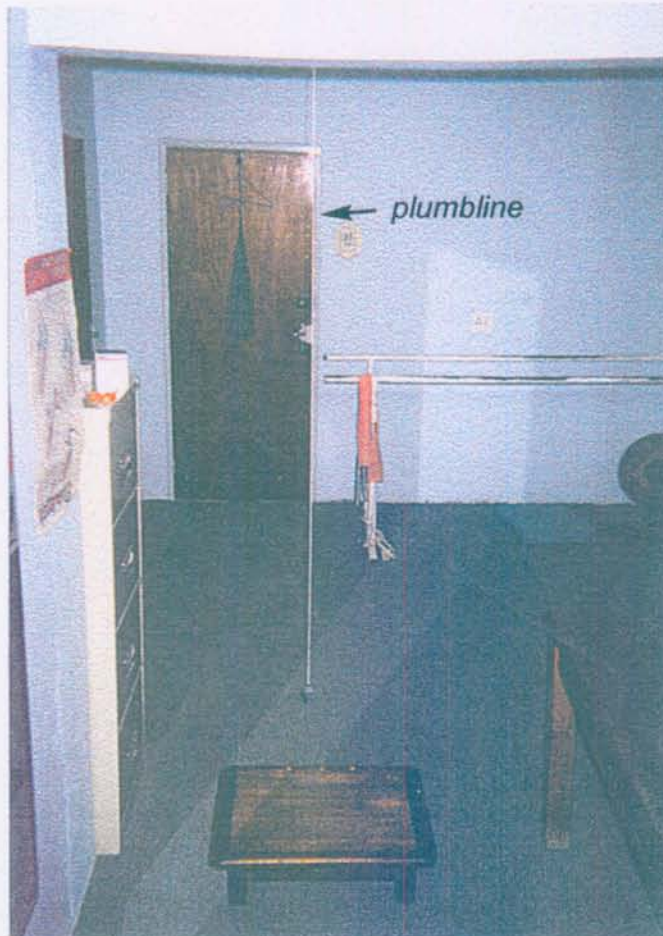


Figure 4: Plumbline

3.6.2. PHYSICAL EXAMINATION

(Evaluation form: Appendix D)

All subjects were dressed similarly: (Figure 1)

MALES: Loose fitting running shorts without shirts and barefoot.

FEMALES: Loose fitting running shorts and halter-neck tops with thin straps, so that the back was exposed.

SUBJECTIVE INFORMATION:

- ◇ **Age:** The age of the subject was noted in years and months.
- ◇ **Gender:** The gender of the subject was noted.
- ◇ **Age of menarche:** In the cases of females the age of menarche was noted in years.

OBJECTIVE EVALUATION:

All measurements were done three times and the mean was determined.

- ◇ **Height:** The subject was requested to stand with his / her back against a fixed measuring cane. His / her heels had to be against the wall (or as close as possible) and his / her feet had to be together (or as close as possible). A spirit level was placed on the head of the subject to eliminate faulty parallax. The height of the subject was noted in millimetres.(Figure 5)



Figure 5: Measurement of height

- ◇ **Leg length discrepancy:** The subject was asked to lie supine on the examination bed. The pelvis was levelled by placing the iliac crests on a straight line. The tips of the anterior superior iliac spines were palpated and marked with a pen. The tips of the medial malleoli were palpated and marked with a pen. A standard tape measure was used to determine the distance between the anterior superior iliac spines and the medial malleolus. The same procedure was followed with the other leg. Any difference between the two legs, was noted.
- ◇ **Straight leg raise:** The subject was asked to lie supine on an examination bed. The greater trochanter of the femur was palpated and marked with a pen. The lateral condyle of the distal end of the femur was also marked with a pen and these two points were joined by a line alongside the shaft of the femur. The zero of the inclinometer was determined level to the examination bed. The heel of the relevant leg was placed on the researcher's shoulder and the knee was stabilised in extension with one hand. The leg of the subject was raised by means of the researcher's shoulder, while her other hand maintained the inclinometer alongside the shaft of the femur. The opposite knee of the subject was stabilised by means of the researcher's other knee. The leg being measured was lifted to a level where the onset of tension in the hamstring or calf muscles was felt by the subject. Care was taken that no pelvic rotation took place. A reading on the inclinometer indicated the degrees of hip flexion during straight leg raise and this was noted. The same procedure was followed with the opposite leg. (Figure 6)

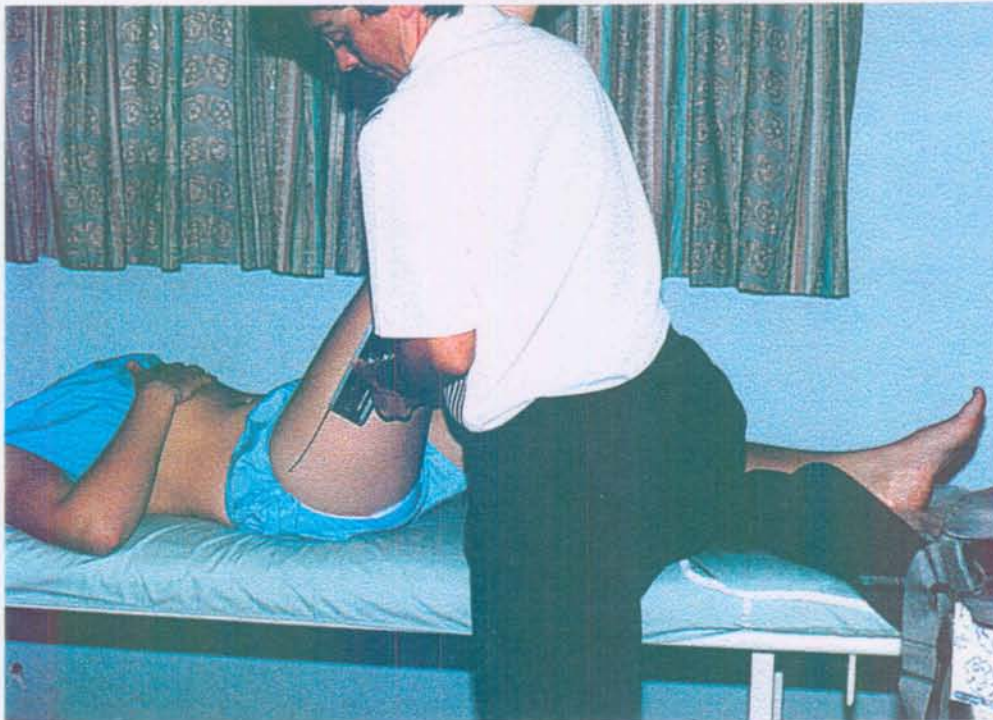


Figure 6: Measurement by means of straight leg raise

- ◇ **Degrees of hip flexion tightness:** (Thomas test)⁵³ With the subject still in supine, the inclinometer was zeroed on the level of the examination bed. The subject was requested to flex one hip and knee and to pull the knee onto his/her chest to the end range of movement. The level of the examination bed was used as the zero level for the inclinometer. The inclinometer was placed alongside the shaft of the opposite femur, and a reading on the inclinometer noted. This indicated the degrees of hip flexion contracture. (Figure 7)

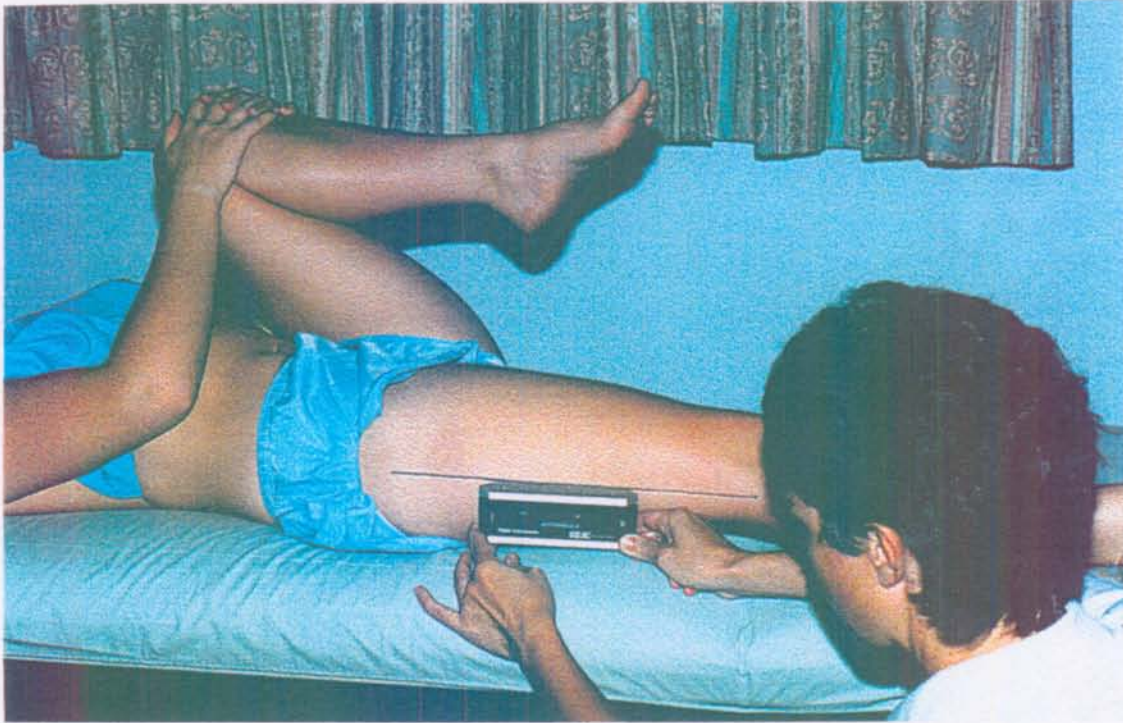


Figure 7: Measurement of hip flexor tightness

- ◇ **Hump size:** The subject was asked to stand with feet in line with the hips. The toes were placed on a straight line. A mark was made on the floor midway between the two big toes. The subject was requested to place the palms of the hands together and to direct them towards the mark on the floor, placing the chin on the sternum. In this way active trunk rotation was prevented. The subject was asked to flex the trunk up to ninety degrees, pointing the fingers towards the mark. The subject was observed from posterior. The spirit level was placed transversely across the spine in the thoracic area (Figure 8). The spirit level was maintained while a measurement, using a metal ruler graduated in millimetres, was taken. The point where the spirit level was placed, and the point at which the measurement by means of the ruler was made, had to be exactly the same distance from the spine. The same measurement was taken in the thoraco-lumbar region and the lumbar region. The difference in millimetres as well as the side of the hump, was noted.

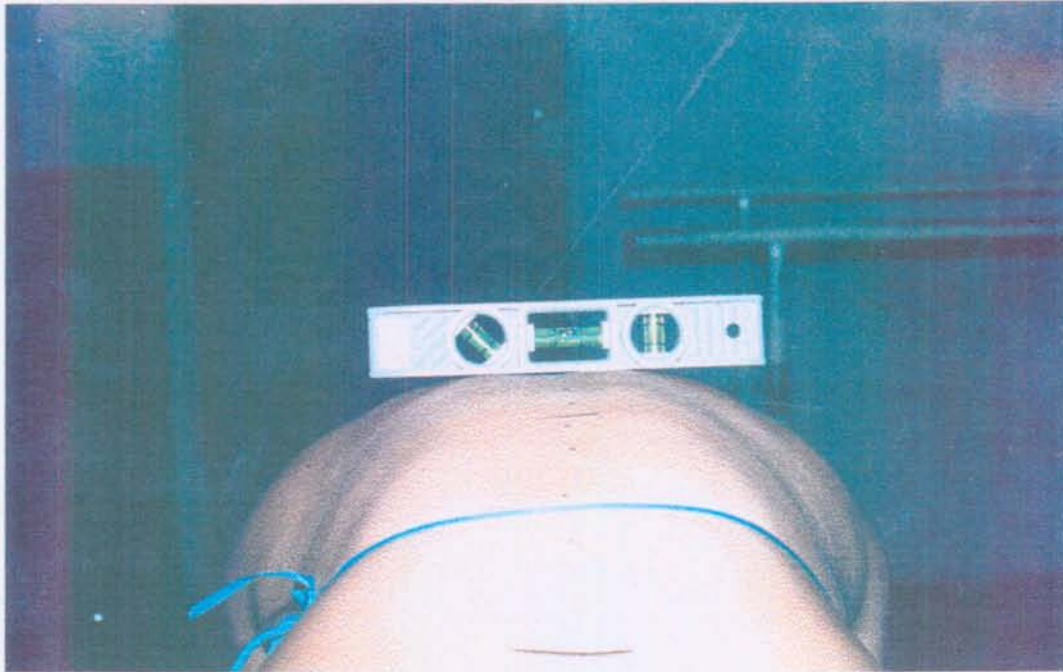


Figure 8: Measurement of hump size

- ◇ **Angle of trunk rotation:** The rotational prominence or angle of trunk rotation was measured by means of the inclinometer. The subject was requested to stand with the feet in line with the hips. The palms of the hands were placed together and directed to a mark midway between the two big toes and the chin flexed to the sternum. The subject was requested to flex the trunk to ninety degrees. The most prominent part of the hump was measured by means of the inclinometer. The inclinometer was zeroed on a spirit level placed horizontally and then placed across the spine from the hump to the same level on the opposite side of the spine. Any angle was noted. (Figure 9)

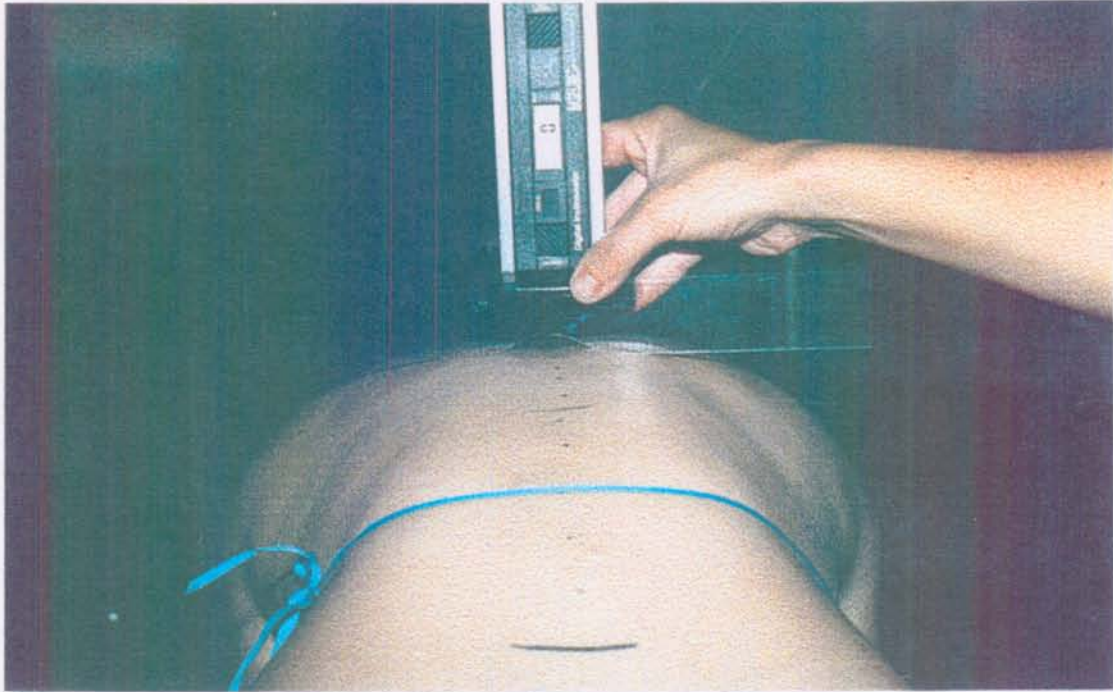


Figure 9: Measurement of trunk rotation

- ◇ **Plumblines:** The subject was asked to flex forwards in the same way as described previously. The tip of the spinous process of each vertebra, or as close as possible to the tip (in cases where rotation was advanced), was marked with a pen. The subject was asked to stand erect after the markings were completed. A plumblines hanging from the ceiling, was used. The patient was positioned so that the seventh cervical vertebra was aligned with the plumblines. (Figure 10) If there was a deviation of the spine from the plumblines, the distance from the gluteal cleft to the plumblines was measured with the graduated ruler. The side to which the gluteal cleft was shifted in relation to the plumblines, was also noted. The rest of the spine was observed to determine whether there was a deviation from the vertical line. In the case of a deviation, the area of maximum deviation was noted and then measured by means of the graduated ruler.

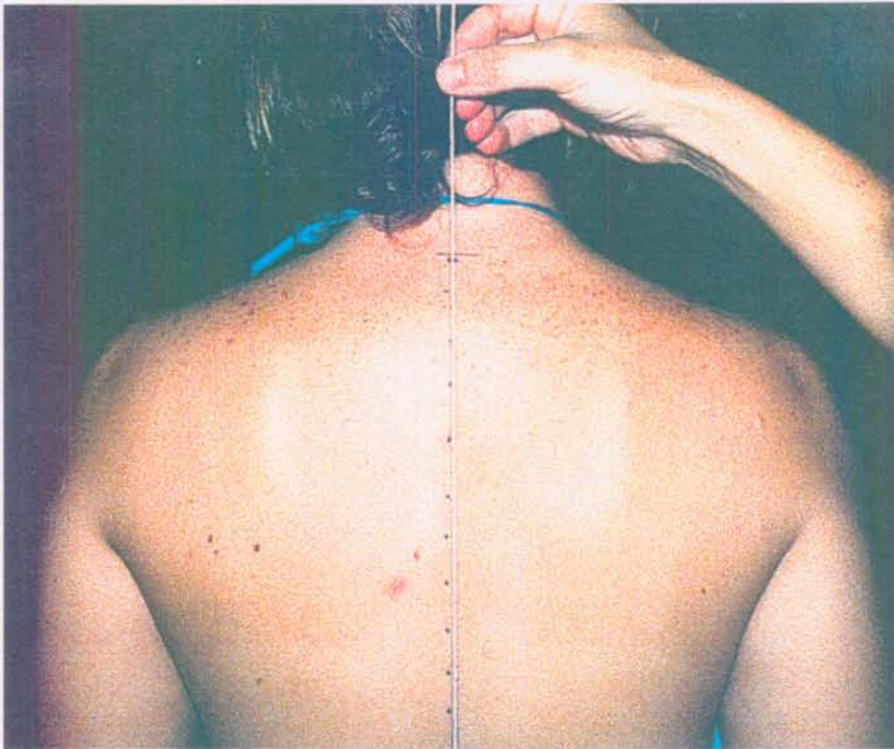


Figure 10: Measurements by means of a plumbline

- ◇ **Kyphosis / Lordosis** : The sagittal curves of the subject were viewed laterally to determine the start of the normal / abnormal kyphotic and lordotic curves. The subject was asked to stand up straight, but no postural correction was done. The subject was asked to look at a specific point level with the eyes on the opposite wall. The following levels were marked on the subject's back to determine the normal / abnormal sagittal curves: lumbo-sacral junction, thoraco-lumbar junction or the superior end of the lordosis, the cervico-thoracic junction or the superior end of the kyphosis. The digital inclinometer was used to measure the curves in the sagittal plane. All the readings were taken three times and then the average reading was used. The short base of the inclinometer was placed on the lumbo-sacral junction and then zeroed at this point as described in 3.6.1. The inclinometer was then moved to the thoraco-lumbar junction

and a reading was taken. This reading was the degree of the lordotic curve. To determine the kyphotic curve the thoraco-lumbar junction or the superior end of the lordosis / inferior end of the kyphosis was used for the zero reading. The inclinometer was then placed on the cervico-thoracic junction to measure the degree of kyphosis present. (Figure 11)

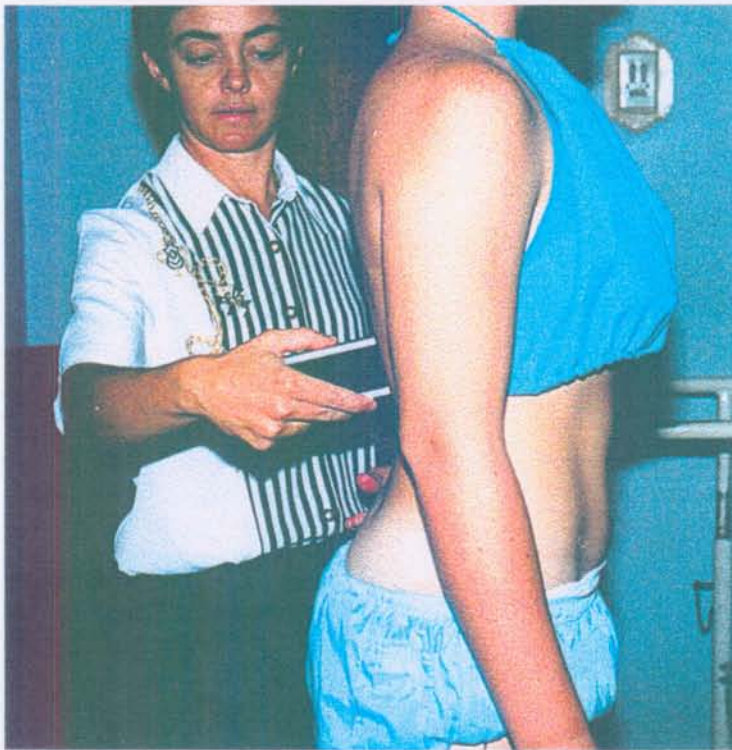


Figure 11: Measurement of kyphosis and lordosis

- ◇ **Forward head posture:** The subject was viewed from the side with the plumbline hanging on the lateral side in such a manner that the plumbline passed through the centre of the ear. The position of the line as it passed through, posterior or anterior to the shoulder, was observed. If the plumbline passed in front of the shoulder, the subject was considered to have a forward head posture. This was noted. (Figure 12)

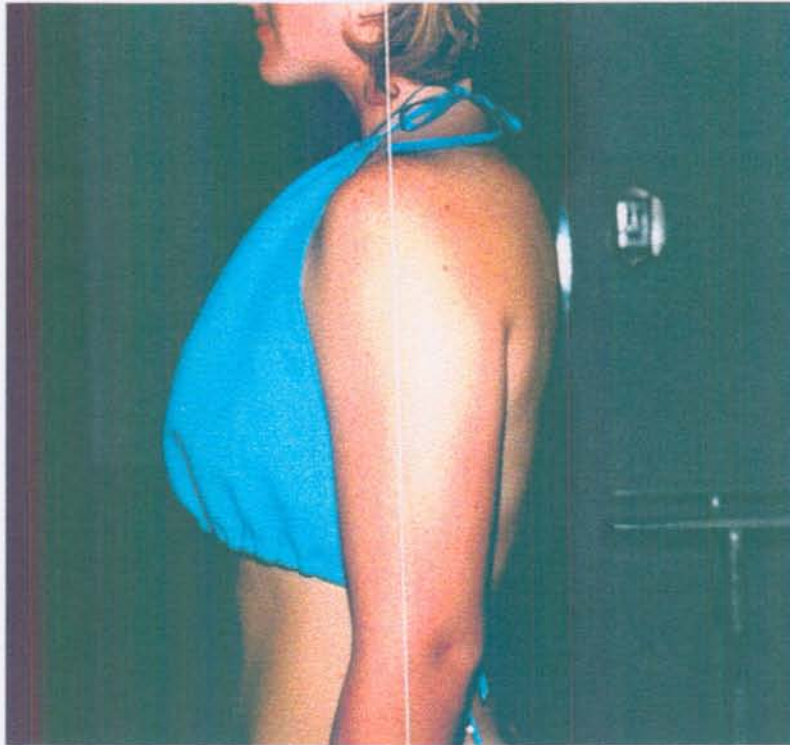


Figure 12: Measurement of forward head posture

- ◇ **Postural observations:** (Figure 13) The subject, in standing, was observed from posterior for asymmetrical winging of a scapula, and if so, the side of asymmetrical winging was noted. Any shoulder girdle elevation was noted, indicating the elevated side. The arms hanging next to the trunk were observed to determine if one arm was hanging further away from the trunk than the other, and on which side it was further way.

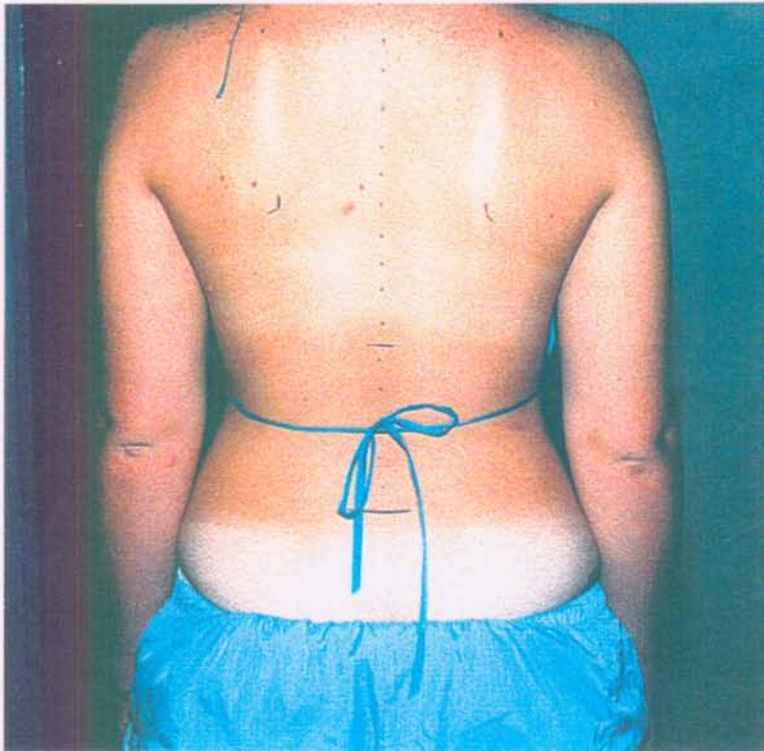


Figure 13: Postural observations

After completion of the physical evaluation, the mother was interviewed in order to obtain the necessary information for the questionnaire. The procedure was conducted in this order to avoid researcher bias when carrying out the objective evaluation. Relevant subjective information which would have been obtained prior to the objective evaluation, may have biased the researcher in her observations and measurements.

3.6.3. QUESTIONNAIRE (Appendix E)

Once the evaluation was completed, the researcher interviewed the mother of the subject and completed the questionnaire. The following data was obtained during the structured interview.

Developmental milestones:

- The age at which the subject sat independently.
- Whether the subject crawled, at what age he/she started crawling, and for what period of time he/she crawled before walking;
- Whether any other way was used to move forward;
- The age at which the subject walked independently.

Use of developmental aids:

- Whether the mother made use of a sit chair / transport chair, and for what period of time per day;
- Whether the mother made use of a walking ring for the subject, and for what period of time per day;
- Whether the mother made use of a "Jolly Jumper" and for what period of time per day.

Other factors:

- The family history concerning kyphosis and scoliosis;
- The gestation period as well as the process of birth (normal, Caesarean section, or normal with instrumentation);
- The preferred lying position of the subject as a baby;
- Hearing problems, and if so, the side of defective hearing, and the age at which the subject developed a hearing problem;
- Defective eyesight, the specific side that was affected, the age at which this problem

- started, and whether the subject was far sighted or short sighted;
- Whether the mother knew that her child had a spinal deformity, and when it was first noticed;
 - Whether the child had a sudden growth spurt, and at what age it took place.

3.7. PILOT STUDY

The first twelve subjects to make appointments were considered as candidates for the pilot study. After their evaluations were completed, all problems were considered. The data of these subjects were not included in the analysis. The following problems were experienced during the physical evaluation:

- When the plumbline was placed on the seventh cervical vertebra, as described by most of the authors^{8,27,32}, the free hanging of the plumbline was disturbed in cases of kyphosis. It was then decided to make use of a plumbline hanging from an overhead arch and to orientate the subject so that the spine of the seventh cervical vertebra was in line with the plumbline, as close as possible to the body of the subject, without disturbing the free hanging of the plumbline.
- The researcher attempted to measure the lordotic curve of the cervical spine by means of the inclinometer, but the shortbase of the inclinometer was too long in the case of younger children. The contact of the shortbase on the spinous processes was lost. The forward head posture was then measured by means of a plumbline (as previously described).

The questionnaire was also pre-tested. The mothers of the twelve subjects were interviewed by means of a structured questionnaire. Categories for "not applicable" and "cannot remember" were added to relevant questions. The age categories, (for example, 9-12 months and 12-15 months) had an overlap of one month. The first category was

considered up to the day before 12 months, while the latter was considered from the exact day that the baby turned 12 months.

3.8. RESEARCH BIAS

3.8.1. VALIDITY

Although some research articles indicate that non-invasive methods of measuring the spinal curve is not as accurate as radiographs,¹²² others show a good correlation between surface measurements and radiographs.^{16,63,94} The inclinometer is the non invasive method that has shown the best results regarding accuracy in the measurement of spinal curvature.^{16,63,94} Measurements with the inclinometer show a high intra- and inter-tester correlation.⁹⁴ Surface measurement of thoracic rotation is a valid method to screen for scoliosis.^{10,20} Although radiographs are the most reliable method for the measurement of leg length discrepancy, and other researchers prefer the measurement of relative iliac crest height⁵⁴, the method of measurement from the anterior superior iliac spine to the medial malleoli is a valid method.^{32,37} The ability to recall developmental milestones such as sitting and walking was found to be good in cases where children were four to five years old.¹²² Unfortunately, no study was found that determined the reliability of recall of parents of adolescents.

3.8.2. RELIABILITY

The reliability (also see section 3.8.4.) of each of the objective measurements was controlled by taking three measurements, and then determining the mean. If there was a variation of more than five degrees, or five millimetres, the measurements had to be repeated.

The reliability was further tested by means of blinding. A second observer was trained to repeat the readings of the first ten subjects, thus testing inter-tester reliability.

3.8.3. SELECTION BIAS

Selection bias was eliminated by using all the volunteers who replied. This was a sample of convenience. Although the schools that were approached were multi-racial only the white parents responded to the request for participation. The sample was therefore not representative of the South African population. Selection for the control and case groups was controlled by the specific inclusion criteria for each group. The numbering of the cases and controls was done in a systematic manner. After the objective evaluation was completed, it was determined if the subject was a case or a control according to the results. In each group the consecutive number was then assigned to the subject.

3.8.4. INFORMATION BIAS

INTERVIEWER BIAS: Only one interviewer was used.

INSTRUMENTAL BIAS: The same tape-measure, ruler, spirit level, plumbline and inclinometer were used. No calibration was needed for the inclinometer.⁸³

QUESTIONNAIRE BIAS: The questionnaire was pre-tested and a pilot study was done to ensure that all the evaluation techniques were possible. A structured interview was used.

RECALL BIAS: Some mothers had difficulty to remember precise ages of certain developmental stages. Categorized answers, according to normal developmental stages, were used to minimise the recall bias.

MEASUREMENT BIAS: A second researcher was trained to repeat the evaluation of the first ten subjects. Inter-observer reliability was tested by means of a paired t-test. Analysis of data obtained from the two observers showed a significant difference in only four of the variables of the physical evaluation. The measurements of the height of the subjects

showed a significant difference ($p=0,02$). The differences between the two observers differed between zero and five millimetres, but only three of the measurements were three millimetres or more. Only the measurements of the left hip flexion tightness showed a significant difference ($p=0,05$). These differences varied between zero and 3,7 degrees, and once again only three of the measurements differed by more than two degrees. The measurement of hump size differed in only three of the subjects whilst the other measurements were the same for both researcher and control researcher. The lordotic measurements also differed in only three of the measurements with a significant difference of $p= 0,05$. All the above mentioned differences were found when evaluating the first four subjects, thus leading to a conclusion, that the measurements of the two observers differed less, as the experience of the second observer improved. Reasons for deviations in only four of the measurements of the variables, could be due to the fact that although the control researcher was trained, she lacked experience in handling the instruments. The importance of accuracy was explained to the second researcher, but perhaps insufficient time was taken to obtain precise measurements. However, the measurements of the study were considered inter-observer reliable for the following reasons:

- differences were observed in only four (4) of the variables measured
- differences never exceeded more than five millimetres or 3,7 degrees
- differences decreased as experience improved.

3.9. STATISTICAL ANALYSIS OF THE DATA

The statistical analyses that were applicable to this study were:

- comparison between means of variables from the case and control groups by paired

t- tests.

- examination of relationships of frequencies in 2 X 2 tables by calculating chi square values
- tabular probability values (p values) of all comparisons (means and Chi squares) are given whenever relevant and special note is taken where $p=0,01$ or less
- Pearson correlation coefficient was used to calculate the correlation between the angle of trunk rotation and the hump size
- a Logit analysis of the variance tables to determine the maximum likelihood of the ages of developmental milestones to predict the development of a spinal deformity

Chi square and t-test values which have tabular p values of 0,05 or less, were regarded as significant. Probability values of 0,05 to 0,1 show a trend of predictability with regard to the variables investigated, and the possible development of deformities. However, it must be remembered that Chi square and t-test values equal to or greater than the 10 % level of probability present differences or associations which are less predictable than when the level is progressively smaller.

3.10. SUMMARY

In the research methodology of this case-control study, sampling was done from schools in the community according to specific inclusion and exclusion criteria. During the research procedure non-invasive methods were used to screen the subjects for any spinal deformities that they may have developed. A structured questionnaire was used to determine the developmental milestones and other possible factors that could influence the development of spinal deformities. The results of the data from the objective evaluation and information obtained from the interviews are given in the next chapter.

CHAPTER 4

RESULTS

4.1. INTRODUCTION

Lectures on back care and / or written details of the study were given to three thousand scholars aged twelve to seventeen years at selected schools in the Middelburg area. Forms were handed out to three thousand scholars, requesting them to voluntarily participate in the study. One hundred and thirty two scholars responded. The respondents were telephoned to make an appointment for the evaluation. Fifteen of these volunteers then decided to withdraw from the study, while seven subjects had moved out of the Middelburg area. One hundred and ten (110) adolescents were evaluated. Data from five of these adolescents could not be used due to the fact that their mothers were not available to complete the questionnaire. One adolescent was excluded from the study group due to a previous fracture of the femur, which caused a leg length discrepancy of more than one centimetre. One hundred and four adolescents complied with the inclusion criteria for the study sample. Although most of the schools were multiracial, only white parents responded to the request for participation in this trial.

4.2. PHYSICAL EVALUATION OF SUBJECTS

4.2.1. CASES AND CONTROLS

The data of the 104 adolescents who complied with the inclusion criteria for the study group were processed and the subjects were allocated to either the case or control groups according to the specific criteria for each group, as described in section 3.5..

See figure 14 for the distribution of case and control subjects.

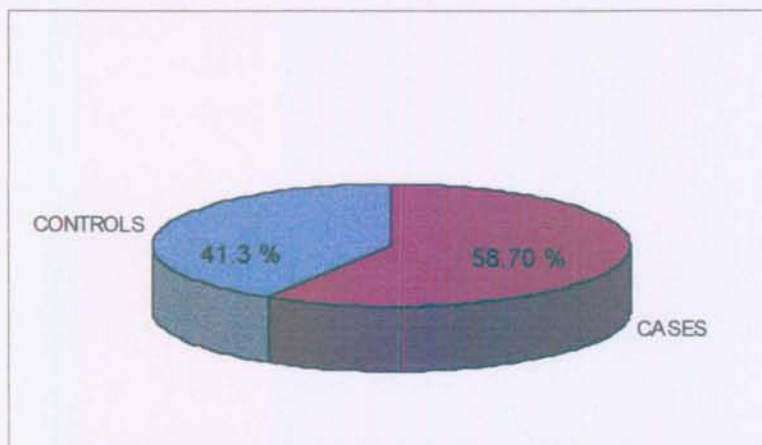


Figure 14: Distribution of cases and controls.

The higher number of cases can be attributed to the fact that mothers who thought their children had a deformity, were more eager to participate in the study.

4.2.2. GENDER

There was an uneven distribution of girls and boys in both the case and control groups. There were more girls than boys in the total study group. The case group, as well as the control group, had more girls than boys. (See table 1)

Table 1: Percentage of girls and boys.

Gender	Cases (N=61)	Controls (N=43)	Total (N=104)
Girls	73,77%	69,77%	72,1%
Boys	26,23%	30,23%	27,9%

This uneven distribution was probably due to the fact that all the volunteers who complied with the criteria for the study were used and this was a sample of convenience.

The distribution of boys and girls in the different planes in which the deformities were present, is reflected in table 2. It is interesting to note that deformities, especially in the coronal plane, occurred predominantly amongst female subjects.

Table 2: Distribution of boys and girls of the case group in the different planes of deformities.

Planes	Boys (N=16)	Girls (N=45)
Sagittal	4 (25,01%)	10 (22,22%)
Coronal	6 (37,51%)	25 (55,55%)
Combined sagittal and coronal	6 (37,51%)	10 (22,22%)

4.2.3. AGE

The ages of the adolescents in the case and control groups varied from 12 years to 17 years and 11 months. The mean age for the case group was 14,85 years, compared to the mean age for the control group, which was 13,84 years. See figure 15 for the line-diagram of the ages of the cases and controls.

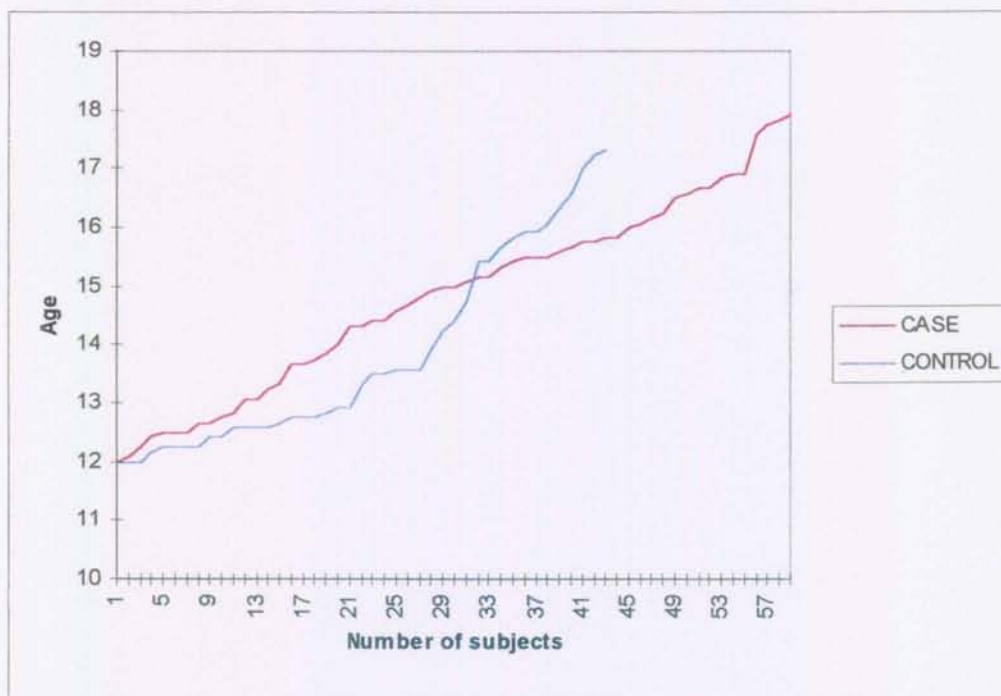


Figure 15: Comparison of the ages of the case and control subjects.

The line diagram showed a similar age distribution in the case and control groups.

4.2.4. MENARCHE

There was a larger percentage of adolescent girls who had reached their menarche in the total study group, than adolescent girls who had not reached their menarche.

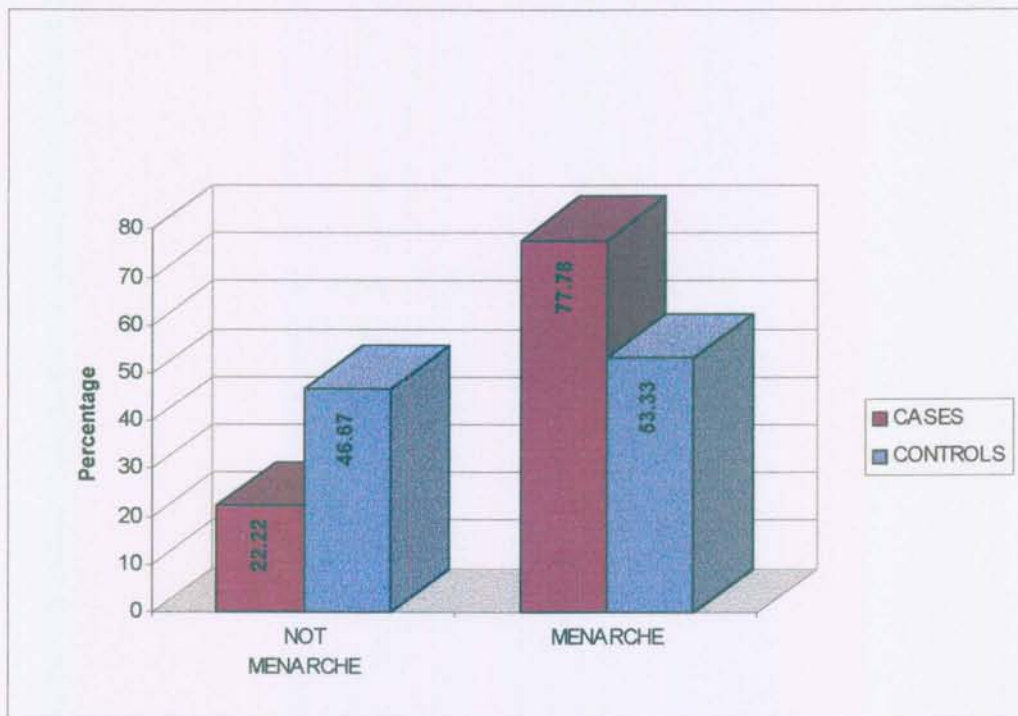


Figure 16: Percentage of cases and controls who had reached their menarche.

A significantly higher percentage of females in the case group than those in the control group had reached their menarche ($p = 0,013$). (See figure 16)

4.2.5. HEIGHT

The height of the total number of subjects varied from a minimum of 139,5 centimetres to a maximum of 191,0 centimetres, with a mean of 163,0 centimetres (standard deviation of 10). See figure 17.

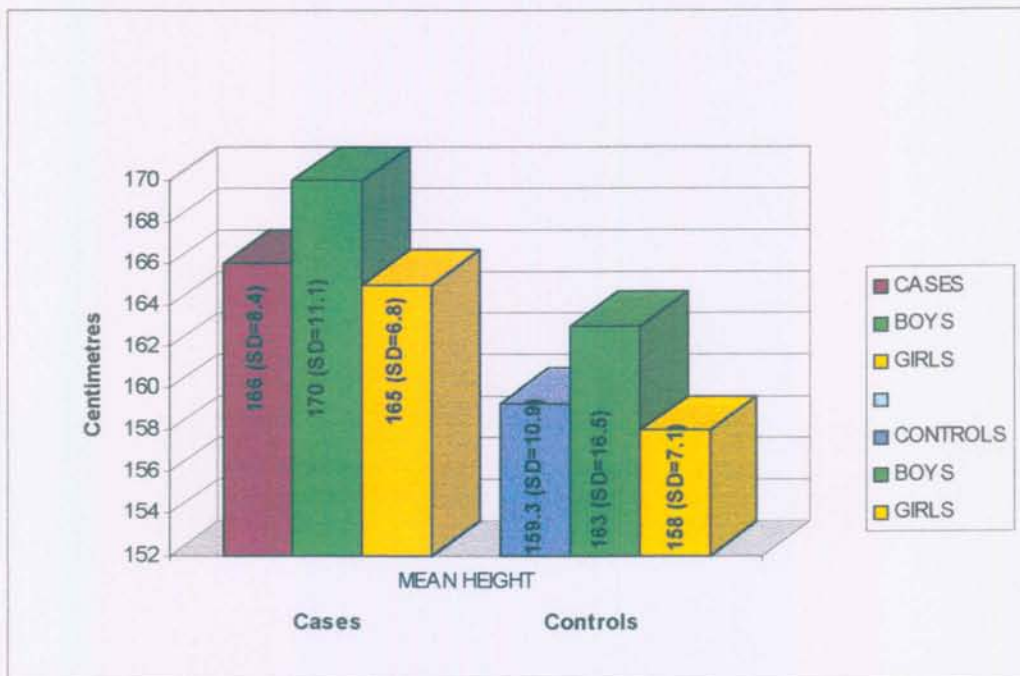


Figure 17: Mean height for cases and controls, indicating the mean height for boys and girls.

The height of the total number of subjects from the case group was highly significantly taller than those from the control group ($p=0,0004$). There was a trend for boys of the case group to be taller than boys from the control group ($p=0,092$), but girls from the case group were highly significantly taller than girls from the control group. ($p < 0,0001$)

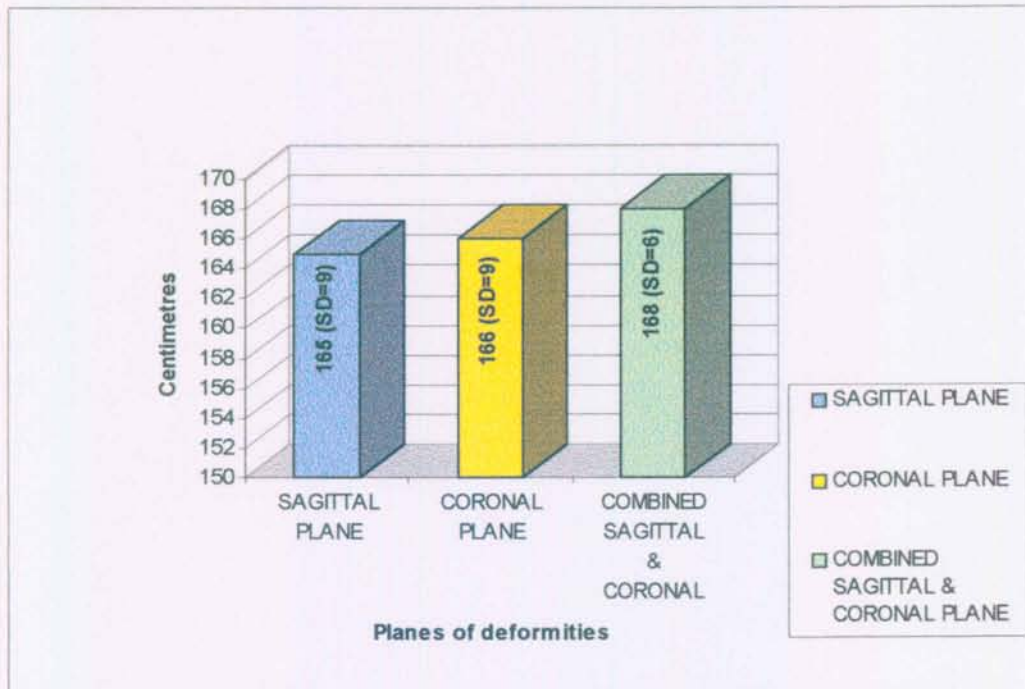


Figure 18: Mean height for the cases in each specific plane of deformity.

Subjects with combined sagittal and coronal plane deformities were significantly taller than those with sagittal plane deformities ($p=0.02$) and they also presented with a trend to be taller than those with coronal plane deformities ($p=0.07$). The comparison in height between the sagittal and the coronal plane deformities showed a non-significant difference ($p=0.3$). See figure 18.

4.2.6. LEG LENGTH DISCREPANCY

The mean leg length discrepancy for the control and case subjects did not differ much (appendix G figure 45). More left-sided than right-sided longer legs were found. (See appendix G figure 46)

4.2.7. STRAIGHT LEG RAISE

The range of motion of the hip joint was used in order to determine the degree of straight leg raise possible. There was no difference between the straight leg raise of the case and the control groups. There was also not much difference between the straight leg raise of the left and right side of all the subjects (appendix G figure 47). It was interesting to note that the mean average of hip flexion did not exceed 56 degrees. For the percentages of cases and controls who had either under or above 50 degrees of hip flexion, see figure 19.

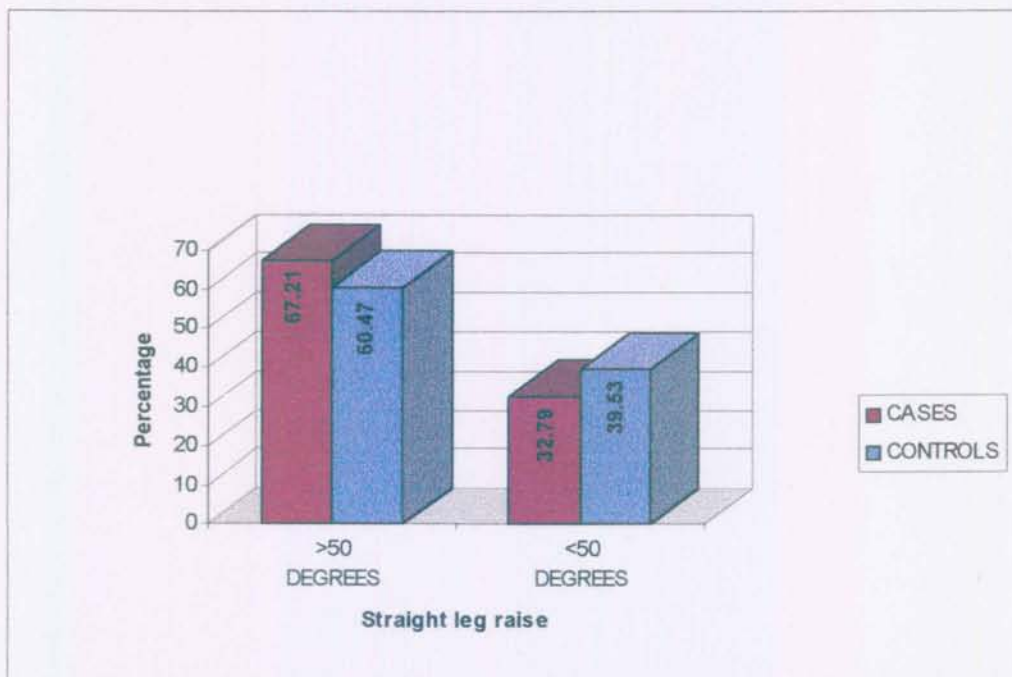


Figure 19: Percentage of cases and controls who presented with a straight leg raise of less than 50 degrees.

The control group presented with a higher percentage of subjects who had a straight leg raise of less than 50 degrees, but this was a non-significant value ($p=0,24$). The difference

of the straight leg raise test amongst the planes of deformities of the case group was also non-significant (appendix G table 8).

4.2.8. THOMAS TEST

It was interesting to note that the majority of subjects in this sample had a positive Thomas test. Hip flexor tightness was more or less equal in the case and control groups. A normal Thomas test was found in only six of the left hip flexors, and four of the right hip flexors of the total sample. No difference in the percentage of hip flexor tightness between the case and control groups was found (appendix G figure 48). More left-sided hip stiffness was seen in the case as well as the control group (appendix G figure 49).

4.2.9. HUMP SIZE

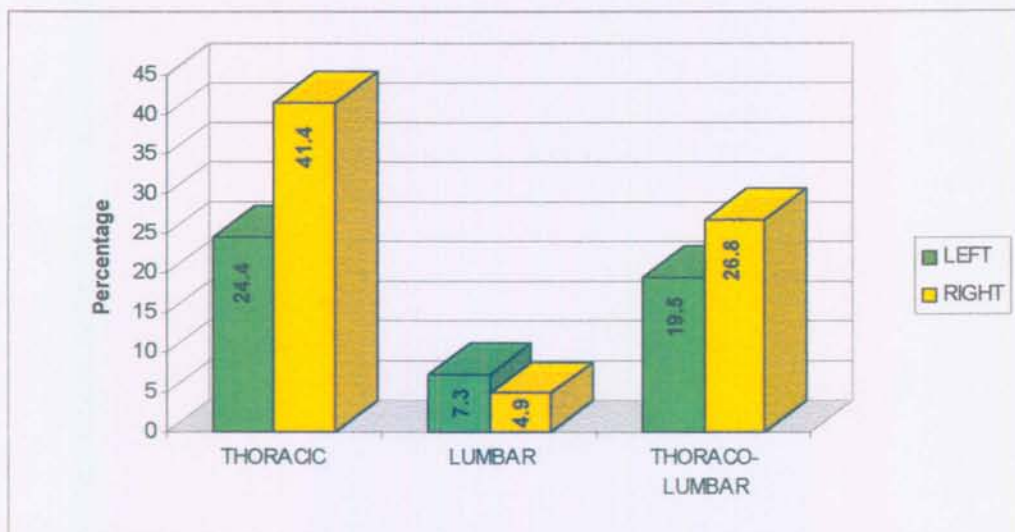


Figure 20: Percentage of the cases who presented with a hump size of more than six millimetres (N=41) in the different areas of the spine, indicating the side of the hump.

Thoracic humps of six millimetres or more were found significantly more than lumbar ($p < 0,0001$), and thoraco-lumbar ($p = 0,04$) humps. Thoraco-lumbar humps of six millimetres or more presented significantly more than lumbar humps ($p = 0,0003$).

In the thoracic area more right- than left-sided humps of six millimetres or more were found. The difference between the percentages of left- and right-sided humps in the thoracic area was significantly higher on the right-hand side ($p = 0,05$). No statistical difference was found between the left- and right-hand sides in the lumbar ($p = 0,32$) and the thoraco-lumbar ($p = 0,22$) areas with humps of six millimetres or more. (See figure 20)

Thoracic right- and left-sided humps of six millimetres or more were present significantly more frequently than lumbar humps of six millimetres or more (right side $p < 0,0001$; left side $p = 0,02$) Left-sided humps of six millimetres or more in the thoracic area were not significantly more frequent than humps seen in the thoraco-lumbar area ($p = 0,3$) (See figure 20); but there was a trend for more right-sided thoracic humps of six millimetres and more than right sided thoraco-lumbar humps ($p = 0,08$).

4.2.10. ANGLE OF TRUNK ROTATION

An angle of trunk rotation of more than five degrees was observed in 41 % of the subjects from the case group. A significant correlation between the angle of trunk rotation and the hump size in the thoracic, lumbar as well as the thoraco-lumbar areas, was found. The following table indicates the results, calculated by means of the Pearson correlation coefficient. (See table 3)

Table 3: Correlation between the humpsize measured and the angle of trunk rotation.

	Correlation coefficient compared to angle of trunk rotation	Significant value of correlation with angle of trunk rotation
Thoracic hump	0,65	0,0001
Lumbar hump	0,42	0,0001
Thoraco-lumbar hump	0,71	0,0001

4.2.11. PLUMBLINE

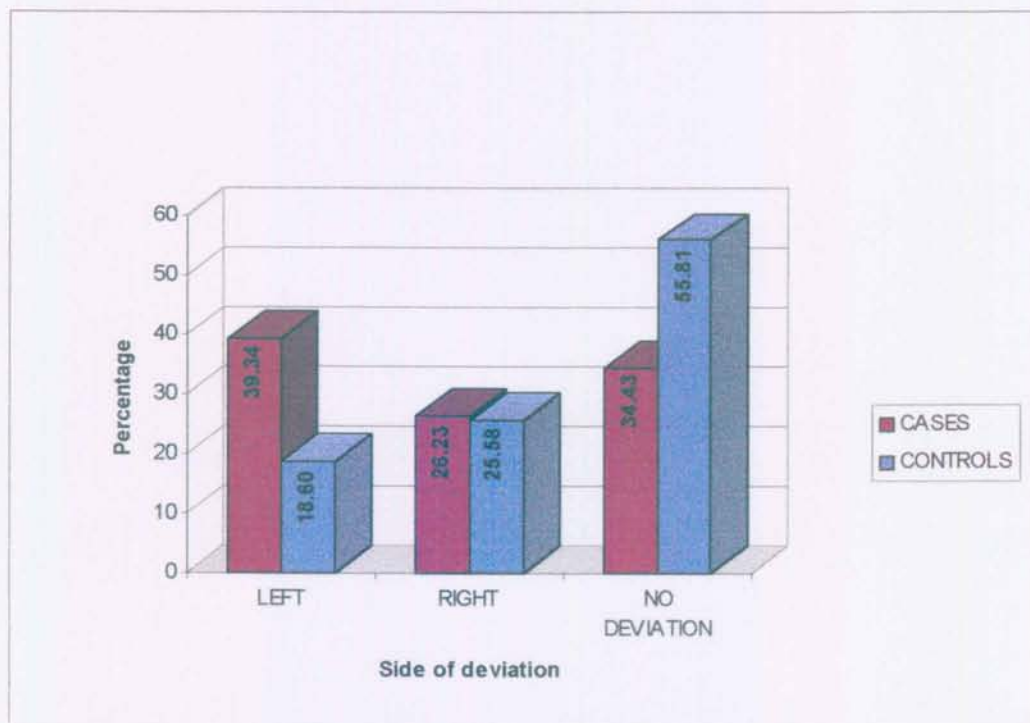


Figure 21: Percentage of cases and controls who presented with left and right sided deviations from the centre of the gluteal cleft.

In the case group the deviation of the plumbline from the gluteal cleft had a trend to occur more frequently to the left ($p=0,06$), while the plumbline in the control group had a tendency to be slightly more to the right ($p= 0,4$). (See figure 21)

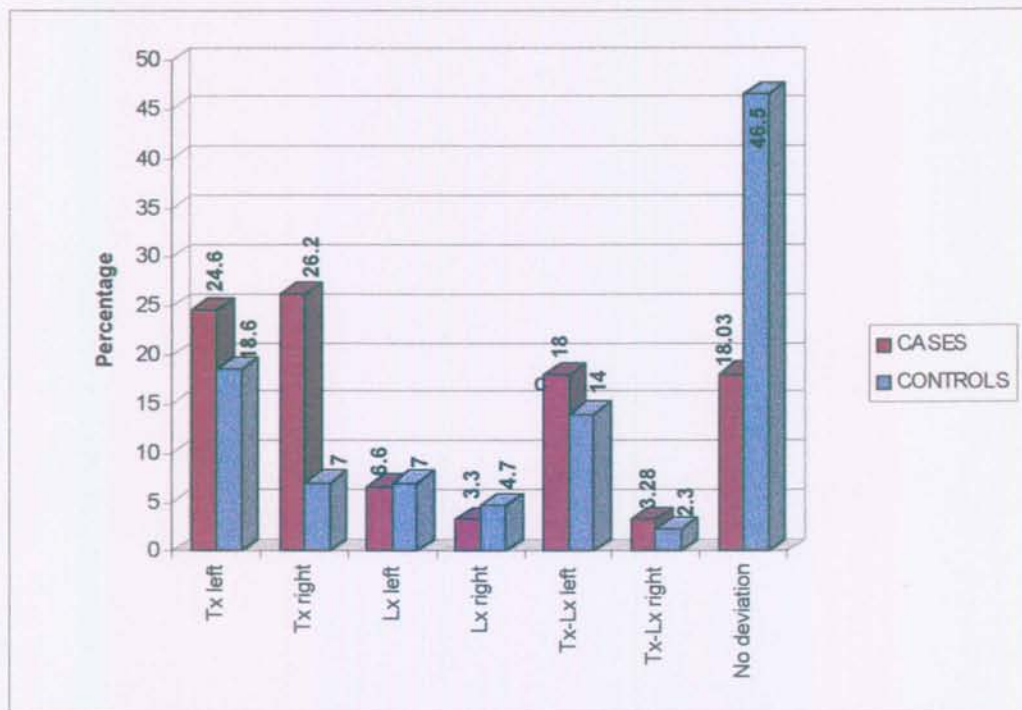


Figure 22: Percentage of cases and controls who presented with a deviation from the midline of the spine.

The spinal area most affected by deviation from the plumbline was the thoracic area. The measurements of the distance of the plumbline from the gluteal cleft, as well as from the midline of the spine, were influenced by the slightest weight transfer and swaying of the upper body of the subject, and were therefore considered unreliable.

4.2.12. KYPHOSIS AND LORDOSIS

A hyperkyphosis (kyphosis of more than 45 degrees) was noted in 49,2 % of the case group. Four subjects from the case group (6,6 %) presented with a hypo-kyphosis (kyphosis of less than 20 degrees). The mean hypo-kyphosis was 16,65 degrees with a standard deviation of 4,3 , a minimum of 10,3 degrees and a maximum of 19,3 degrees. The mean thoracic kyphosis for the cases where a hyperkyphosis was present, was 53,1 degrees with a standard deviation of 6,15 , a minimum of 45,3 degrees and a maximum of 72 degrees. No subjects presented with a hyper-lordosis (exceeding 60 degrees), and only one subject presented with a hypo-lordosis (19 degrees).

4.2.13. FORWARD HEAD POSTURE

An abnormal forward head posture was observed in 45,9 % of the case subjects. Defective eyesight was reported in only 21,43 % of the subjects who presented with a forward head posture. Of the subjects who presented with a hyperkyphosis, 56,7 % also presented with a forward head posture. (See figure 23)

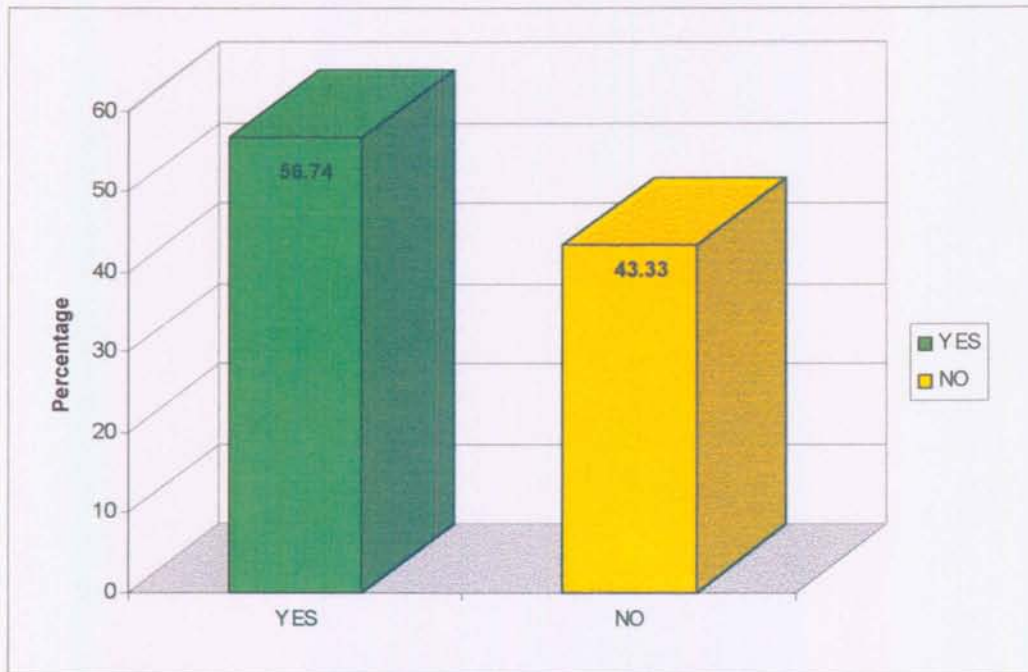


Figure 23: Percentage of cases who presented with a forward head posture as well as a hyperkyphosis.

There was a tendency for a forward head posture to be present in combination with a hyperkyphosis, but this was non-significant. ($p=0,15$)

4.2.14. WINGING OF SCAPULAE

Asymmetrical winging of the scapulae was seen in 55,74 % of the cases. It was interesting to note that 37,21 % of the control subjects also presented with an asymmetrical winging of the scapulae. The following graph (figure 24) indicates the side of the winging.

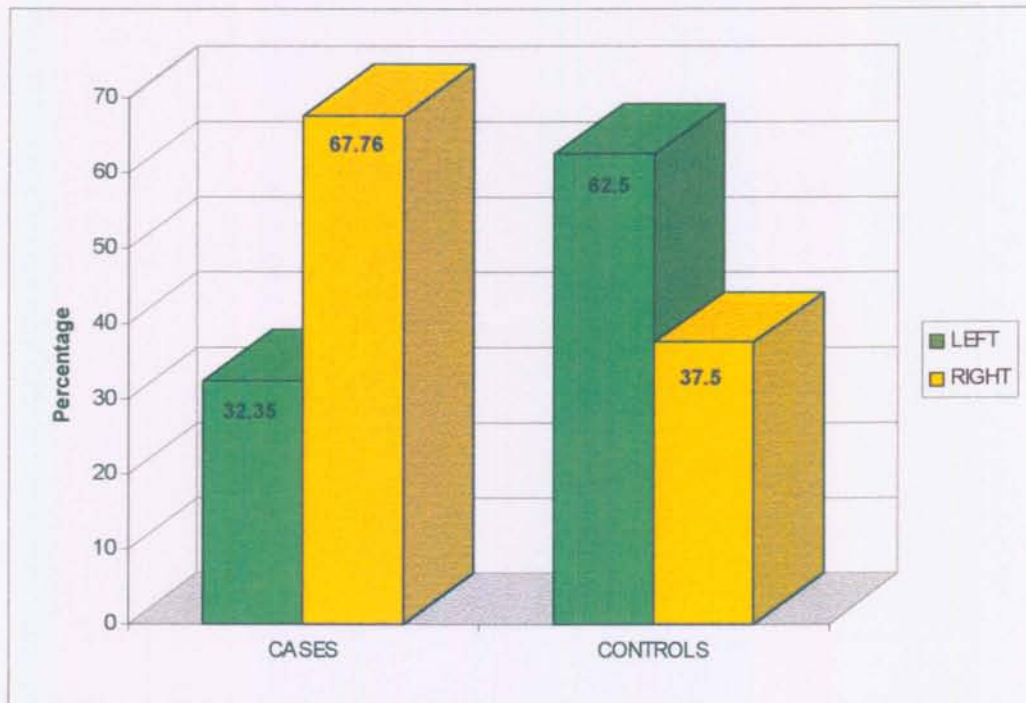


Figure 24: Comparison between the left and right sides regarding winging of the scapula.

Right-sided winging of the scapulae was seen significantly more frequently than left sided winging in the case group. ($p=0,02$) The opposite trend was present in the control group, where left sided winging was seen more often than right sided winging. ($p=0,079$)

4.2.15. ASYMMETRIC ELEVATED SHOULDER

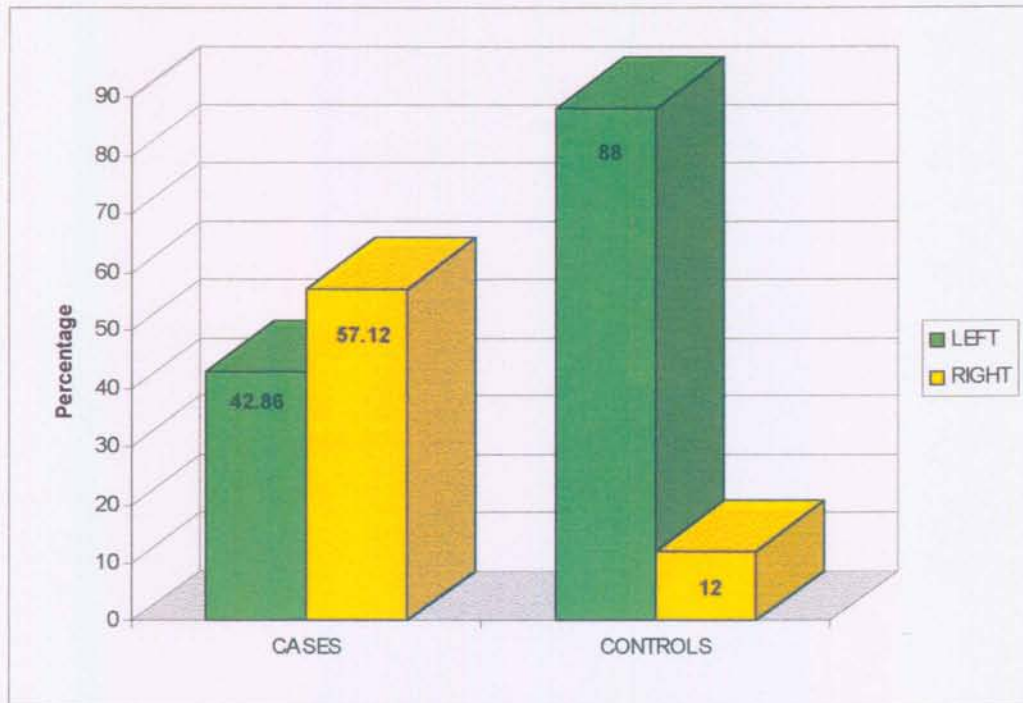


Figure 25: Comparison between the left- and right-sided elevated shoulders.

Those subjects in the case group who presented with an asymmetrical elevated shoulder, more frequently had right-sided than left-sided elevated shoulders ($p=0,095$). In the control group the opposite was observed ($p<0001$).

4.2.16. ARM DISTANCE FROM TRUNK

One arm hanging further from the trunk than the other was seen in 68,85 % of the case group, and in 51,16 % of the control group.

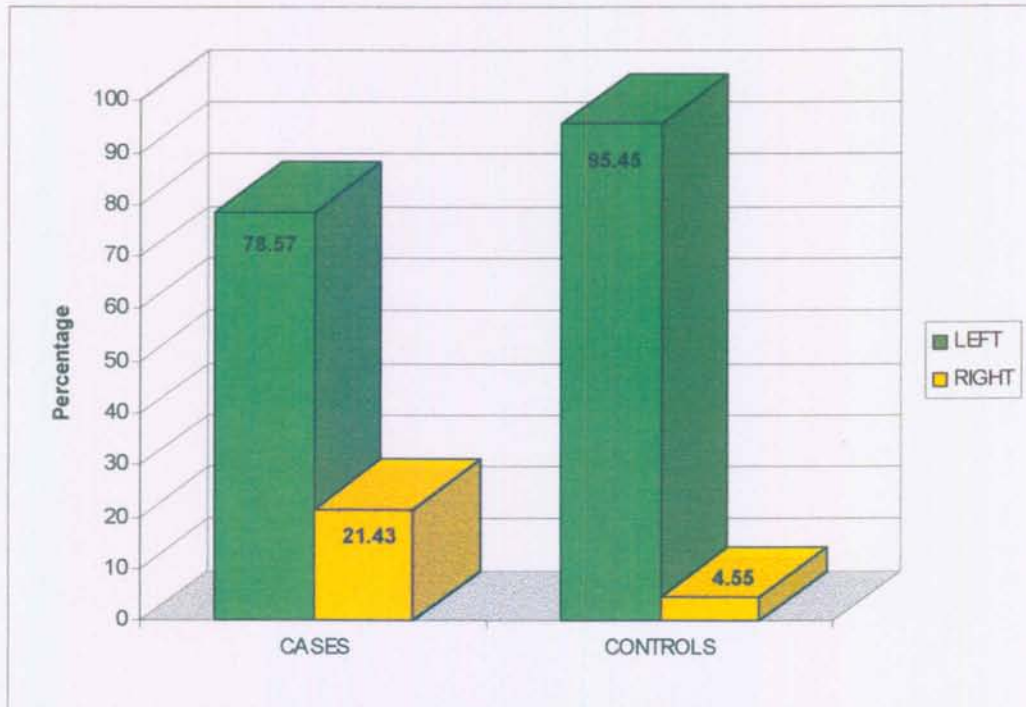


Figure 26: Comparison of the left and right arm hanging further from the trunk than the other.

A comparison between the left and the right arm hanging further from the body, of those subjects who presented with an asymmetrical hanging of the arms, showed the left arm was significantly further away from the body than the right arm in the case ($p < 0,0001$) as well as in the control group ($p < 0,0001$).

4.3. QUESTIONNAIRE

All the questionnaires were completed by the same researcher who also carried out the physical evaluations. The mothers of all volunteers were interviewed in order to obtain the relevant information.

4.3.1. DEVELOPMENTAL MILESTONES

4.3.1.1. SITTING

Most of the subjects sat at a normal developmental time, which is between six and nine months.

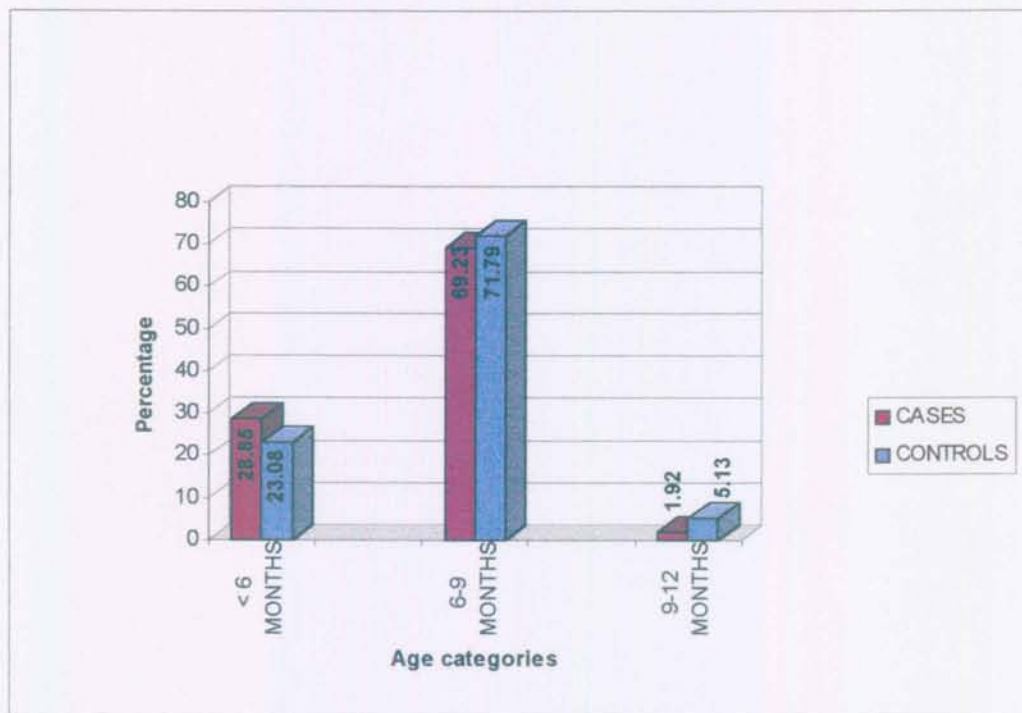


Figure 27: Comparison of the percentage of cases and controls who sat at a specific age.

Although the percentage of case group subjects who sat before six months was higher than the percentage in the control group, it was non-significant ($p=0,27$). In the age group of six to nine months, there were more subjects from the control group who sat, but this was also non-significant ($p=0,4$). The results from the Logit analysis showed that the age of sitting did not influence the likelihood of developing a spinal deformity ($p=0,25$).

4.3.1.2. CRAWLING

Only a small percentage of subjects from the case and control groups did not crawl. (Figure 28).

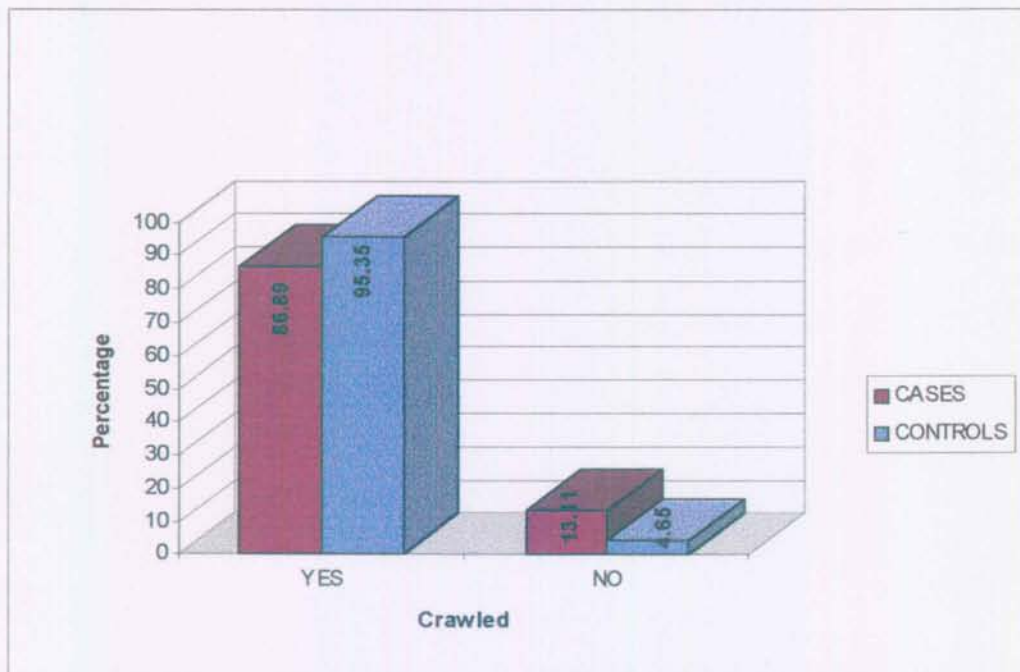


Figure 28: Comparison of percentage of cases and controls who crawled.

The control group presented with a trend for a higher percentage crawlers than the case group. ($p=0,075$)

The largest percentage (53,85 %) of subjects crawled at a developmental time of between six and nine months. Of those who crawled, the age at which the case and control subjects commenced crawling was compared. (See figure 29)

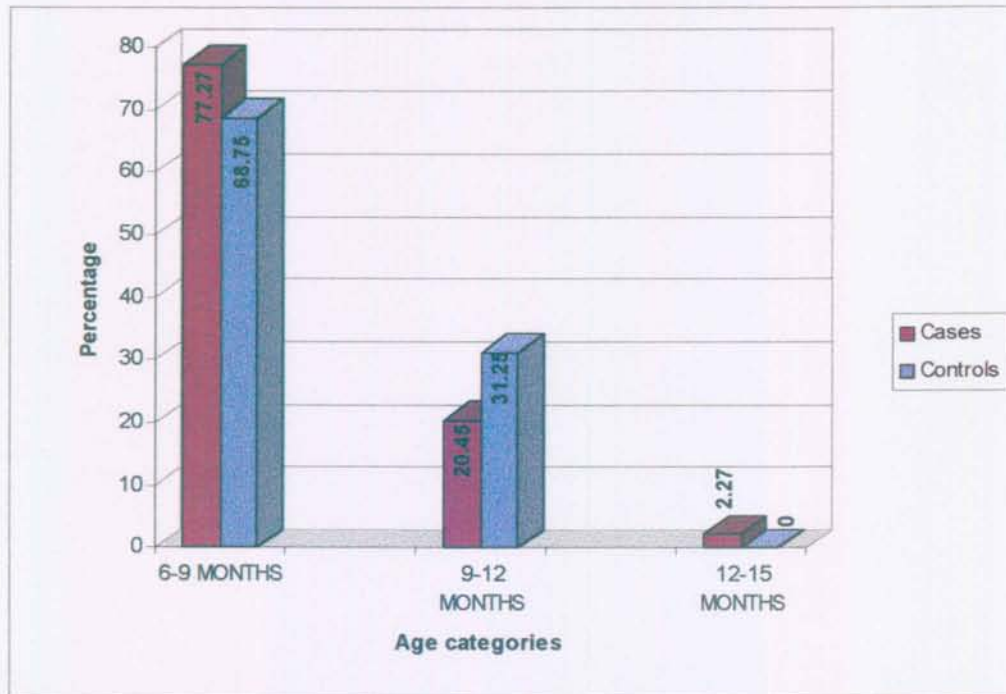


Figure 29: Comparison between percentage of case and control subjects who crawled indicate the age at which they crawled.

One subject in the case group crawled at a very late stage (12-15 months). In the category of six to nine months, there was a trend for more of case than control group subjects to have crawled; however it was not significantly higher ($p=0,2$). A higher tendency for crawling at the normal developmental period of nine to twelve months, was found in the control group ($p=0,14$). Most adolescents crawled for a period of two to three months as babies (figure 30).

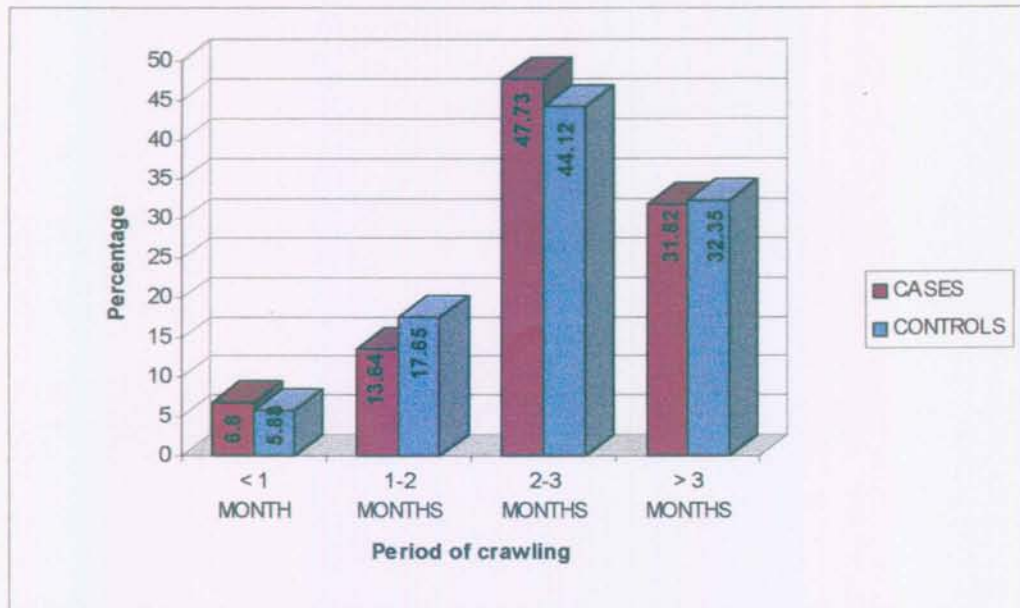


Figure 30: Comparison between case and control subjects who crawled indicating the period of crawling.

The one to two month period of crawling was reported slightly more in the control group, but this was non-significant ($p=0,3$). No significant difference between the two groups was found in the two-to-three month time period of crawling ($p=0,38$).

The percentage of case as well as control subjects, who moved forward in an alternative way to crawling, was lower than that of subjects who did not make use of another way of locomotion before walking (figure 31).

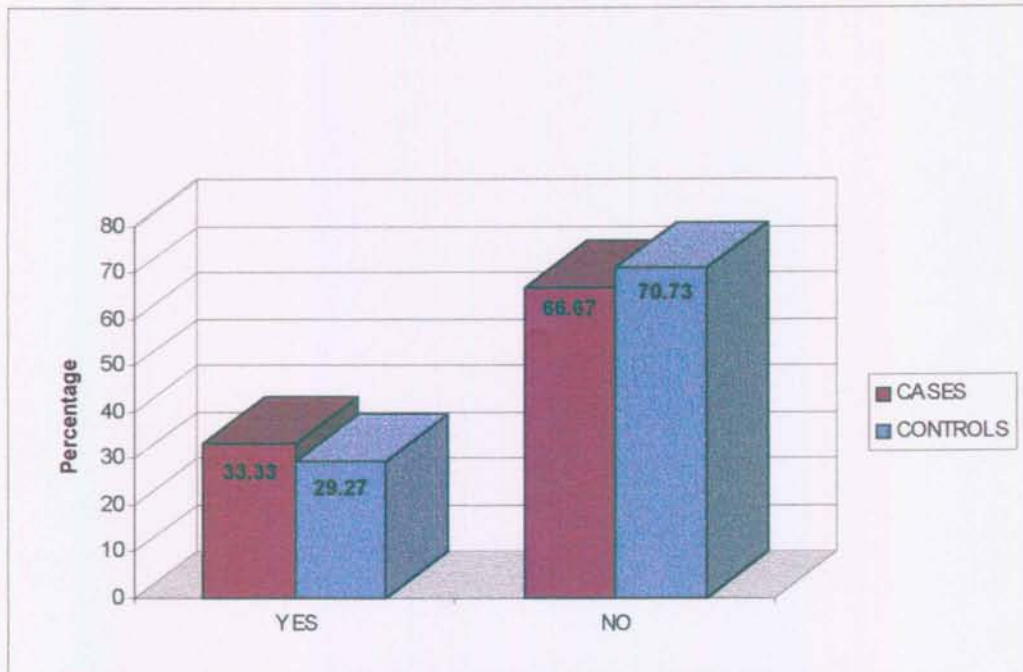


Figure 31: Percentage of case and control subjects who moved forward in an alternative method to crawling.

There was a tendency for more subjects from the case group (33,3 %) than the control group (29,27 %), to move forward in an alternative way to crawling, but this was non-significant. ($p=0,33$) Of those who did move forward in an alternative method to crawling, the following comparisons were made:

Table 4: Percentage case and control subjects who made use of alternative methods of locomotion.

Methods	Creeping	Shuffling	Hands and feet
Cases	50% (n=10)	45% (n=9)	15% (n=3)
Controls	50% (n=6)	42% (n=5)	8,3% (n=1)

4.3.1.3. WALKING

Most of the adolescents reportedly walked at an age between nine to twelve months. (Figure 32)

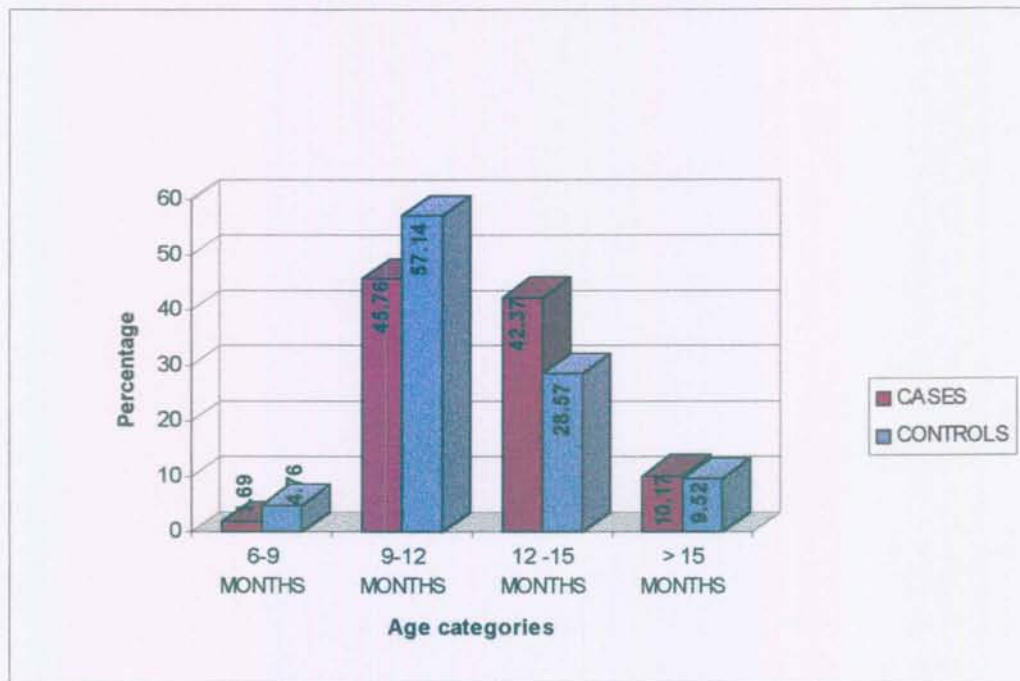


Figure 32: Comparison between case and control group subjects regarding the age at which they walked.

It was interesting to note that there was a higher tendency for the control group to walk at an age between 9 to 12 months ($p=0,13$), while subjects from the case group began walking later, between 12 to 15 months ($p=0,078$).



The Logit analysis showed that there was a trend for subjects who did not crawl and were late walkers (walking later than the age of 12 months) to have a greater likelihood of developing spinal deformities during adolescence. (Table 5).

Table 5: Maximum likelihood of crawling and walking influencing the development of spinal deformities

Age of crawling	Age of walking	Likelihood to develop spinal deformity
After 9 months	Before 12 months	0,26
After 9 months	After 12 months	0,49
Before 9 months	Before 12 months	0,51
Before 9 months	After 12 months	0,74
Did not crawl	Before 12 months	0,76
Did not crawl	After 12 months	0,90

4.3.2. DEVELOPMENTAL AIDS

4.3.2.1. SIT CHAIR

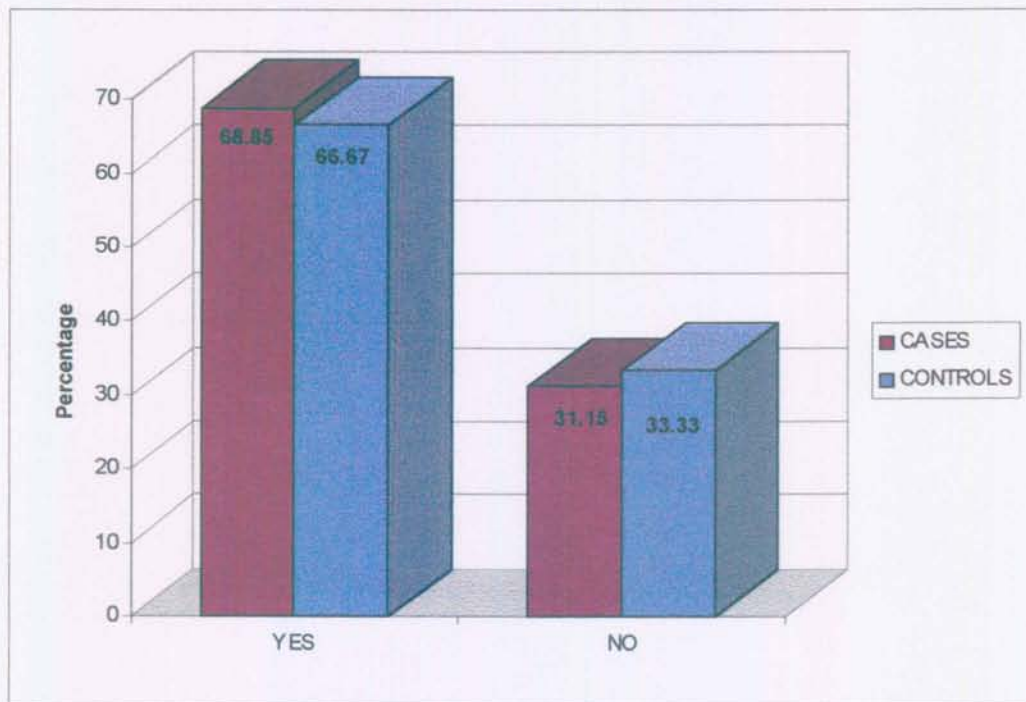


Figure 33: Comparison between case and control subjects who were placed in a sit chair as babies.

The comparison between the case (68,9 %) and control (66,7 %) group subjects who were placed in a sit chair as babies showed a non-significant higher percentage in the case group. ($p=0,41$). (See figure 33)

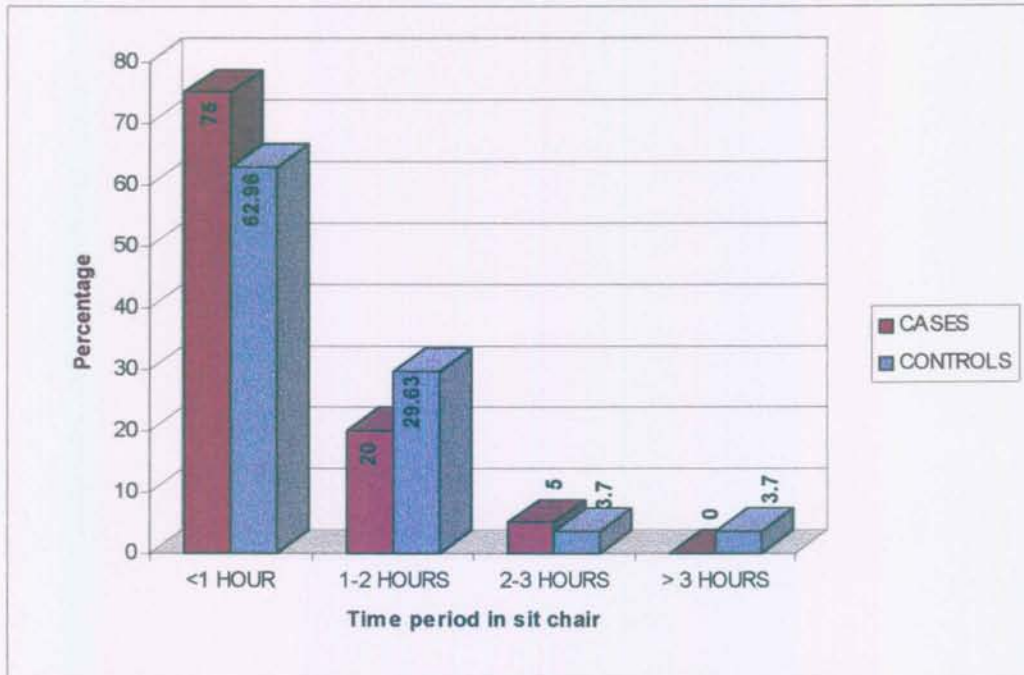


Figure 34: Percentage of case and control subjects placed in a sit chair, indicating periods spent in the chair.

There was a higher trend of having used the sit chair in the case group for the period of under one hour ($p=0,15$), while the control group showed a higher trend of use in the one to two hour period ($p=0,18$). The differences between the case and control group subjects with regard to the time which they spent in sit chairs were non-significant (figure 34).

4.3.2.2. WALKING RING

There was a higher percentage of case (70,5 %) and control (60,5 %) subjects who were placed in a walking ring, than those who were not placed in a walking ring. (Figure 35)

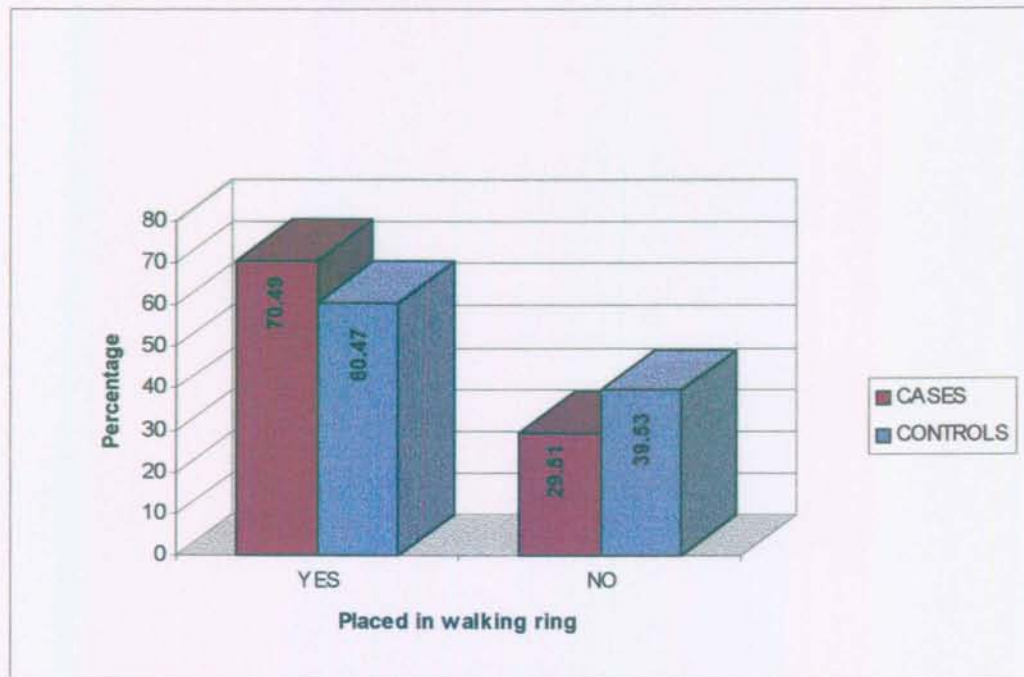


Figure 35: Comparison between percentage of case and control subjects who were placed in walking rings as babies.

Although it was statistically non-significant, there was a higher trend for the case group subjects to have used a walking ring than for the control group ($p=0,14$).

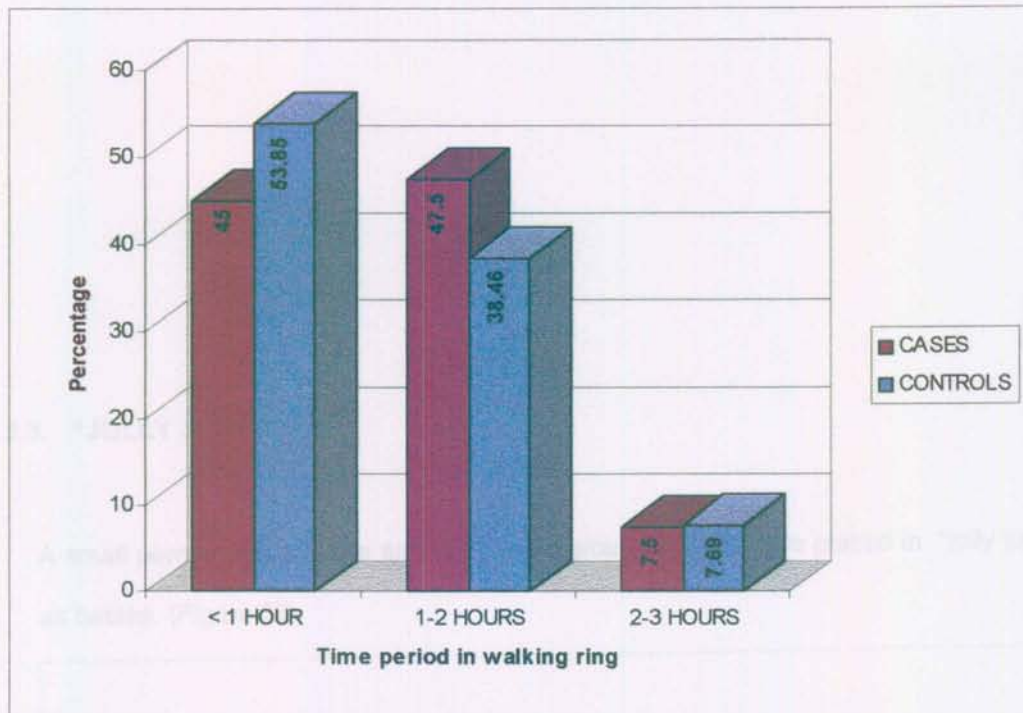


Figure 36: Comparison between percentage of case and control subjects who were placed in walking rings indicating period of time.

The period of less than one hour, that the babies were placed in walking rings, was used more in the control group than in the case group ($p=0,24$), while the time period of one-to-two hours was used more in the case group than in the control group ($p=0,23$). (See figure 36)

4.3.2.3. "JOLLY JUMPER"

A small percentage of case and the control group subjects were placed in "jolly jumpers" as babies. (Figure 37)



Figure 37: Percentage of case and control group subjects who were placed in "jolly jumpers" as babies.

A higher percentage of the control group (32,6 %) than of the case (26,2 %) group was placed in "jolly jumpers" as babies, but this was non-significant ($p=0,24$).

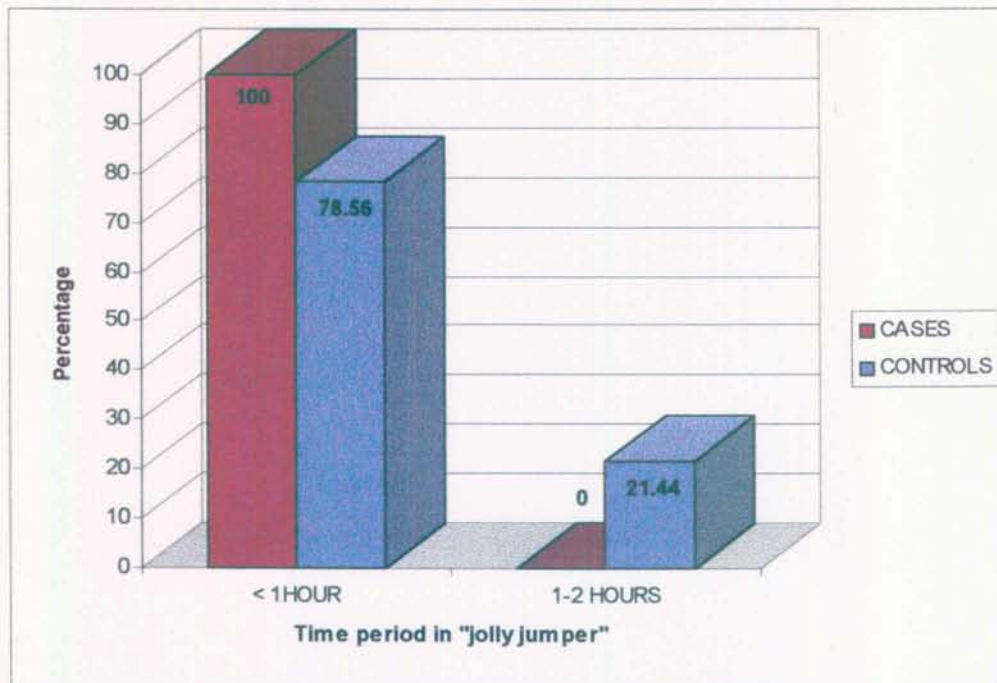


Figure 38: Comparison between case and control subjects indicating the time period spent in the "jolly jumper".

All the subjects from the case group and most of the subjects from the control group (78,56 %) who were placed in "jolly jumpers" as babies used it for under one hour. The percentage of case group subjects placed in the "jolly jumper" for less than an hour, was significantly higher . ($p=0,038$) See figure 38.

4.3.3. OTHER FACTORS

4.3.3.1. FAMILY HISTORY OF DEFORMITIES

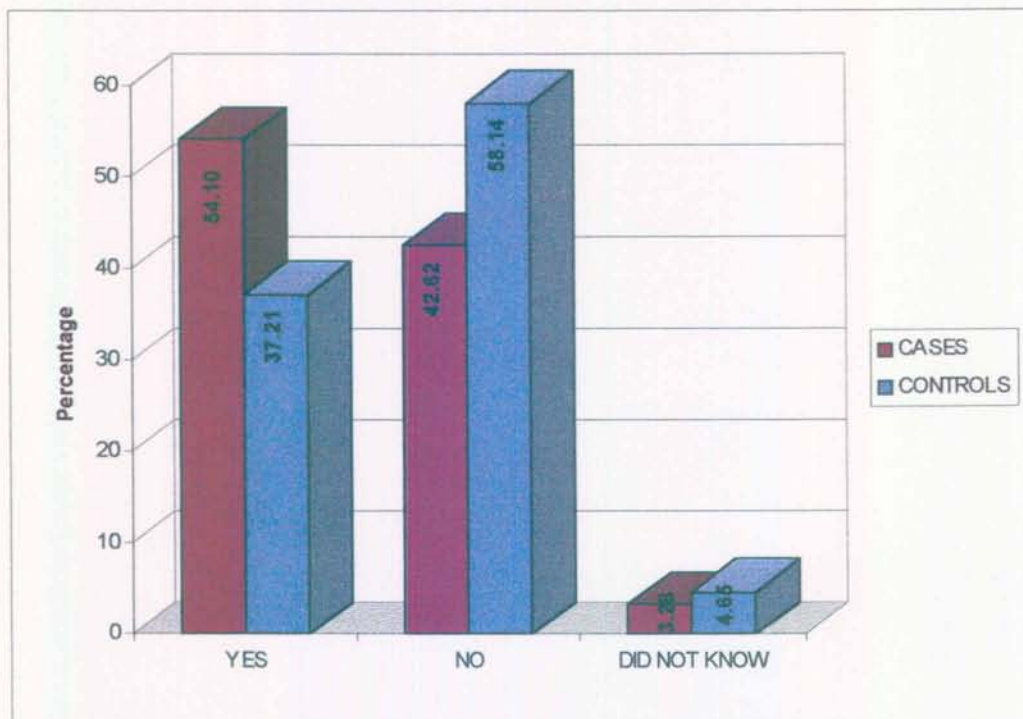


Figure 39: Percentage of the cases and controls who presented with a family history.

A significantly higher percentage of the case group than of the control group presented with a family history of deformities. ($p=0,045$) See figure 39.

Table 6: Comparison between the case and control groups of those subjects who presented with a direct family history of deformities.

Relationship	Percentage of cases	Percentage of controls
Mother	21,22	37,49
Father	24,23	18,76
Brother	3,03	6,26
Sister	9,08	18,76

Only the fathers of the case group showed a larger percentage in terms of a family history than the control group. It was interesting to note that there was a higher percentage of mothers in the control group with a family history of deformities than in the case group (table 7). Mothers presented with mainly scolioses in both the case and control groups (appendix G table 10), and fathers presented with mainly kyphosis in both the case and the control groups.

Table 7: Comparison between cases and controls of those subjects who presented with a family history of deformities on the maternal side.

Relationship	Percentage :cases	Relationship	Percentage :controls
Grandmother(n=12)	36,36	Grandmother(n=4)	25,0
Grandfather(n=4)	12,12	Grandfather(n=2)	12,5
Uncle(n=2)	6,06	Uncle(n=0)	0
Aunt(n=4)	12,12	Aunt(n=1)	6,25

A higher percentage of family history of deformities in grandmothers on the maternal side was reported in the case group. The deformities most frequently reported in the grandmothers were scolioses (33,3 %) and kyphoses (33,3 %) in the case group, and kyphoses (50 %) in the control group (appendix G table 10).

On the paternal side, no family history of deformities was reported in the control group. Twenty one percent of the case group with a family history of deformities reported that the paternal side was affected. More grandfathers (12,13 %) presented with a deformity and the presence of kyphosis was commonly mentioned (appendix G table 11).

4.3.3.2. GESTATION

Two mothers from the case group could not recall the gestation period of their children. Most of the subjects were born after a normal gestation period of 40 weeks.

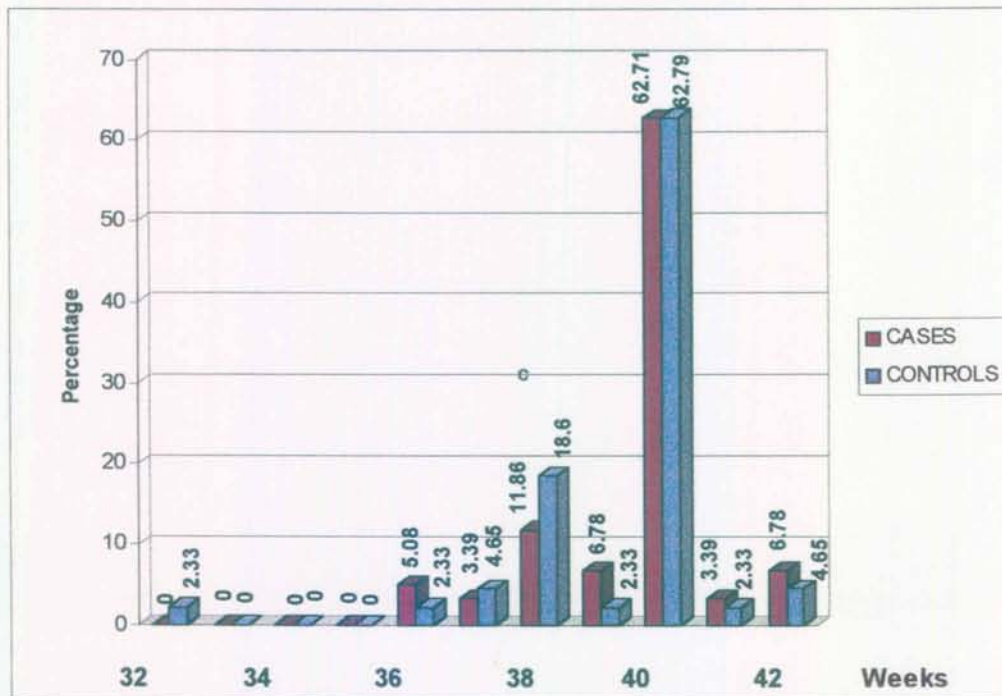


Figure 40: Percentage of cases and controls according to gestation periods.

An almost equal number of subjects from the case and control groups were carried full term (see figure 40). The thirty-eight-week-period of gestation was reported more frequently in the control group than in the case group, but this was non-significant ($p=0,17$). A higher percentage of control group subjects were carried up to the 38 week

gestation period, but this was due to the fact that a higher percentage of Caesarean deliveries were done in the control group. (Refer to 4.3.3.3.)

4.3.3.3. BIRTH METHOD

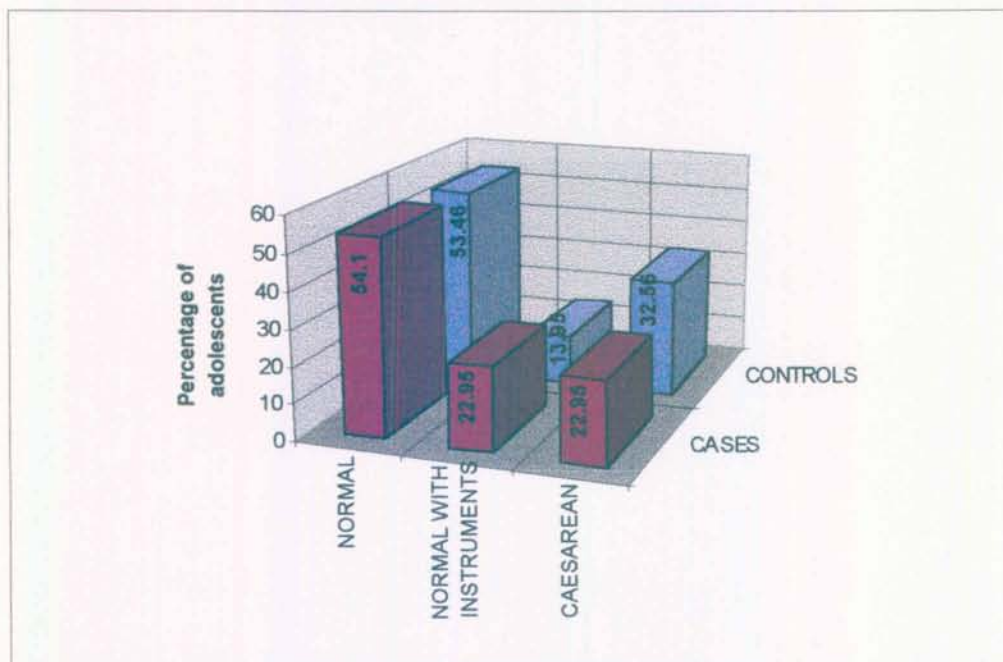


Figure 41: Method of birth indicating the percentage of cases and controls.

Normal births were reported more or less equally in the case and control groups ($p=0,95$). A higher percentage of cases than controls were born normally, but instruments were used during the birth process ($p=0,13$). Caesarean births were reported more frequently amongst the controls than the cases ($p=0,14$). No correlation was found between the method of birth and the development of deformities.

4.3.3.4. LYING POSITION

Most subjects preferred to lie on their sides as babies.

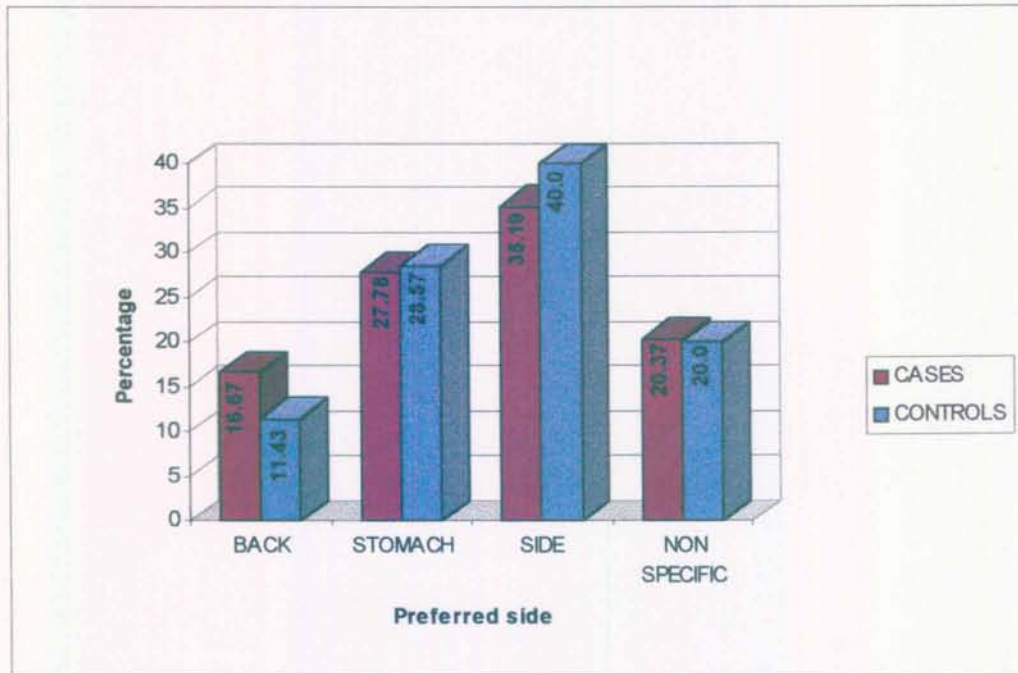


Figure 42: Comparison of percentage of cases and controls who preferred a specific lying position.

A slightly higher percentage of case group subjects preferred back lying as babies ($p=0,25$). The other positions showed no relevant difference in the distribution between the percentages of the case and the control groups (figure 42).

4.3.3.5. DEFECTIVE HEARING

A small percentage of the case group (9,84 %) as well the control group (11,63 %) presented with a hearing problem (appendix G figure 50). One subject from the case group who presented with defective hearing had a sagittal plane deformity, two subjects

with defective hearing had a coronal plane deformity, while defective hearing was present in three of the subjects who presented with a combined sagittal and coronal plane deformity. In the case group right sided defective hearing occurred more frequently, while left-sided defective hearing occurred more in the control group. (See appendix G table 12) Defective hearing was noticed mostly after ten years of age. (See appendix G table 13)

4.3.3.6. DEFECTIVE VISION

Defective vision was reported in 19,67 % of the case group, compared to 18,60 % of the control group (appendix G figure 51). Defective vision was mostly present in both eyes in the case as well as the control group, and mainly noticed at an age of more than ten years in both groups (appendix G table 14 and 15). The subjects from the case as well as the control group were mainly far-sighted (appendix G table 16). A forward head posture was seen in 30 percent of the subjects who presented with a visual problem. An equal distribution of subjects with sagittal, coronal and combined sagittal and coronal plane deformities who presented with defective eyesight, occurred.

4.3.3.7. KNOWLEDGE OF DEFORMITY

Approximately one third (32,79 %) of the mothers from the case group were aware that their children had a deformity. One of the mothers of the control group thought that her child had a deformity, but the subject did not comply with the inclusion criteria for the case group. Eighty percent of the mothers who knew that their children had a deformity, noticed the deformity at an age between ten to fifteen years, while the other 20 % noticed the deformity after the age of fifteen years.

4.3.3.8. GROWTH SPURT

A significantly higher percentage of cases than controls presented with a sudden growth spurt ($p=0,009$). (See figure 43)

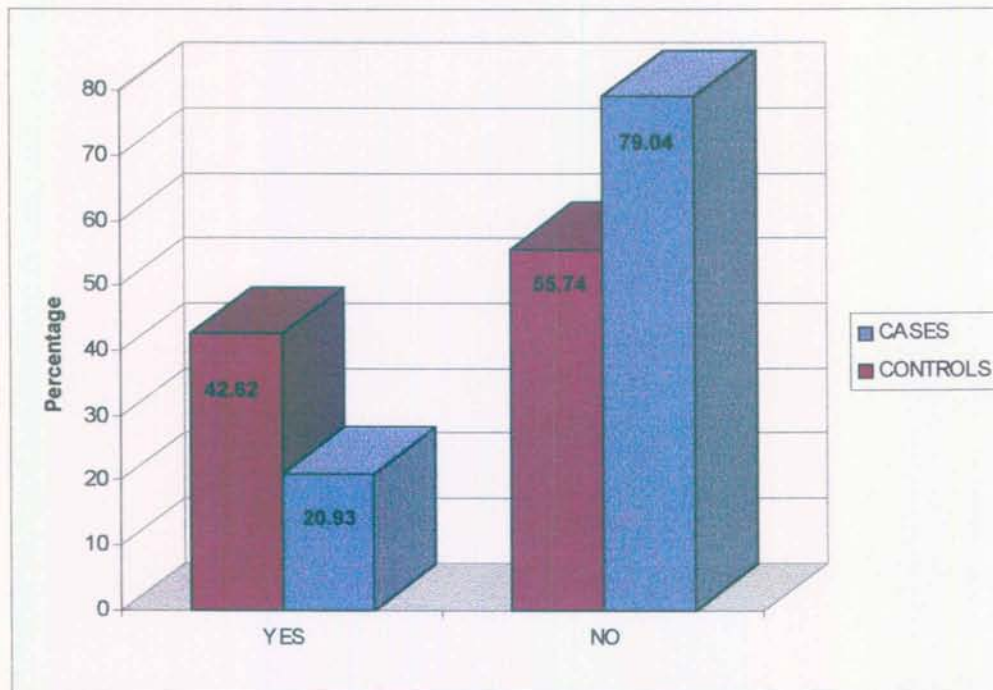


Figure 43: Percentage of case and control subjects who presented with a sudden growth spurt.

Most of the subjects presented with a sudden growth spurt between the ages of 10 and 15 years. (See figure 44)

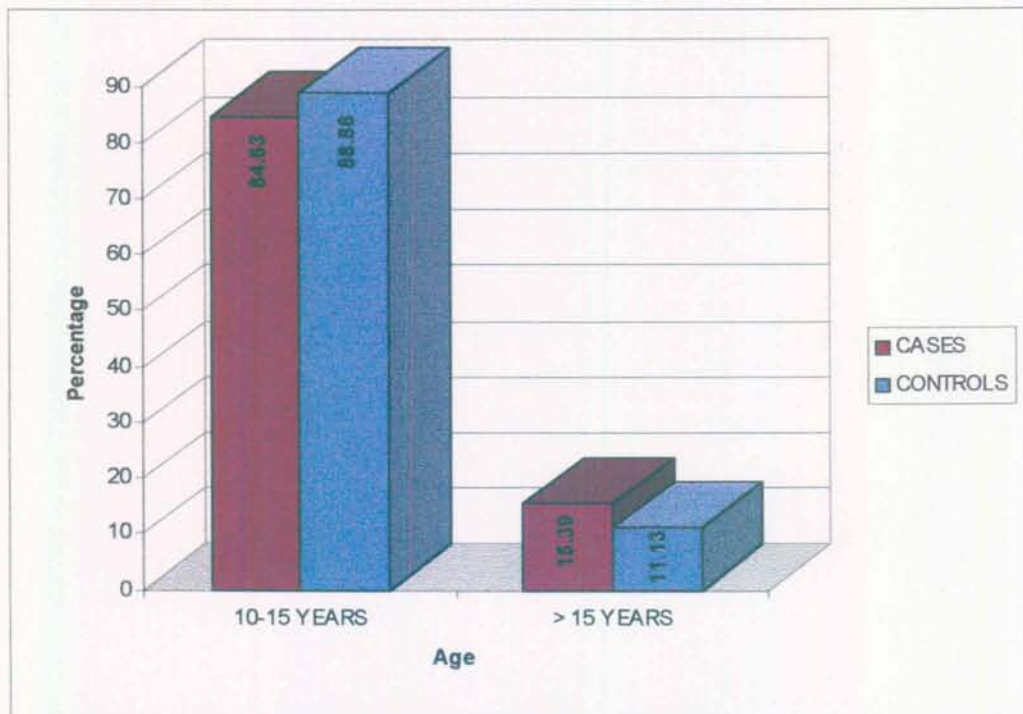


Figure 44: Comparison between cases and controls indicating the age of a sudden growth spurt.

The case as well as the control group showed a higher percentage of sudden growth spurt in the age group of ten to fifteen years. The differences between the case and control group in the age category of 10 to 15 years as well as more than fifteen years were non-significant ($p=0,38$). (See figure 44)

4.4. SUMMARY

The data (obtained from the 104 subjects) given in this chapter, presented significant results in the evaluation of the menarche and height. Humps of more than six millimetres were found significantly more frequently in the right thoracic area, resulting in more right-sided winging of the scapulae as well as right-sided elevated shoulders. A significant report of a family history of deformities was noted. Crawling, as well as walking, were noted as possible influential factors with regard to the development of spinal deformities in the adolescent years. The results will be discussed in the following chapter.

CHAPTER 5

DISCUSSION OF RESULTS

5.1. INTRODUCTION

The aim of this study was to investigate if developmental milestones such as sitting, crawling and walking could influence the development of spinal deformities in adolescents. Other factors which may have played a role, such as the gestation period, preference of lying position and the use of aids, such as sit chairs, walking rings, and “jolly jumpers”, were also taken into consideration. Factors such as defective eyesight and defective hearing were noted as they may also have contributed to the development of postural abnormalities.

In order to determine whether the subjects complied with the criteria for the case or control group, a thorough objective evaluation of each adolescent had to be performed. The subjects were then allocated to either the case or control group, according to the inclusion criteria for each group. A questionnaire was completed to record the developmental milestones of each of the case and control subjects. Although previous researchers have hypothesised that abnormal developmental milestones may be a neuromuscular cause of spinal deformities²⁰, no research to validate or negate the hypotheses was found in the literature review. The hypothesis that certain developmental milestones and other factors are associated with the prevalence of spinal deformities was only partially supported in this study. The study did, however, indicate that:

- babies who walked later (after twelve months) appeared to be more at risk to develop spinal deformities during adolescence
- babies who did not crawl and commenced walking at an age after twelve months seemed to have a non-significant risk to develop spinal deformities.

The sample in this study is not representative of the population in South Africa. Therefore generalisation of the results to a multiracial population cannot be made. The results are only applicable to the white population of Middelburg, Mpumalanga.

Spinal deformities have a variety of aetiological factors³⁹ which were also investigated in this study. Poor posture due to hypotonia could develop into a postural disorder.^{5,23} Abnormal developmental milestones, leading to impairment of neuromuscular control, were investigated as a possible aetiological factor in the development of spinal deformities.

5.2. PHYSICAL EVALUATION

5.2.1. CASES AND CONTROLS

There were 104 adolescents who complied with the criteria for either the case or the control group. Following the physical examination, more subjects (58,7 %) were allocated to the case than to the control group (41,3 %). The prevalence of deformities in this sample is much higher than the prevalence given in the literature for the general population, that is 0,5 % for scolioses,⁹ and 0,5 to 8 % for Scheuermann's kyphoses.²⁰ Hyperkyphoses of more than 35 degrees were found in 13,5 % of adolescents.¹⁷ All the studies referred to in the literature were done overseas, and not in South Africa. The percentages in the two groups may have resulted from the fact that subjects volunteered to participate in the study. Approximately one third of the mothers of volunteers knew that their offspring had a deformity. This was a sample of convenience, and therefore, subjects who knew or suspected that they had a deformity, were probably more willing to volunteer for the study.

5.2.2. ETHNICITY

Unfortunately the sample in this study was not representative of the population in South Africa due to the fact that only white mothers responded to the request for volunteers. This may be due to the fact that the mothers of black and / or Asian scholars are possibly unaware of the significance of spinal deformities in adolescents.

5.2.3. GENDER

There was an uneven distribution of girls and boys in the total study group. There were more girls in the case as well as in the control group (table 1).

A higher percentage of the girls compared to the boys presented with a deformity in the coronal plane and a slightly higher percentage of the boys presented with a sagittal plane deformity (table 2) . Although these findings were non-significant, the trend correlates with the literature which indicates that the frequency of idiopathic scoliosis is significantly higher in girls than boys.^{8,31,34} However, kyphoses are found more frequently in boys.¹⁷

The fact that a smaller percentage of boys in this study presented with a sagittal plane deformity than coronal plane deformity, is probably due to the fact that the combined coronal and sagittal plane deformities were separated from those who presented with a sagittal plane deformity only (table 2). The literature states that a scoliosis is present in the area of maximum kyphotic deformity.^{11,45} This implies that sagittal and coronal plane deformities were grouped together, and not considered separately.

5.2.4. AGE

The mean age for the case group (14,85 years) was higher than the mean age of the control group (13,84 years). This is probably due to the fact that adolescents tend to develop deformities during puberty when their growth spurts take place.^{5,6,7} The subjects were allocated to the case or control group according to whether a deformity was present or not. It is therefore more likely for subjects with deformities to be older than their counterparts.

5.2.5. MENARCHE

There was a significantly higher percentage ($p=0,013$) of subjects in the case group who had reached their menarche at the time of the evaluation (figure 16) . While growth is considered to be one of the aetiological factors of spinal deformities, the onset of puberty and menarche in girls are associated with the age of sudden growth.^{1,3,29} These factors, as well as the fact that girls from the case group were significantly taller ($p<0,0001$) than girls from the control group, correlate with the higher percentage of girls who had reached their menarche. (See 5.2.5.)

5.2.6. HEIGHT

Girls as well as boys from the case group were taller than those from the control group (p value for girls: $<0,0001$; boys = $0,092$). (See figure 17) The mean height for boys was more than the mean height for girls. Taller adolescents, especially girls, tend to be more prone to develop idiopathic scoliosis.^{1,3,5,31} Increased height also influences the development of a kyphosis.^{17,32} These findings from previous studies found in the literature are verified by this study.

It was interesting to note that the subjects with combined sagittal and coronal plane deformities were significantly taller than those with only sagittal plane deformities ($p=0,02$), whilst there was a trend for subjects with combined sagittal and coronal plane deformities to be taller than those with only coronal plane deformities ($p=0,07$). No significant height difference was found between the presence of either a coronal plane or sagittal plane deformity. No relevant information could be found in the literature that compared the mean height of subjects with coronal or sagittal plane deformities, or to compare the mean height of combined coronal and sagittal deformities with single plane deformities.

5.2.7. LEG LENGTH DISCREPANCY

There was not much difference between the cases and controls regarding leg length. A very slight higher mean in the leg length discrepancy was found in the control group, but this was non-significant. (See appendix G figure 45) More left sided (41,3 %) than right sided (30,8 %) longer legs were found. (See appendix G figure 46) There was no correlation between the different planes of deformities and the presence of leg length discrepancies. The slight leg length discrepancies observed in this study did not influence the deformities. A leg length discrepancy is commonly present in the general population, but a difference of ten millimetres is needed to cause asymmetry of the spine.⁵⁴

5.2.8. STRAIGHT LEG RAISE

There was no significant difference between the case and control groups regarding the range of hip flexion when performing a straight leg raise. The mean range for the straight leg raise for both the groups on the left-, as well as the right-hand sides, varied from 54,40 to 55,5 degrees. This was only slightly higher than the minimum norm of 50 degrees hip

flexion stated in the literature.⁵⁹ This general lack of flexibility could be due to the fact that adolescents spend the major part of their day sitting at school and doing homework. Unfortunately the physical activity of participating subjects was not considered in this investigation. The difference between the straight leg raise on the left and right sides in both the case and control groups, showed no significance. (See appendix G figure 47) The literature indicates that tight hamstrings could be expected with hyper-kyphoses⁴⁸, but the mean straight leg raise in subjects with different planes of deformities did not show a significant difference. (See appendix G table 8) Therefore there was no correlation between the decreased hamstring flexibility and the presence of deformities in this study.

5.2.9. THOMAS TEST

Most of the subjects from the case (95,08 %) and the control group (97,67 %) presented with hip flexor tightness. (See appendix G figure 48) A normal Thomas test (where the hip joint remained in neutral⁵⁹) was found in only six of the left hip flexors and four of the right hip flexors. Once again, the fact that adolescents spend a great deal of the time during the day in a sitting position at school could result in hip flexor tightness. Although there was a slight tendency for a higher mean for left-sided hip flexor tightness than right sided tightness in all the subjects, the difference was non-significant.(See appendix G figure 49) No relevant literature could be found.

5.2.10. HUMP SIZE

Thoracic humps of more than six millimetres were most frequently measured in the thoracic area (figure 20). Right-sided thoracic humps were present significantly more frequently than left-sided humps ($p=0,05$). The literature states that 80 % of the thoracic curves were found to be convex to the right^{11,32,33}, which supports the findings of this

study. Although only a few lumbar humps were observed in this study, there was a tendency for more left-sided lumbar humps of more than six millimetres to be present. However, the difference between the presence of left- and right-sided lumbar humps were non-significant ($p=0,32$). The literature indicates that spinal curves in the lumbar area are present towards the left in 90 % of the lumbar curves.^{11,32}

In this study, thoraco-lumbar humps were found significantly more frequently than lumbar humps ($p=0,0003$). Thoraco-lumbar humps of more than six millimetres were also present more frequently on the right-hand side than on the left-hand side but this was non-significant ($p=0,22$). (See figure 20) Due to the fact that no radiographs were taken in this study, it was difficult to determine the presence of double curves. A trend was noticed that right-sided thoracic humps of at least six millimetres and more, were present more frequently than thoraco-lumbar humps on the right-hand side ($p=0,08$).

The thoracic area is more vulnerable for the development of scolioses than any other spinal area. This study, as well as previous studies^{11,32,33}, indicate that right sided thoracic curves develop more frequently than left sided thoracic curves.

5.2.11. ANGLE OF TRUNK ROTATION

An angle of trunk rotation of five degrees and more was present in 41 % of subjects from the case group, and in 68 % of subjects from the case group who presented with a hump size of six millimetres or more. A significant correlation was found between the angle of trunk rotation, measured by means of the inclinometer, and the hump sizes, measured by means of a spirit level and a graduated ruler.

5.2.12. PLUMBLINE

A deviation of the plumbline from the gluteal cleft occurred more frequently ($p=0,06$) towards the left hand side in subjects from the case group. Due to the fact that double curves and pelvic deviations were not taken into consideration, this deviation of the plumbline was not necessarily an indication of the side of the primary curve.

It was interesting to note that almost half of the subjects from the control group also presented with a deviation from the plumbline. This could be an indication of the number of subjects with poor postures who participated in this study. Although non-significant, this deviation of the plumbline from the gluteal cleft was present more often towards the right in the control group. This could be an indication of the postures that develop due to the unilateral carrying of school bags.

The spinal area where a deviation from the plumbline was most frequently present was the thoracic area, which was also the area where most of the humps occurred. The literature indicates that any deviation from the plumbline of less than ten millimetres can be considered as normal.³⁶ The measurements in millimetres of the distance of the plumbline from the gluteal cleft and from the midline of the spine were influenced by the sway of the body, due to weight transfer, and the fact that many of the subjects struggled to stand still: These measurements were thus considered unreliable and were discarded from the results of this study.

5.2.13. KYPHOSIS AND LORDOSIS

Almost half of the subjects from the case group (49,2 %) presented with a hyperkyphosis. This percentage consisted of subjects who presented with only a sagittal plane deformity

and those who had combined sagittal and coronal plane deformities. The mean measurement of kyphosis for the group with hyperkyphosis was 53,1 degrees. In the literature the mean for normal subjects varied.^{2,8,17,47,78,88} As guidelines by the Scoliosis Research Society state that a normal kyphosis should not exceed 45 degrees, this was considered the gold standard for this study.⁴⁷

The postural round back could be a result of weak postural muscles and could proceed to develop into a structural kyphosis.^{5,23,51} Therefore the data for the postural round back as well as the structural hyperkyphosis were included in this study. No postural correction of the subjects was done prior to taking measurements.

Only 6,6 % of the subjects presented with a hypokyphosis (mean of 16,65 degrees; standard deviation: 4,3)). One subject presented with a hypolordosis, and hyperlordoses were not found in this sample.

5.2.14. FORWARD HEAD POSTURE

A forward head posture was present in 45,9 % of subjects from the case group 56,7 % of subjects with a hyperkyphosis also presented with a forward head posture. There was a trend for a forward head posture to be present with a hyperkyphosis but this was non-significant ($p=0,15$). No study was found to correlate hyperkyphoses with forward head postures, but Hilibrand *et al* (1995)³⁸ did determine a significant relationship between hypokyphoses seen in idiopathic scolioses and the flattening of cervical lordoses.

5.2.15. WINGING OF SCAPULAE

Asymmetrical winging of the scapulae was observed in both the case (54,74 %) and control group (37,21 %). The asymmetrical winging of the scapulae was significantly more frequently present on the right side ($p=0,02$) in the case group, while the left-sided asymmetrical winging in the control group was observed more frequently ($p=0,079$). The higher percentage of winging on the right hand side of subjects from the case group correlates with the fact that more right sided thoracic humps were present in this study, as well as results in the literature.^{11,32,33} Once again the high percentage of asymmetrical winging of the scapulae could be an indication of poor postural control of subjects in this study.

5.2.16. ASYMMETRICAL ELEVATED SHOULDER

The presence of an asymmetrically elevated shoulder was observed in both the case and control groups (figure 12). In the case group a trend for more right-sided elevation of the shoulder was observed ($p=0,95$). This correlates with the higher percentage of right sided asymmetrical scapular winging and the higher percentage of right sided thoracic humps. The literature indicates that a right sided thoracic scoliosis would result in the right sided scapula to be elevated and forcibly lifted by the rib hump.³²

The asymmetrical elevation of the shoulder girdle was significantly more frequently present on the left-hand side in subjects from the control group ($p<0,0001$). This asymmetrical posture could possibly be due to the fact that adolescents carry their school bags in one hand only, pulling the right hand shoulder down. Unfortunately, this study did not include the side of preference for carrying a school bag, nor the dominant side of the subjects.

5.2.17. ARM DISTANCE FROM TRUNK

The presence of one arm further away from the trunk was also observed in both the case and control groups (figure 26). Most of the subjects from the case and the control groups presented with the left arm significantly further from the trunk ($p < 0,0001$ in the case and the control groups). With the higher percentage of thoracic humps it would be expected that the case group would lean more towards the right, causing the right arm to be further away from the body. This incongruity in data could be due to the fact that double curves were not noted. Only the arm hanging further from the trunk was noted and not the flank folds. It was initially decided not to include the flank folds because it could be possible that flank folds have not yet developed in early scoliosis.

A "normal spine" (kyphosis/lordosis within normal limits, without deviation from the plumbline and no humps of six millimetres and more) was present in 17,3 % of the total number of subjects. The literature indicates that symmetrical spines have a prevalence of 22 %.⁶⁶

Once the objective evaluation was complete, the mother was interviewed with regard to developmental milestones and other factors which may have influenced the development of adolescent spinal deformities.

5.3. QUESTIONNAIRE

An analysis of information obtained during interviews with the mothers follows. Findings with regard to the developmental milestones (sitting, crawling and walking) will be discussed, followed by other possible contributing factors such as developmental aids, family history, gestation, birth method, lying position, defective hearing and vision, and growth spurt.

5.3.1. DEVELOPMENTAL MILESTONES

5.3.1.1. SITTING

Most of the subjects from the case and the control groups sat at an average developmental time of between six and nine months (figure 27). Although a baby should be able to sit independently by the age of six to nine months, postural control in this position has not yet developed.^{102,113,120}

Slightly more subjects from the case group than the control group sat before six months, but this was non-significant (figure 27). Sufficient postural tone is present by the age of six months to maintain the body against gravity in a sitting position, but the position is not yet erect.¹⁴ It would appear that a possible lack of postural control before six months, results in a tendency for subjects who sat early, to develop a deformity.

5.3.1.2. CRAWLING

Only 13,11 % of the subjects from the case and 4,65 % from the control group did not crawl (figure 28). The literature indicates that 82 % of infants are crawlers.²⁵ This study presented with 86,9 % of crawlers in the case group, compared to the 95,4 % in the control group. The percentage of crawlers was higher in the control group ($p=0,075$) than in the case group. This trend could indicate that crawling is an important milestone in the developing sufficient postural control to prevent spinal deformities at a later stage.

Crawling on hands and knees is the most important pre-standing locomotion activity²⁵. Researchers found that crawlers, who were evaluated at an age of five years, showed no asymmetry, whilst children who shuffled or just stood up and walked, did show asymmetry

in their motor activity. Hypotonia in the central trunk is related to the choice of locomotion before walking.²⁴ The fact that non-crawling subjects from this study, showed the highest association with the presence of spinal deformities (table 5), supports the findings of the aforementioned researchers, as well as the unsupported hypothesis of Boachie-Adjei *et al* (1996)², stating that abnormal developmental milestones may be a cause of spinal deformities.

Crawling (case and control groups) mostly commenced at an age of six to nine months (figure 29). Slightly more (non-significant, $p=0,2$) subjects from the case than from the control group crawled at the age of six to nine months. Although crawling at an age of six to nine months cannot really be considered pathological, the literature does show that the normal average age at which crawling should commence, is between nine and twelve months.¹⁴ In this study, a slightly higher percentage (non-significant, $p=0,14$) of subjects from the control group commenced to crawl between nine to twelve months (figure 29). There was one subject from the case group who crawled very late (12 - 15 months). It was interesting to note that this subject was very tall (172,5 centimetres) at the age of 15 years and 10 months, and presented with a hyperkyphosis of 60,3 degrees. Once again it can be postulated that a lack of postural control, due to late gross motor milestones, could have contributed to the development of this hyperkyphosis.

Subjects who did crawl, mostly crawled for long periods (figure 30). The period of crawling most frequently noted in the case and control groups, was two to three months. Although non-significant ($p=0,38$), slightly more subjects from the case group were reported to have crawled for this period of time. The period of crawling for longer than three months, was noted equally in the case and control groups. Crawling for less than one month was reported slightly more frequently in subjects from the control than from the case group, but this was non-significant (figure 30). Although it can be reported that crawling is an important factor in the prevention of hypotonia and subsequent deformities,

this study showed no evidence that a short or long period of crawling was beneficial. The literature states that crawling develops between 10 and 12 months and during this period diagonal trunk control should develop¹¹⁴ ; but the ideal time period necessary to develop this motor skill, before walking commences, was not found in the literature.

More subjects from the case group were reported to have had an alternative method of locomotion prior to walking. However, no significant comparison concerning the alternative method of locomotion could be made between subjects from the case and the control groups. (See table 4)

5.3.1.3. WALKING

Humans do not acquire sufficient postural control to stand upright and walk until the last month of their first year.^{102,114,116} There were very early and very late walkers in both the case and the control groups in this study (figure 32). More subjects from the control group had walked by the end of their first year (figure 32). It was, however, in the time period of 12 to 15 months, that a trend for a higher frequency of subjects from the case group, 42,37 % cases compared to 28,57 % controls, were reported to have started walking ($p=0,078$). Although this period for commencing walking is not considered abnormal, it can be considered slightly late.^{114,116} It could be hypothesised that the late walkers had a degree of hypotonia and that this delayed the walking milestone. This can be verified by the fact that, according to the Logit analysis, the subjects who did not crawl and commenced walking after the age of 12 months, were more prone to develop spinal deformities (probability of 0,90). Bottos *et al* (1989)²⁴ found that missing the stages of crawling or creeping did not influence the neurodevelopmental evolution up to an age of five years. However, from the results of this study, it would seem that the fact that the subjects did not crawl could be attributed to hypotonia during babyhood and that they therefore became late walkers.

5.3.2. DEVELOPMENTAL AIDS

5.3.2.1. SIT CHAIR

Very little literature was found on the effect of developmental aids on the milestones of babies. Bottos et al (1989)²⁴ suggest that babies should move on the floor in their first year of life. Children who are restricted from moving freely, due to overprotective parents and continuous choice of locomotion by parents, could be limited in their experience of locomotive strategies.²⁴

There was a slightly higher tendency for subjects from the case group to be placed in a sit chair more frequently than subjects from the control group ($p=0,41$). (See figure 33) There was no evidence that the duration of use of a sit chair had any influence on the development of deformities. There was, however, an interesting tendency for more subjects from the case group to have used the sit chair for less than one hour, compared to the tendency for subjects from the control group to have used the sit chair for one to two hours (figure 34). It could be postulated that subjects from the case group were removed from the sit chair earlier (less than an hour) because they became tired as a result of weak postural muscles. Unfortunately, this study did not investigate why the mothers removed the subjects from their sit chairs at a specific time.

5.3.2.2. WALKING RING

There was a trend for subjects from the case group to use walking rings more frequently than subjects from the control group ($p=0,14$). (See figure 35) Postural control was possibly not stimulated due to a lack of full weight bearing in a walking ring. This could be why the use of a walking ring was reported more frequently amongst case subjects.

Although non-significant, the time period of one to two hours' use of the walking ring was reported more frequently amongst the subjects from the case group, while the shorter period (under one hour) was reported more frequently in subjects from the control group. This finding could possibly suggest that the longer subjects were placed in the walking ring the less postural control they developed.

5.3.2.3. "JOLLY JUMPER"

A small percentage of the subjects from case and control groups were placed in "jolly jumpers" as babies. There was a slightly higher percentage for subjects from the control group to use a "jolly jumper". A possible explanation for this could be that the jumping action in the "jolly jumper" may have stimulated muscle contraction and therefore contributed to postural control. There was no significant evidence of any influence of the time period in the "jolly jumper" on the development of spinal deformities (figure 38).

5.3.3. OTHER FACTORS

5.3.3.1. FAMILY HISTORY

A family history of deformities was reported significantly more frequently in the case group than in the control group. The literature also indicates that both adolescent idiopathic scoliosis^{1,2,5,8,11,29,32} and Scheuermann's kyphosis¹¹ have a genetic basis. It was interesting to note that more mothers from the control than case group had a family history of deformities although this was of no statistical significance. Deformities of the grandmothers and grandfathers may have been due to geriatric changes. The researcher was unable to determine whether their deformities were definitely due to changes during adolescence.

No family history of deformities in distant family on the paternal side were reported in the control group. This could be due to the fact that only the mothers were questioned, and that they were uncertain of the paternal family history.

5.3.3.2. GESTATION

Most of the subjects (62,75 %) were born after a gestation period of 40 weeks (figure 40). The percentage of the cases compared to the percentage of the controls who were full term, were more or less equal (figure 40). The thirty eight week gestation period was reported more frequently in subjects from the control group, but this could be due to more Caesarean deliveries in the control group (figure 41).

5.3.3.3. BIRTH METHOD

Normal births were seen almost equally in the case and control groups. Normal births with the aid of instruments occurred slightly more frequently in the case group, while births by means of Caesarean section were reported slightly more often in the control group (figure 41). Birth method had no significant influence on deformities.

5.3.3.4. LYING POSITION

The most preferred lying position for subjects from both the case (35,19 %) and the control group (40 %), was side lying. This could be due to the fact that most of the nursing homes and hospitals teach mothers to position their babies in side lying in order to prevent choking (cot deaths). Lying on a specific side could be a likely cause of trunk asymmetry^{114,117}, although no evidence to support this statement was found in this study.

More subjects from the case than control group preferred back lying in babyhood but this was non-significant ($p=0,25$). Babies who are positioned in supine are rarely symmetrical,^{114,117} and a posterior tilting of the pelvis and increased flexor tone could lead to a more kyphotic posture.¹¹⁴ This could be a reason for the higher percentage of subjects from the case group who preferred back lying.

Prone encourages symmetrical positioning¹¹⁷ and was reported more or less equally in the case and in the control groups. Infants who sleep in a prone position roll over sooner than infants who prefer side or back lying.¹¹⁸ Unfortunately, rolling over as a gross motor milestone, was not evaluated in this study.

5.3.3.5. DEFECTIVE HEARING

A slightly higher percentage of subjects from the control group (11,63 %) than from the case group (9,84 %) presented with defective hearing.(See appendix G figure 50) The deformities noted amongst those with defective hearing were: one subject with a sagittal plane deformity, two with a coronal plane and three with combined sagittal and coronal plane deformities. Only 8 % of case subjects with coronal and combined coronal and sagittal plane deformities presented with defective hearing. This is an indication that defective hearing did not have an influence on the development of asymmetry in this study. To date the effect of defective hearing on an asymmetrical spine has not yet been researched.

5.3.3.6. DEFECTIVE VISION

A slightly higher percentage of subjects from the case than from the control group presented with defective eyesight (appendix G figure 51). However, only 30 % of those with defective eyesight presented with a forward head posture, and there was an equal

distribution of sagittal and coronal plane deformities amongst the subjects with defective eyesight. Correlation between defective eyesight and deformities was not found in this study. The literature only describes the association of lateral gaze palsy with progressive scoliosis²². It can only be postulated that poor eyesight could have an influence on the development of a forward head posture.

5.3.3.7. KNOWLEDGE OF DEFORMITY

It was interesting to note that 67,21 % of mothers of subjects in the case group did not realise that their offspring had a deformity. Those mothers who were aware of a deformity noticed it at an age between 10 and 15 years. This time period correlates with the ages when growth spurts occur in adolescents and when adolescent scolioses develop.^{1,9}

5.3.3.8. GROWTH SPURT

A significantly higher percentage ($p=0,009$) of sudden growth spurt in subjects from the case group was reported (figure 30). This growth spurt occurred most frequently in the ten to fifteen years age period. The growth velocity *per se* is not a primary cause of adolescent idiopathic scoliosis, but it appears that taller adolescents develop deformities.^{4,5,7,31} Progression of the spinal curve occurs during a growth spurt which takes place at around twelve years in girls and two years later in boys.¹ The growth spurts noted in this study are in accordance with those reported in the literature.^{1,5,6,8,9}

5.4. SUMMARY

Although recall bias must be taken into consideration, it was clear from this discussion of the results that some data correlates with that found in the literature. Screening of adolescents in

this study indicated that poor postures and deformities are widely prevalent amongst white adolescents in Middelburg, Mpumalanga. This far exceeds the prevalence of deformities given in the literature. The results of the information obtained from the questionnaire also indicate some correlation with the literature.

This study showed some correlation with the literature with regard to certain aspects: the ratio of deformities according to – gender, age, family history, age of milestones and the effect of growth spurts. Once again it must be noted that no generalisation of results can be made as the sample was limited to white adolescents. The effect of other factors such as the use of walking rings and “jolly jumpers” on the development of spinal deformities was not found in the literature.

The fact that much of the information with regard to developmental milestones was given retrospectively, may have affected the validity of this study.

CHAPTER 6

CONCLUSION AND RECOMMENDATIONS

6.1. INTRODUCTION

The specific aims of this study were to determine the influence of certain developmental milestones, the use of developmental aids and certain other factors on the development of spinal deformities. The developmental milestones were:

- the age at which the subjects sat independently as babies
- whether the subjects crawled or not
- the age at which the subjects crawled as babies
- other ways of locomotion that the subjects used before they walked
- the age at which the subjects walked independently

The developmental aids were sit chairs, walking rings and "jolly jumpers"

Other factors observed were:

- family history
- period of gestation
- birth method
- preference of lying position
- the effect of hearing defects
- the effect of poor eyesight
- growth spurt.

6.2. CONCLUSIONS

Considering the ethnicity of the sample, the following conclusions with regard to the aims of this study were made and would therefore be applicable to white adolescents in Middelburg, Mpumalanga:

6.2.1. DEVELOPMENTAL MILESTONES

- ⇒ No significant influence of the gross motor milestone of sitting and development of deformities was found in this study, although more subjects from the case group sat at an earlier age.

- ⇒ There was a non-significant trend for more crawlers to be present in the control group. More subjects in the control than in the case group crawled between nine to twelve months (considered the normal period). Although this was statistically non-significant, it appears from the literature that crawling at this stage is beneficial to the development of postural control.¹¹⁴ No evidence of the advantage of a short or long period of crawling was obtained from this study. An alternative method of locomotion, other than crawling, showed no significant influence on the development of deformities.

- ⇒ Late walkers (twelve to fifteen months) were associated with the development of spinal deformities. The Logit analysis indicated that late walkers who also did not crawl had the highest probability of developing spinal deformities.

6.2.2. DEVELOPMENTAL AIDS

- ⇒ The sit chair had no significant influence on the development of spinal deformities, although subjects from the case group were placed in a sit chair slightly more frequently than their counterparts.

- ⇒ A walking ring was used more frequently in subjects from the case group, although this was statistically non-significant. It can, however, be postulated that a walking ring may negatively influence the development of postural control.

- ⇒ Although no significant influence of a "jolly jumper" on spinal deformities was found, there was a slightly higher tendency for subjects from the control group to use a "jolly jumper". This could imply that possible stimulation of muscle contraction could have positively influenced the postural control.

6.2.3. OTHER FACTORS

- ◆ A correlation between spinal deformities and a family history of deformities was found.

- ◆ The gestation period as well as the birth method had no influence on the development of spinal deformities.

- ◆ The most preferred lying position for both the case and control group subjects was side lying, possibly due to the fact that this is the position preferred by nursing homes to prevent choking. Although non-significant, a higher percentage of subjects from the case group preferred back lying which may have tended to influence the development of kyphotic posture.



- ◆ Defective hearing did not have an influence on the development of asymmetry.
- ◆ No correlation between poor vision and spinal deformities was found. It can only be postulated that poor vision may have a negative influence resulting in a forward head posture.
- ◆ Many mothers in Middelburg, Mpumalanga, were unaware of the presence of deformities in their offspring.
- ◆ A sudden growth spurt was reported significantly more frequently in the case than in the control group.
- ◆ Although non-significant, there was a higher percentage of girls who presented with deformities in the coronal plane, while a higher percentage of boys presented with a sagittal plane deformity.
- ◆ The mean age was higher in the case group.
- ◆ Significantly more subjects from the case group had reached their menarche at the time of evaluation.
- ◆ The girls and boys from the case group were significantly taller than those from the control group. Subjects with combined sagittal and coronal plane deformities were significantly taller than those with only a sagittal plane deformity. A trend was noted for subjects with combined coronal and sagittal plane deformities to be taller than those with only a coronal plane deformity.

- ◆ The leg length discrepancies of subjects in this study were minimal and, not associated with the presence of deformities.
- ◆ No correlation was found between decreased hamstring flexibility and the presence of deformities.
- ◆ Most of the subjects presented with hip flexor tightness, but a significant association with deformities was not found.
- ◆ The thoracic area is the most vulnerable area for deformities of the spine. Right-sided thoracic curves occurred significantly more frequently than left-sided thoracic curves. Thoraco-lumbar curves were found significantly more frequently than lumbar curves.
- ◆ There was a trend for more spinal deviation to the left side of the gluteal cleft to be present in subjects of the case group subjects. Deviations of the spine occurred most frequently in the thoracic area.
- ◆ Almost half of the subjects from the case group presented with a hyperkyphosis.
- ◆ There was a tendency for a forward head posture to be present with a hyperkyphosis, although this was statistically non-significant.
- ◆ Significantly more right than left-sided winging of the scapula, as well as a trend for more right-sided elevated shoulders, were present in the subjects from the case group, which correlated with the higher occurrence of right sided thoracic curves.
- ◆ Subjects from the case and control groups, presented with the left arm hanging further from the trunk significantly more frequently, than to the right side.

- ◆ A "normal spine" (where the kyphosis and lordosis were within normal limits, no deviation from the plumbline was present, and no humps of six millimetres and more were measured) was present in only 17,3 % of subjects in this study compared to 22% in the literature.⁵⁵

6.3. CRITICAL EVALUATION OF THE STUDY

The following shortcomings were identified after the completion of this study:

- Recall bias – milestones reported by the mothers were obtained retrospectively making the accuracy of this information dubious.
- The study was conducted on a limited population. No generalisation of results can be made.
- A sample of convenience was conducted, possibly resulting in more subjects who knew or suspected that they had a deformity, to be willing to participate in the study.
- The age of 12 to 17 years was used in this study to enable the sample to be large enough for statistical analysis. It would have been ideal to evaluate subjects of the same age. It is possible that the younger subjects could still develop a deformity later.
- Due to the fact that the sample was not large enough, statistically significant results were not always possible. A larger sample would have made it possible to make more valid conclusions with regard to the different planes of deformities.
- An equal sampling of boys and girls in each of the groups would have been better.
- As no radiographs were taken, the level of the kyphosis and scoliosis could not be determined precisely. The end vertebrae were thus not determined.
- Babies most frequently walk at the age of one year. The categories used in this study with regard to walking could have been confusing. The age of one year (12 months) should have been the median of a category of walking (11-13 months).

- The knowledge of mothers with regard to visual and auditory problems was not always accurate.
- The questionnaires were completed with only the help of the mothers, which caused possible bias with regard to information of deformities on the paternal side
- Hand dominance of subjects was not evaluated. Although some authors suggest that hand dominance should be evaluated, no correlation between hand dominance and idiopathic scoliosis was found in the literature.^{33,49} Hand dominance could, however, give important information with regard to posture and the preference of carrying a school bag.
- A standing evaluation of leg length discrepancy would have been better to determine the direct effect of any difference on the posture or spine
- Measurement of the distance from the plumbline to the spine was inaccurate and therefore not taken into consideration in this study.
- The fact that there were too many variables made the analysis of the study difficult. In view of the fact that the plumbline measurements were ineffective, it could have been left out completely. The aim of the objective evaluation was to identify whether a spinal deformity was present in order to allocate the subject to a case or control group. Although tightness of the hip flexors and hamstring muscles may influence a spinal deformity, the focus in this study should have been limited to the presence of the deformity. It was difficult to determine the exact influence of auditory and visual impairment on spinal deformities. Family history has previously been proven to have an influence on spinal deformities and was not the focus of this study. The questionnaire could have been limited to the developmental aspects only.
- Participation in sports and physical education were not considered. Physical activities may play a role in the development, prevention and / or stabilising of deformities.

6.4. RECOMMENDATIONS

This study has highlighted the difficulty of identifying developmental milestone predictors for the prevalence of spinal deformities. The retrospective nature of reports received from the mothers may have affected the validity and reliability of information.

The following recommendations are made in view of the shortcomings of this study:

- Conduct a longitudinal study in co-operation with baby clinics in South Africa to determine the influence of developmental milestones on the prevalence of spinal deformities. An accurate detailed recording of the developmental milestones of babies should be made at their follow-up visits to clinics, and the babies should be followed up until the age of 16 years to determine the prevalence of spinal deformities. More accurate information with regard to the developmental milestones, gestation period and birth process will be obtained. The sample will also be more representative of the general population.
- Conduct a comparative study, considering the different ethnic groups, to determine the influence of developmental milestones on the development of adolescent spinal deformities.
- The use of aids such as sit chairs, walking rings and "jolly jumpers" and their possible association with the development of spinal deformities should receive more attention.
- Determine auditory and visual disabilities by means of specialised evaluations.
- The sway of the body due to weight transfer and the fact that many of the subjects struggled to stand still, could be corrected in future studies by letting the subjects hold onto a horizontal bar.
- Education of mothers with regard to the importance of normal developmental milestones and the possible negative effect of a walking ring as a developmental aid should be

emphasised. The relationship between sudden growth spurts, taller subjects and a genetic factor and the presence of spinal deformities was highly significant. Mothers of subjects should be educated to evaluate the spines of their offspring, especially where these aforementioned factors are relevant.

- A further study should be conducted to investigate whether the physical activities of scholars affect the development, progression, prevention and / or stabilisation of deformities.
- The fact that no black, or Asian mothers responded to the request for participation in this trial is an interesting point, and leads to further research questions:
 - what is the prevalence of spinal deformities in these ethnic groups
 - is it necessary to educate the previously disadvantaged population of South Africa with regard to the possible development of spinal deformities and significance thereof ?

The fact that no literature was found comparing spinal deformities in adolescents of ethnic groups, identifies a gap in research in South Africa.

6.5. SUMMARY

It would appear, from the study, that deviations from normal developmental milestones, and certain other factors (as described earlier), did not have a significant influence on the prevalence of spinal deformities in white adolescents in Middelburg, Mpumalanga. Developmental milestones cannot be considered to be an aetiological factor, but they may affect postural tone in adolescents.

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APPENDIX A

LECTURE AT SCHOOLS

Back problems are seen increasingly in young children. There are a variety of causes. Some can be hereditary, while others may be due to injuries. Many problems may be due poor posture.

There are two problems that I would like to explain:

- Scoliosis or an S-formed back:

The development of an S-formed back is usually permanent. If this deformity is noticed early it can be treated successfully; if not, the deformity can worsen and cause severe complications. Movement can be affected and respiratory complications can develop.

Scolioses are seen in at least three per cent of all adolescents. It is present more frequently in girls, especially in those girls who grow fast. If one's parents have spinal deformities one would be more vulnerable to develop a deformity. This deformity can be verified by X-rays, but certain recognisable postural features can also identify this problem:

- * one shoulder will be higher
- * one shoulder blade will stand away from the body
- * one arm will hang further from the body or a skin fold will be present on the one side
- * a prominent rib hump will be present

The second back problem that I would like to explain is the kyphosis or hunched back. This can develop in one specific area of the back or in the back as a whole, and is seen in eight per cent of adolescents. A kyphosis is present more frequently in boys than in girls, and hereditary factors can also cause this deformity.

These conditions can be treated by means of exercises and a brace. In severe cases the back will be operated on, resulting in a stiff back.

A few important factors that you can look at are:

- * Do not do your homework on the floor or the bed
- * Sit on a good supporting chair at a table
- * It is ideal for the table to be inclined
- * Sit with your chair close to the table
- * Prevent poking of the chin when doing homework
- * Never carry your bookcase over only one shoulder
- * Ideally, carry your bookcase over both shoulders, but do not lean forwards
- * Sit up straight in front of the television and in the classroom
- * Stand up straight with your weight evenly distributed between both feet
- * When you do sport activities, warm up well with emphasis on the stretching of hamstring muscles
- * Do not sleep on your stomach
- * Support your neck in a neutral position by means of a pillow
- * Do not pick up heavy objects
- * Always bend your knees and keep your back straight when you pick up an object

Information forms will be handed out. Please give them to your parents. A volunteer form for a research study I am conducting, has also been attached.

Thank you

APPENDIX B

INFORMATION LETTER

SPINAL DEFORMITIES IN ADOLESCENTS

Scoliosis (S - formed back) and kyphosis (round back) are very common disorders that start during adolescence. The reasons for the development of these disorders are not all known. A research study is currently being done in Middelburg to identify certain causative factors of back deformities. The research is aimed at children between twelve and seventeen years who attend any of the schools in Middelburg. There are no costs involved in participating in this research study. During the research your child's back will be examined for any deformities. Afterwards the mother of the child will be interviewed with regard to the child's development for approximately twenty minutes.

It is in the interest of your child and other children to participate in this study, irrespective of whether your child has a deformity or not. Early diagnosis and treatment of a deformity provide a better prognosis for the child. The results of this study could enable physiotherapists to help prevent and treat deformities in a more effective way. An exercise programme, to either treat or limit a deformity, will be given to your child after the examination of his / her back.

The researcher is a Master's student at the Department of Physiotherapy of the University of Pretoria and the research will be done in Middelburg, Mpumalanga.

Please complete the attached form and return it to the school before 23 / 09 / 98 or contact me at any of the following telephone numbers : (w) 013 - 2824440 (h) 2824280 cell. 0828952403.

Thank you

Ms René Alberts



VOLUNTEER

I hereby give permission that you may contact me and my child for an appointment.

PARENT:.....

CHILD:.....AGE:.....

SCHOOL:.....

TEL NO : (W).....(H).....

SPINALE DEFORMITEITE BY ADOLESSENTE

'n Skoliose (S - vormige rug) en 'n kifose (boggelrug) is algemene deformiteite wat by adolessente voorkom. Die redes vir die ontwikkeling van hierdie deformiteite is nie almal bekend nie. Daar word tans 'n navorsingstudie gedoen in Middelburg om sekere oorsaaklike faktore van spinale deformiteite te identifiseer. Die studie word gedoen op kinders tussen twaalf en sewentien jaar wat skoolgaan in Middelburg. Daar is geen kostes verbonde aan deelname in hierdie studie nie.

Tydens die navorsingprosedure sal u kind se rug geëvalueer word vir enige deformiteite. Daarna sal die moeder van die kind ondervra word met betrekking tot die ontwikkeling van die kind. Dit is in belang van u kind sowel as ander kinders om deel te neem aan hierdie navorsingstudie, hetsy u kind 'n afwyking het of nie, en of u 'n afwyking vermoed. Vroeë diagnose en behandeling van 'n deformiteit sal lei tot 'n beter prognose. Die resultate van hierdie studie kan moontlik fisioterapeute help om in die toekoms deformiteite beter te behandel of moontlik te voorkom. 'n Oefenprogram sal na afloop van die evaluasie aan u kind gegee word om sy / haar spiere te versterk en /of om die deformiteit te behandel.

Die navorser van hierdie studie is 'n Magister student van die Departement Fisioterapie aan die Universiteit van Pretoria en die navorsing word gedoen in Middelburg, Mpumalanga. Voltooi asseblief die volgende vorm en stuur dit terug aan die skool voor 23 / 09 / 98 of kontak my by enige van die volgende telefoonnummers: (w) 013 - 2824440 (h) 013 - 2824280 sel. 0828952403.

Baie dankie

Mev. René Alberts



VRYWILLIGER

Hiermee stem ek as ouer toe dat u my kan kontak vir 'n afspraak met my en my kind.

OUER:.....

KIND:..... OUDERDOM:.....

SKOOL:.....

TEL: (W).....(H).....

APPENDIX C

INFORMED CONSENT

Protocol : 94/98

TITLE:

AN INVESTIGATION INTO THE ASSOCIATION BETWEEN DEVELOPMENTAL MILESTONES OF BABIES AND THE PREVALENCE OF SPINAL DEFORMITIES IN ADOLESCENTS.

RESEARCH STUDY

I,....., willingly agree to participate in this research study which has been explained to me by Ms René Alberts. This research study is being conducted by the Departement of Physiotherapy at the University of Pretoria where Ms Alberts is a post-graduate student.

PURPOSE OF STUDY

The purpose of this study is to determine if there is an association between the milestones of babies and the prevalence of spinal deformities in adolescents.

DESCRIPTION OF PROCEDURES

This is a research study where certain criteria are necessary for eligibility to either the case or control groups.

This study includes a physical evaluation of the adolescent's spine. The adolescent will be examined for any abnormality in the curve of the spine. He/She will be dressed in a pair of shorts and the girls will also wear a halter-neck top. After the physical examination the mother will be interviewed with regard to certain aspects of the development of the adolescent during his/her early years. The physical examination will take approximately twenty minutes.

RISKS OR DISCOMFORTS

There is no danger of any exposure of intrusive procedures. No discomfort will be experienced during any of the examination techniques.

CONTACT PERSONS

The researcher is a Master's student at the Physiotherapy Department of the University of Pretoria and the research will be done in Middelburg, Mpumalanga.

BENEFITS

It is in your interest to participate in this study because early diagnosis and treatment of a deformity provides a better prognosis for adolescents. The result of this study could enable us as physiotherapists to help prevent and treat deformities in a more effective way.

ALTERNATIVES

The control and experimental groups will both undergo the same evaluation procedures.

VOLUNTARY PARTICIPATION

Participation in this study is voluntary. No compensation for participation will be given. Each participant will receive an exercise programme to prevent/treat the appropriate deformity. You are free to withdraw your consent to participate in this research study at any time. If you refuse to participate or withdraw, you will still receive an exercise programme.

CONFIDENTIALITY

A record of the participant's evaluation will be kept in a confidential file at the private physiotherapy practice of Ms René Alberts and also in a computer file of the Window '95 program at 13 Letaba Street, Middelburg, Mpumalanga. No information by which you can be identified will be released or published.



I have read all the above, had time to ask questions, received answers concerning the areas I did not understand and I willingly give my consent to participate in this research study. Upon signing this form, I will receive a copy.

(PATIENT SIGNATURE)

DATE

WITNESSES SIGNATURE:

1. _____

2. _____

DATE

DATE

(SIGNATURE OF PARENT)

DATE

WITNESSES SIGNATURES:

1. _____

2. _____

DATE

DATE

PHYSIOTHERAPIST SIGNATURE

DATE



APPENDIX D

EXCLUSION CRITERIA

- (i) Any congenital deformities of lower limbs, chest or back?
- (ii) Previous fractures to vertebrae?
- (iii) Any spinal deformity of neurological origin?
- (iv) Previous thoracic surgery?
- (v) Any disease such as cystic fibrosis, TB?
- (vi) Permanent use of crutches/wheelchair?

YES	NO
YES	NO
YES	NO
YES	NO
YES	NO
YES	NO

PHYSICAL EVALUATION

1. Respondent No:		V1				1 2 3					
2. Card No:		V2	1				4				
3. Case	1	Control	2				V3		5		
4. Age:	Years			Months			V4				6 7 8
5. Gender:	Male	1	Female	2				V5		10	
6. Age of menarche in females					years		V6			11 12	
7. Height	<div style="display: flex; justify-content: space-between; align-items: center;"> </div>					mm	V7				13 14 15
8. Leg length discrepancy:	(L)		(R)								
Difference:	<div style="display: flex; justify-content: space-between; align-items: center;"> </div>					mm	V8				17 18 19
8.1 Longest Leg:	Left (1)		Right (2)		Equal (3)				V9		20
9. Straight leg raise: (Inclinometer)											
Degrees (L)	<div style="display: flex; justify-content: space-between; align-items: center;"> </div>					V10				21 22 23	
Degrees (R)	<div style="display: flex; justify-content: space-between; align-items: center;"> </div>					V11				24 25 26	
10. Thomas Test											
Degrees of hipflexion (Inclinometer)	L	<div style="display: flex; justify-content: space-between; align-items: center;"> </div>					V12				27 28 29
	R	<div style="display: flex; justify-content: space-between; align-items: center;"> </div>					V13				30 31 32



11. Scoliosis

Hump Size: Tx

			mm
--	--	--	----

V14

--	--	--

33 34 35

Side:

Left (1)	Right (2)	Not applicable (3)
----------	-----------	--------------------

V15

--

36

Hump Size: Lx

			mm
--	--	--	----

V16

--	--	--

37 38 39

Side:

Left (1)	Right (2)	Not applicable (3)
----------	-----------	--------------------

V17

--

40

Hump Size: Tx-Lx

			mm
--	--	--	----

V18

--	--	--

41 42 43

Side:

Left (1)	Right (2)	Not applicable (3)
----------	-----------	--------------------

V19

--

44

Angle of trunk rotation:

Forward Bending

		degrees
--	--	---------

V20

--	--

45 46

12. Plumblines:

Distance from gluteal cleft

			mm
--	--	--	----

V21

--	--	--

47 48 49

Left (1)	Right (2)	Not applicable (3)
----------	-----------	--------------------

V22

--

50

Maximum distance from spine

			mm
--	--	--	----

V23

--	--	--

51 52 53

Tx(L) (1)	Tx(R) (2)	Lx(L) (3)
Lx(R) (4)	Tx-Lx(L) (5)	Tx-Lx(R) (6)
Not applicable (7)		

V24

--

54

13. Tx Kyphosis: (Inclinometer)

Degrees

--	--	--

V25

--	--	--

55 56 57

14. Lx Lordosis:

Degrees

--	--	--

V26

--	--	--

58 59 60

15. Cx-Tx junction:

Forward head posture

Yes (1)	No (2)
---------	--------

V27

--

61



16. Postural Observations:

**Asymmetric winging
of Scapula**

Yes (1)	No (2)
---------	--------

V28
62

Left (1)	Right (2)	Not applicable (3)
----------	-----------	--------------------

V29
63

**Asymmetric elevated
shoulder**

Yes (1)	No (2)
---------	--------

V30
64

Left (1)	Right (2)	Not applicable (3)
----------	-----------	--------------------

V31
65

**One arm further
from trunk**

Yes (1)	No (2)
---------	--------

V32
66

Left (1)	Right (2)	Not applicable (3)
----------	-----------	--------------------

V33
67



APPENDIX E

QUESTIONNAIRE

Respondent:

V1
1 2 3

Card No:

V2 2
4

1. Does your child have defective hearing

YES (1)	NO (2)	Do not know (3)
---------	--------	-----------------

V34
5

1.1 If YES, is it:

Left Sided (1)	Right Sided (2)	Both (3)
Do not know (4)	Not applicable (5)	

V35
6

1.2 If YES, when did it develop:

< 1 year (1)	1 – 5 years (2)	5 – 10 years (3)
> 10 years (4)	Do not remember (5)	Not applicable (6)

V36
7

2. Does your child have defective eyesight?

YES (1)	NO (2)	Do not know (3)
---------	--------	-----------------

V37
8

2.1 If YES, is it:

Left sided (1)	Right sided (2)	Both (3)
Do not know (4)	Not applicable (5)	

V38
9

2.2 If YES, at what age did it develop?

< 1 year (1)	1 – 5 years (2)	5 – 10 years (3)
> 10 years (4)	Do not remember (5)	Not applicable (6)

V39
10

2.3 If Yes, is He/She

Far sighted (1)	Short sighted (2)	Do not know (3)
Not applicable (4)	Other (5)	Both (6)

V40
11

3. Did you know that your child had a deformity?

Yes (1)	No (2)	Not Applicable (3)
---------	--------	--------------------

V41
12

4. When was the deformity first noticed?

< 5 years (1)	5 – 10 years (2)	10 – 15 years (3)
> 15 years (4)	Do not know (5)	Not applicable (6)

V42
13



5. Does any family member, according to your knowledge, have a deformity?

Yes (1)	No (2)	Do not know (3)
---------	--------	-----------------

V43
14

5.1 If YES what is their relationship

Mother

Yes (1)	No (2)	Not Applicable (3)
---------	--------	--------------------

V44
15

Kyphosis (1)	Scoliosis (2)	Kypho-scoliosis (3)
	Not applicable (4)	Do not know (5)

V45
16

Father

Yes (1)	No (2)	Not Applicable (3)
---------	--------	--------------------

V46
17

Kyphosis (1)	Scoliosis (2)	Kypho-scoliosis (3)
	Not Applicable (4)	Do Not know (5)

V47
18

Sister

Yes (1)	No (2)	Not Applicable (3)
---------	--------	--------------------

V48
19

Kyphosis (1)	Scoliosis (2)	Kypho-scoliosis (3)
	Not Applicable (4)	Do not know (5)

V49
20

Brother

Yes (1)	No (2)	Not Applicable (3)
---------	--------	--------------------

V50
21

Kyphosis (1)	Scoliosis (2)	Kypho-scoliosis (3)
	Not Applicable (4)	Do not know (5)

V51
22

Maternal side:

Grandmother

Yes (1)	No (2)	Not Applicable (3)
---------	--------	--------------------

V52
23

Kyphosis (1)	Scoliosis (2)	Kypho-scoliosis (3)
	Not Applicable (4)	Do not know (5)

V53
24

Aunt

Yes (1)	No (2)	Not Applicable (3)
---------	--------	--------------------

V54
25

Kyphosis (1)	Scoliosis (2)	Kypho-scoliosis (3)
	Not Applicable (4)	Do not know (5)

V55
26

Grandfather

Yes (1)	No (2)	Not Applicable (3)
---------	--------	--------------------

V56
27

Kyphosis (1)	Scoliosis (2)	Kypho-scoliosis (3)
	Not Applicable (4)	Do not know (5)

V57
28



Uncle

Yes (1)	No (2)	Not Applicable (3)
---------	--------	--------------------

V58
29

Kyphosis (1)	Scoliosis (2)	Kypho-scoliosis (3)
	Not Applicable (4)	Do not know (5)

V59
30

Paternal side:

Grandfather

Yes (1)	No (2)	Not Applicable (3)
---------	--------	--------------------

V60
31

Kyphosis (1)	Scoliosis (2)	Kypho-scoliosis (3)
	Not Applicable (4)	Do not know (5)

V61
32

Uncle

Yes (1)	No (2)	Not Applicable (3)
---------	--------	--------------------

V62
33

Kyphosis (1)	Scoliosis (2)	Kypho-scoliosis (3)
	Not Applicable (4)	Do not know (5)

V63
34

Grandmother

Yes (1)	No (2)	Not Applicable (3)
---------	--------	--------------------

V64
35

Kyphosis (1)	Scoliosis (2)	Kypho-scoliosis (3)
	Not Applicable (4)	Do not know (5)

V65
36

Aunt

Yes (1)	No (2)	Not Applicable (3)
---------	--------	--------------------

V66
37

Kyphosis (1)	Scoliosis (2)	Kypho-scoliosis (3)
	Not Applicable (4)	Do not know (5)

V67
38

6. Can you remember during which week of pregnancy your child was born?

YES (1)	NO (2)
---------	--------

V68
39

6.1 If YES, how many weeks?

<input type="text"/>	<input type="text"/>
----------------------	----------------------

V69
40 41

7. Was the birth:

Caesarian (1)	Normal (2)
Normal with Instruments (3)	

V70
42



8. Did your child prefer:

Back lying (1)	Stomach lying (2)	Side Lying (3)
Not one specifically (4)	Do not remember (5)	

V71
43

9. At what age did your child sit independently?

-6 months (1)	6-9 months (2)	Do not remember (5)
9-12 months (3)	+12 months (4)	

V72
44

10. Did your child crawl on his hands and knees?

YES (1)	NO (2)	Do not remember (3)
---------	--------	---------------------

V73
45

10.1 At what age did your child crawl on his hands and knees?

-6 months (1)	6-9 months (2)	Did not crawl (7)
9-12 months (3)	12-15 months (4)	
+15 months (5)	Do not remember (6)	

V74
46

10.2 How long did your child crawl before walking?

-1 month (1)	1-2 months (2)	Not applicable (5)
2-3 months (3)	+3 months (4)	

V75
47

10.3 Did your child move forward in any other way?

YES (1)	NO (2)	Do not remember (3)
---------	--------	---------------------

V76
48

10.3.1 If YES, in what way did your child move forward?

CREEPING ON STOMACH (1)		SHUFFLING ON BUTTOCKS (2)
ROLLING (3)	OTHER WAY (4)	CRAWLING ON HANDS AND FEET (5)
DO NOT REMEMBER (6)		NOT APPLICABLE (7)

V77
49 50 51

52 53 54

55

11. At what age did your child walk independently?

-6 months (1)	6-9 months (2)	9-12 months (3)
12-15 months (4)	+15 months (5)	Do not remember (6)

V78
56

12. Did you make use of a sit chair for your child between birth and one year?

YES (1)	NO (2)	Do not remember (3)
---------	--------	---------------------

V79
57



12.1 If YES, for what length of time per day?

-1 hour (1)	1-2 hours (2)	2-3 hours (3)
+3 hours (4)	Do not remember (5)	Not applicable (6)

V80
58

13. Did you make use of a walking ring for your child between birth and one year?

YES (1)	NO (2)	Do not remember (3)
---------	--------	---------------------

V81
59

13.1 If YES, for what length of time per day?

-1 hour (1)	1-2 hours (2)	2-3 hours (3)
+3 hours (4)	Do not remember (5)	Not Applicable (6)

V82
60

14. Did you make use of a "Jolly jumper" for your child from birth to one year?

YES (1)	NO (2)	Do not remember (3)
---------	--------	---------------------

V83
61

14.1 If YES, for what length of time per day?

-1 hour (1)	1-2 hours (2)	2-3 hours (3)
+3 hours (4)	Do not remember (5)	Not Applicable (6)

V84
62

15. Did your child have a sudden growth spurt?

Yes (1)	No (2)	Do not remember (3)
---------	--------	---------------------

V85
63

15.1 At what age did your child have a sudden growth spurt?

5 - 10 years (1)	10 - 15 years (2)	> 15 years (3)
	Do not remember (4)	Not applicable (5)

V86
64

* Thank you for your participation *

APPENDIX F

PROTOCOL

AN INVESTIGATION INTO THE ASSOCIATION BETWEEN DEVELOPMENTAL MILESTONES OF BABIES AND THE PREVALENCE OF SPINAL DEFORMITIES IN ADOLESCENTS

1. INTRODUCTION

There are numerous spinal deformities in the paediatric population. Idiopathic scoliosis, Scheuermann's kyphosis and the postural round back account for most of these conditions.¹

Idiopathic scoliosis is a combination of lateral curvature in the coronal plane and vertebral rotation.¹ Idiopathic scoliosis should be regarded as a multifactorial disease. No single factor alone has been demonstrated to cause idiopathic scoliosis.² Eighty per cent of structural scoliosis has an unknown cause. The prevalence of idiopathic scolioses in the general population is less than 0,5 % and 1,8 per one thousand for children between eight and eighteen years.³ Factors related to trunk asymmetry, posture, and growth, independent of one another, predict the development of scoliosis.⁴ Idiopathic scoliosis may develop at any age during growth, but it tends to appear more frequently during a growth spurt in the adolescent period.^{3,5} Growth considered in isolation is not a primary cause of idiopathic scoliosis.^{5,6,7} Family studies have shown an increased risk of scoliosis in first degree relatives of patients with idiopathic scoliosis.⁸ Functional impairment in the postural regulation system between the brainstem centre and the proprioceptive system could be an aetiological factor in idiopathic scoliosis.^{9,10}

Kyphosis is by definition a curvature or angulation of the spine in which the concavity faces anteriorly. Scheuermann's kyphosis presents with a typical postural round back and has a prevalence of 0,5 - 8 % in the general population.¹ Postural deformities tend to develop in adolescence when an increase of height and sudden growth spurt occur, but the increase in postural muscle strength is inadequate.⁵ The aetiology of Scheuermann's disease is unknown. The prevalence of kyphosis is higher in males and an autosomal dominant inheritance is associated with this condition.¹

Modified perceptual analysis of sensory data describing erect vertebral alignment could cause disturbances in vertebral orientation of the vertebral spine and postural stability.^{11,12}

The process of crawling provides a start of eye-hand co-ordination, vestibular processing, improvement of balance and equilibrium, spatial awareness, tactile inputs, kinaesthetic awareness and social maturation.¹³ It is believed that the passage through specific obligatory phases of development (creeping and crawling) is a prerequisite for well-organised psychomotor development.¹⁴ Boachie-Adjei and Lonner (1996)¹ hypothesise that abnormal developmental milestones in young children may suggest a neuromuscular cause of spinal deformities. No study has been done to prove this theory.

The literature review was conducted using databases Medline from 1981 to 1998 and CINAHL from 1982 to 1987. The reference lists of each article was screened for relevant articles. Only articles in Afrikaans and English were reviewed. No evidence of any study done to determine if there was any correlation between abnormal development of an infant and spinal deformities during adolescence, was found.

It was decided to do this study to determine the prevalence of spinal deformities in the absence of normal developmental milestones, in adolescents who attend schools in Middelburg, Mpumalanga.

If this study shows a correlation between defective motor development and the development of spinal deformities exists, physiotherapists could instruct young mothers in the stimulation of gross motor skills (such as sitting, crawling, and walking) and the strengthening of hypotonia. This intervention should minimise the risk factors in the development of spinal deformities.

Although only a small percentage of the population is affected by spinal deformities, it is important to prevent this condition due to complications like pulmonary impairment, and the unsuccessful treatment of spinal deformities.^{1,2,8}

2. AIM OF STUDY

2.1. RESEARCH QUESTION

Do abnormal developmental milestones of neurologically intact babies have an influence on the prevalence of spinal deformities in adolescents in Middelburg, Mpumalanga?

2.1.1. MAIN AIM

To determine if certain developmental milestones, namely lying, sitting, crawling and walking, could influence the development of spinal deformities in adolescents aged between twelve and seventeen years, in Middelburg, Mpumalanga.

2.1.2. SUB AIMS

2.1.2.1. To determine if a literature review could show any correlation between the developmental milestones of a baby and the development of spinal deformities in adolescents.

2.2.2.2. To determine if the following factors may have any influence on the prevalence of spinal deformities:

Developmental factors:

- age at which babies sat independently
- whether babies crawled
- age at which babies crawled
- age at which age babies walked independently

Other factors:

- family history of deformities
- period of gestation

- preference of lying position
- other ways of locomotion before babies walked
- the use of aids such as walking rings, sit chairs or “ jolly jumpers “
- any hearing deficiency
- problems with eyesight
- growth spurts
- height
- gender
- menarche in girls
- hip flexor tightness
- lack of flexibility of hamstring muscles

2.3. HYPOTHESIS

Deviations of certain normal developmental milestones namely sitting, crawling and walking, as well as certain other factors, in neurologically intact babies, may influence the development of spinal deformities.

3. RESEARCH DESIGN

A case-control study will be conducted in Middelburg, Mpumalanga. Adolescents with spinal deformities will be compared with adolescents without spinal deformities, with regard to their developmental milestones as babies and other factors.

3.1. STUDY POPULATION

All adolescents, male and female, between the ages of twelve and seventeen years, who attend any of the schools in Middelburg, Mpumalanga, will be considered part of the total population.

The schools are:-

- Dennesig Primary School
- Kanonkop Primary School
- Middelburg Primary School
- CR Swart Primary School
- Kanonkop High School
- Steelcrest High School
- Middelburg High School
- Middelburg Technical High School

3.2. SAMPLING

The sampling frame will include pupils from the community who comply with the criteria and who volunteer to participate in the study. The sampling will be done in the following way:

School principals in the town of Middelburg, Mpumalanga, will be approached for permission to give a lecture on back deformities and back care at each relevant school. This lecture will be given to all pupils aged between twelve and seventeen years at the specific schools (appendix A)

Permission will also be obtained to hand out an information letter on common spinal deformities to this group of pupils (appendix B). The letter has to be given to their parents. They will also be informed about the research study, in which they can voluntarily participate. No costs will be

incurred. The fact that this research would not harm the children in any way, will also be explained. The parents will be asked to return the completed volunteer form to the school, or to telephone the researcher. A form granting consent to participate in the study, will also be included (appendix B).

All the volunteer forms will be collected at the schools. Appointments will be made, to meet with the volunteer and his / her mother. All volunteers who reply will be included in the study if they comply with the inclusion criteria.

3.3. SAMPLE CRITERIA

EXCLUSION CRITERIA

- Any congenital deformities of the lower limbs, chest or vertebrae
- Any abnormal locomotion such as the permanent use of crutches or a wheel chair
- Any leg length discrepancy of more than ten millimetres
- Previous fractures of vertebrae
- Any spinal deformity of neurological origin
- Any chronic lung disease such as cystic fibrosis or tuberculosis
- Previous thoracic surgery

INCLUSION CRITERIA FOR CASES:

All adolescents diagnosed with a spinal deformity after the physical evaluation of height, leg length, straight leg raise, hip flexion tightness, hump size, angle of rotation, deviation from midline, kyphosis/lordosis measurements, and postural observations.

INCLUSION CRITERIA FOR CONTROLS:

All adolescents who show no deformity after the physical evaluation of height, leg length, straight leg raise, hip flexion tightness, hump size, angle of rotation, deviation from midline, kyphosis/lordosis measurements, and postural observations.

3.4. RESEARCH PROCEDURE

When the subjects and their mothers arrive at the physiotherapy practice, they will be informed of procedures. The informed consent form will be handed to the mothers (appendix C). They will be given time to read the informed consent. The researcher will answer any questions. The subjects and their mothers will be asked to sign the informed consent form if they agreed to participate. Thereafter the subjects will be asked to dress in the specific shorts. The females will also wear halter-neck tops with thin straps to expose their backs.

3.4.1. PHYSICAL EXAMINATION (Appendix D)

The subjects and their mothers will be informed of specific procedures which will be followed during the evaluation. An informed consent form will be signed by the subject and his / her mother and they will be questioned to determine if there are any exclusion criteria.

All subjects will be dressed similarly:

MALES: Loose fitting running shorts without shirts and barefoot.

FEMALES: Loose fitting running shorts and halter neck tops with thin straps to expose the back.

SUBJECTIVE INFORMATION:

- ◇ **Age:** The age of the subject will be noted in years and months
- ◇ **Gender:** The gender of the subject will be noted
- ◇ **Age of menarche:** The age of menarche of female subjects will be noted in years

OBJECTIVE EVALUATION:

All measurements will be done three times and the mean will be determined.

- ◇ **Height:** The subject will be requested to stand with his / her back against a fixed measuring cane. His / her heels have to be against the wall (or as close as possible) and his / her feet have to be together (or as close as possible). A spirit level will be placed on the head of the subject to eliminate faulty parallax. The height of the subject will be noted in millimetres.
- ◇ **Leg length discrepancy:** The subject will be asked to lie supine on the examination bed. His / her pelvis will be levelled by placing the iliac crests on a straight line. The tips of the anterior superior iliac spines will be palpated and marked with a pen. The tips of the medial malleoli will be palpated and marked with a pen . A standard tape measure will be used to determine the distance between the anterior superior iliac spines and the medial malleolus. The same procedure will be followed with the other leg. Any difference between the two legs will be noted.
- ◇ **Straight leg raise:** The subject will be asked to lie supine on an examination bed. The greater trochanter of the femur will be palpated and marked with a pen. The lateral condyle of the distal end of the femur will also be marked with a pen and these two points will be joined by a line alongside the shaft of the femur. The zero of the inclinometer will be determined level to the examination bed. The heel of the relevant leg will be placed on the researcher's shoulder and the knee will be stabilised in extension with one hand. The leg of the subject will be raised by means of the researcher's shoulder while her other hand will maintain the inclinometer

alongside the shaft of the femur. The opposite knee of the subject will be stabilised by means of the researcher's other knee. The leg being measured will be lifted to a level where the onset of tension in the hamstring or calf muscles is felt by the subject. Care will be taken that no pelvic rotation takes place. A reading on the inclinometer indicating the degrees of hip flexion during straight leg raise will be noted. The same procedure will be followed with the opposite leg.

- ◇ **Degrees of hip flexion tightness:** With the subject still in supine, the inclinometer will be zeroed on the level of the examination bed. The subject will be requested to flex one hip and knee and to pull the knee onto his/her chest to the end range of movement. The level of the examination bed will be used as the zero level for the inclinometer. The inclinometer will be placed alongside the shaft of the opposite femur and a reading on the inclinometer will be noted. This will indicate the degrees of hip flexion contracture.
- ◇ **Hump size:** The subject will be asked to stand with his/her feet in line with the hips. The toes will be placed on a straight line. A mark will be made on the floor midway between the two big toes. The subject will be requested to place the palms of the hands together, to point them towards the mark on the floor and to place the chin on the sternum. In this way active trunk rotation will be prevented. The subject will be asked to flex the trunk up to ninety degrees while pointing the fingers towards the mark. The subject will be observed from posterior. The spirit level will be placed transversely across the spine in the thoracic area. The spirit level will be maintained while a measurement, using a metal ruler graduated in millimetres, is taken. The point where the spirit level is placed, and the point at which the measurement by means of the ruler is made, have to be exactly the same distance from the spine. The same measurement will be taken in the thoraco-lumbar region and the lumbar region. The difference in millimetres as well as the side of the hump will be noted.
- ◇ **Angle of trunk rotation:** The rotational prominence or angle of trunk rotation will be measured by means of the inclinometer. The subject will be requested to stand with

his/her feet in line with the hips. The palms of the hands will be placed together and pointed to a mark midway between the two big toes, and the chin will be flexed to the sternum. The subject will be requested to flex the trunk to ninety degrees. The most prominent part of the hump will be measured by means of the inclinometer. The inclinometer will be zeroed on horizontally placed a spirit level and will then be positioned across the spine from the hump to the same level on the opposite side of the spine. Any angle will be noted.

- ◇ **Plumbline:** The subject will be asked to flex forwards in the same way as described above. The tip of the spinous process of each vertebra or as close as possible to the tip (in cases where rotation is advanced) will be marked with a pen. The subject will be asked to stand erect after the markings are completed. A plumbline hanging from the ceiling will be used. The patient will be positioned so that the seventh vertebra is aligned with the plumbline. If there is a deviation of the spine from the plumbline, the distance from the gluteal cleft to the plumbline will be measured with a graduated ruler. The side to which the gluteal cleft is shifted in relation to the plumbline will also be noted. The rest of the spine will be observed to determine any deviation from the straight line. In the case of a deviation the area of maximum deviation of the spine from the plumbline will be noted.
- ◇ **Kyphosis / Lordosis :** The curve of the subject will be viewed laterally to determine the start of the normal / abnormal kyphotic curve. The subject will be asked to stand up straight, but no postural correction will be done. The subject will be asked to look at a specific point at eye-level on the opposite wall. The following levels will be marked on the subject's back to determine the normal / abnormal sagittal curve: lumbo-sacral junction, thoraco-lumbar junction or the superior end of the lordosis, the cervico-thoracic junction or the superior end of the kyphosis. The digital inclinometer will be used to determine the curve in the sagittal plane. All the readings will be taken three times and then the average reading will be used. The short base of the inclinometer will be placed on the lumbo-sacral junction and then zeroed at this point. The

inclinometer will then be moved to the thoraco-lumbar junction and a reading will be taken. This reading is the degree of the lordotic curve. The area of the lordosis will be noted. To determine the kyphotic curve the thoraco-lumbar junction or the superior end of the lordosis / inferior end of the kyphosis will be used for the zero reading. The inclinometer will then be placed on the cervico-thoracic junction to determine the degree of kyphosis present. The area of the crest of the kyphosis will be noted.

- ◇ **Forward head posture:** The subject will be viewed from the side with the plumbline hanging on the lateral side in such a manner that the plumbline passes through the centre of the ear. The position of the line as it passes through / posterior or anterior to the shoulder will be determined. If the plumbline passes in front of the shoulder, the subject will be considered to have a forward head posture. This will be noted.
- ◇ **Postural observations:** The subject will be observed from posterior while standing. If an asymmetrical winging of a scapula and if so, the side of asymmetrical winging will be noted. Any shoulder girdle elevation will be noted, indicating the elevated side. The arms hanging next to the trunk will be observed to determine if one arm is hanging further away from the trunk than the other, and on which side it is further away.

3.4.2. QUESTIONNAIRE (Appendix E)

Once the evaluation is completed, the researcher will interview the mother of the subject and complete the questionnaire. The following data will be obtained during the structured interview:

- Hearing problems, and if so, the side of defective hearing and the age at which the subject developed a hearing problem, will be determined.
- Defective eyesight, the side affected, the age at which this problem manifested and if the subject is far sighted or short sighted.



- Whether the mother knows that her child has a spinal deformity, and when it was first noticed.
- Family history concerning kyphosis and scoliosis.
- Age of gestation and the process of birth (normal, Caesarean section, or normal with instrumentation).
- Position of lying that the subject preferred as a baby.
- Age at which the subject sat independently.
- Whether the subject crawled and at which age he / she started crawling and for what period he / she crawled before walking.
- Whether any other way was used to move forward.
- The age at which the subject walked independently.
- Whether the mother made use of a sit chair / transport chair and for what period of time per day.
- Whether the mother made use of a walking ring for the subject and for what period of time per day.
- Whether the mother made use of a "Jolly Jumper" and for what period of time per day
- Did the child have a sudden growth spurt and at what age did it occur?

Selection bias will be eliminated by using all the volunteers who reply. Selection for the control and case groups will be controlled by the specific inclusion criteria of each group.

The numbering of the cases and controls will be done in a systematic manner. On completion of the evaluation the subjects will be allocated to either the case or a control group, according to the results. In each group, numbering will take place by using the next consecutive number.

3.4.3. BIAS

INTERVIEWER BIAS: Only one interviewer will be used.

INSTRUMENTAL BIAS: The same tape-measure, ruler, spirit level, plumbline and inclinometer will be used.

QUESTIONNAIRE BIAS: The questionnaire will be pre-tested and a pilot study will be done to ensure that all the evaluation techniques are possible. A structured interview will be used.

RECALL BIAS: Some mothers might have difficulty in remembering precise ages of certain developmental stages. Categorised answers, according to normal developmental stages, will be used to minimise the recall bias.

INTERVIEWER BIAS: Only one interviewer will be used.

MEASUREMENT BIAS: A second researcher will be trained to repeat the evaluation of the first ten subjects to determine the inter-observer reliability.

3.5. STATISTICAL ANALYSIS OF THE DATA

A confidence interval of 5 % will be used, and thus a significant value of 0,05 will be considered statistically significant in the analysis of the data. The paired t-test will be used to calculate the significant values for the comparison of the means, while the Chi squared test will be used to determine the relationship between frequencies.

The outcome of the variables will be illustrated on separate histograms to compare the outcome of the cases with those of the controls.

4. BUDGET

7.1 Linguist:	R1000-00
7.2 Typist:	R2000-00
7.3 Photo copies:	<u>R3000-00</u>
	R6000-00

5. REFERENCES

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APPENDIX G

ADDENDUM

LEG LENGTH DISCREPANCY

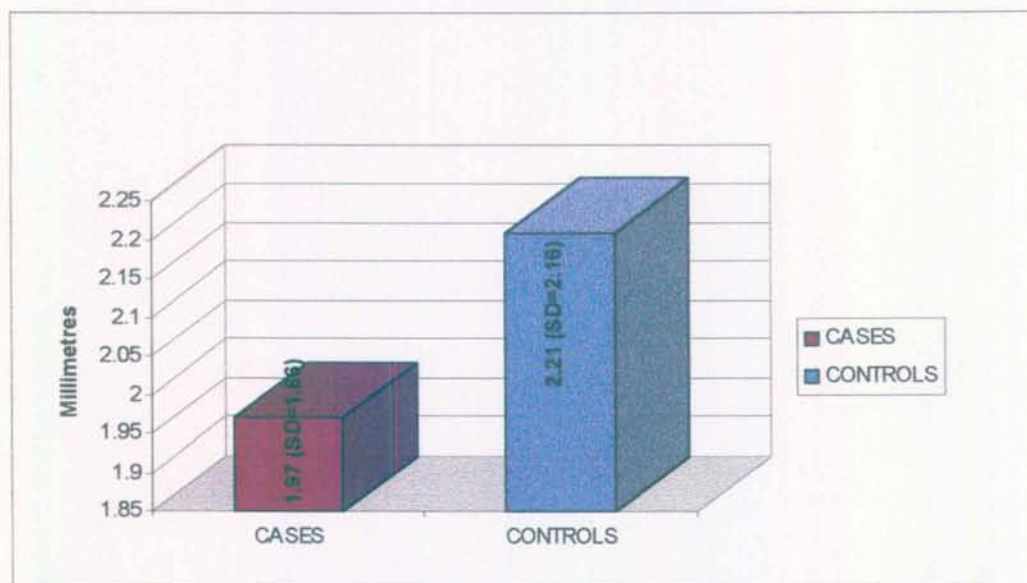


Figure 45: Mean leg length discrepancy for case and control subjects.

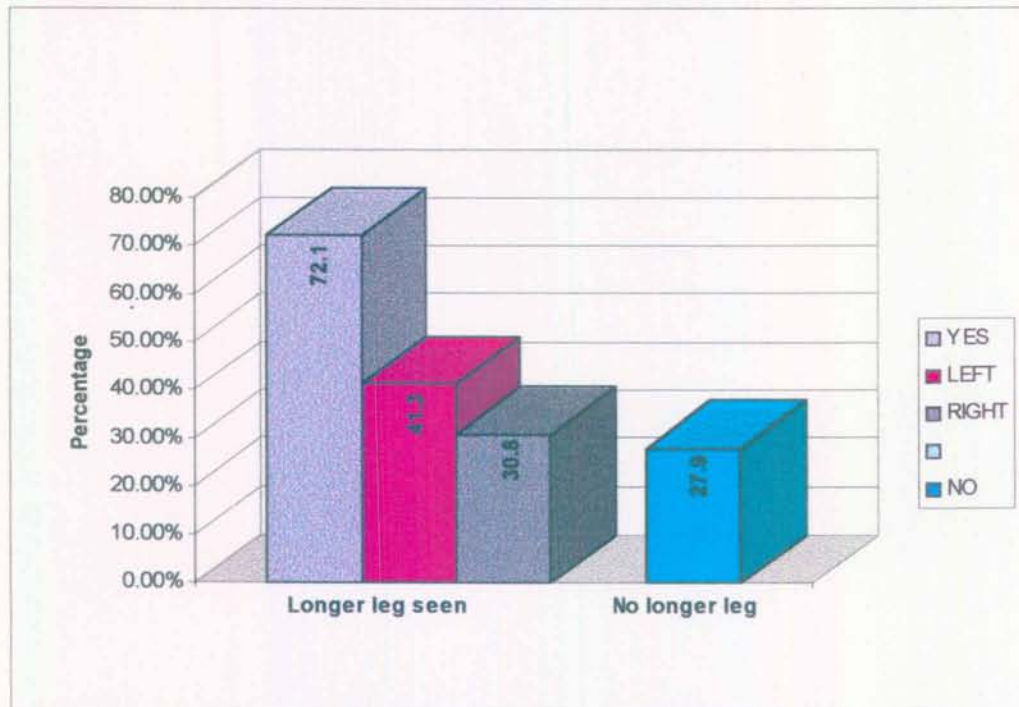


Figure 46: Presence of a longer leg indicating side of the longest leg.

STRAIGHT LEG RAISE

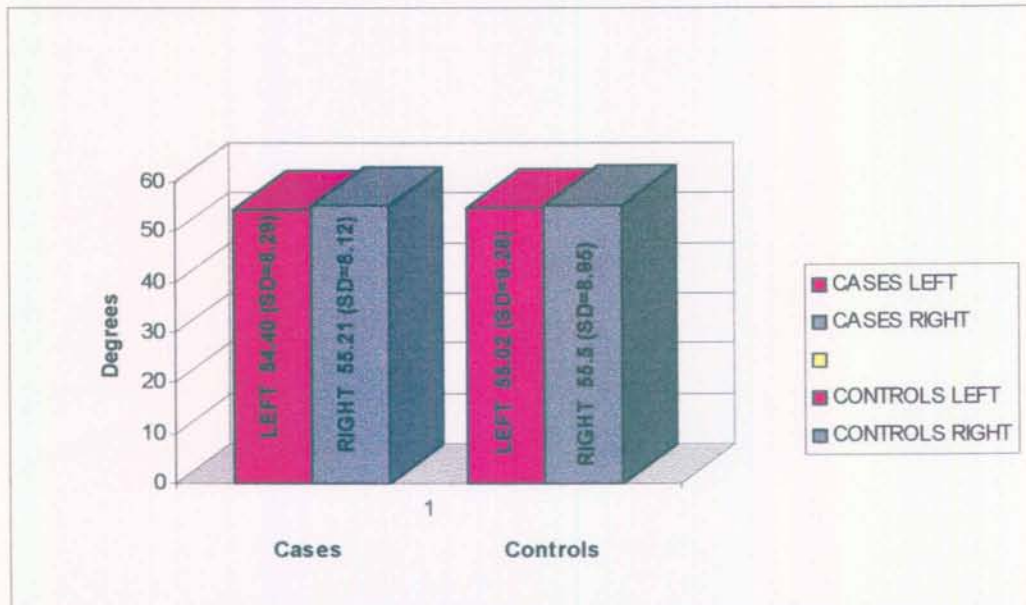


Figure 47: Mean straight leg raise for case and control subjects comparing the left and right side.

Table 8: Mean straight leg raise for the different planes of deformities.

Planes	Mean:left leg	SD	Mean:right leg	SD
Sagittal	54.75	8.41	55.49	8.31
Coronal	53.23	6.27	54.79	6.56
Combined sagittal & coronal	54.94	10.10	55.14	9.56

HIP FLEXOR TIGHTNESS

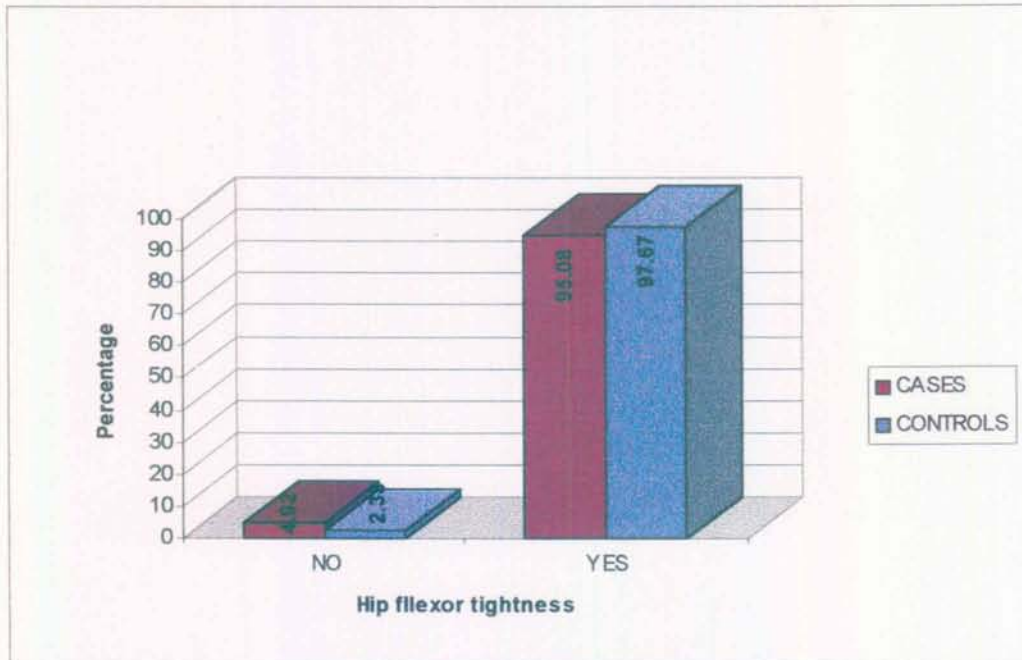


Figure 48: Comparison of the percentage of cases and controls with hip flexor tightness.

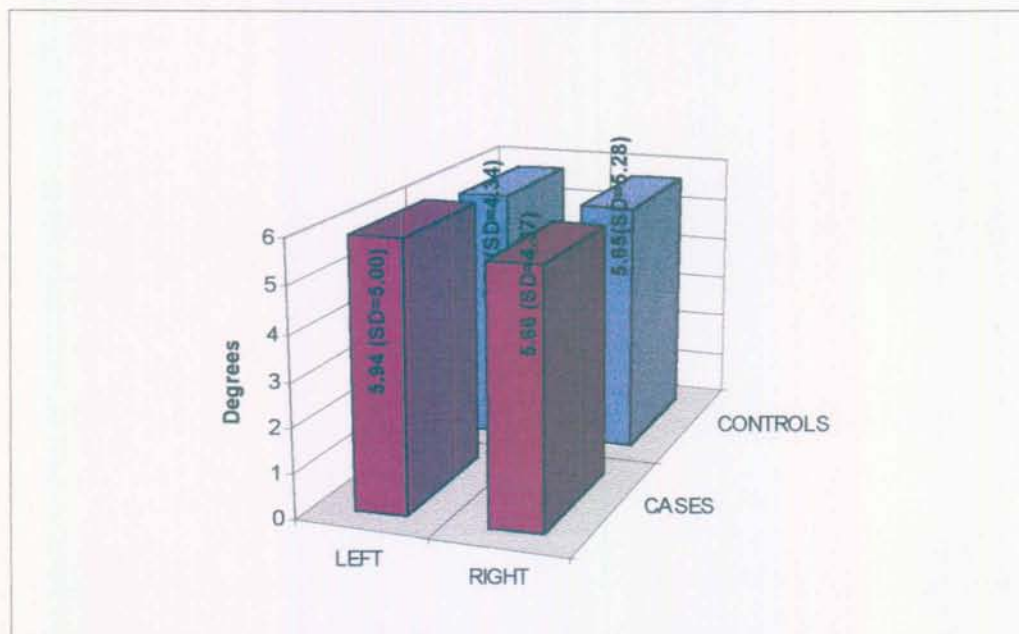


Figure 49: Mean hip flexor stiffness for case and control subjects.



FAMILY HISTORY OF DEFORMITIES

Table 9: Different deformities in direct family

	CASES		CONTROLS	
	Kyphosis	Scoliosis	Kyphosis	Scoliosis
Mother (n=7)	42,9%	57,1%	Mother (n=6)	17,7% 83,3%
Father (n=7)	71,4%	28,6%	Father (n=3)	100% 0%
Brother (n=1)	100%	0%	Brother (n=1)	100% 0%
Sister (n=3)	66,7%	33,3%	Sister (n=3)	33,3% 66,7%

Table 10: Different deformities on the maternal side

Relationship	CASES				CONTROLS			
	K	S	K-S	DNK	K	S	K-S	DNK
Grandmother	33,3%	33,3%	8,3%	25%	50%	25%	0%	25%
Grandfather	0%	25%	0%	75%	50%	50%	0%	0%
Uncle	0%	100%	0%	0%	0%	0%	0%	0%
Aunt	50%	25%	0%	25%	0%	0%	0%	100%

K = kyphosis; S = scoliosis; K-S = kypho-scoliosis; DNK = did not know

Table 11: Presence of different deformities on the paternal side of the cases

Relationship	Kyphosis	Scoliosis	Kypho-scoliosis	Did not know
Grandmother	100%	0%	0%	0%
Grandfather	75%	25%	0%	0%
Uncle	0%	0%	0%	100%
Aunt	0%	0%	0%	0%

DEFECTIVE HEARING

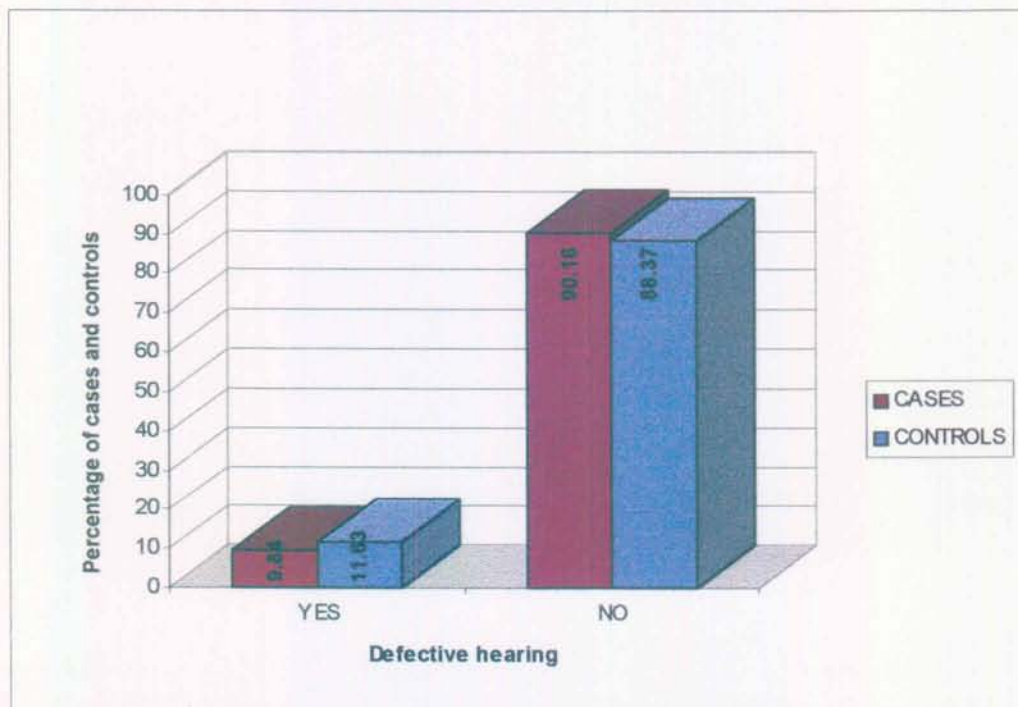


Figure 50: Percentage of case and control subjects who presented with defective hearing.

Table 12: Side of defective hearing in the cases and controls of those who presented with defective hearing.

Side affected	Left	Right	Both	Did not know
Cases n=6	0%	50%	16,7%	33,3%
Controls n=5	40%	20%	20%	20%

Table 13: Percentage of cases and controls who presented with defective hearing, indicating the age at which the defective hearing was noticed

Age	<1 year	1-5 years	5-10years	>10 years	Could not recall
Cases n=6	16,7%	16,7%	0 %	50%	16,7%
Control n=5	20%	0%	20%	40%	20%

DEFECTIVE VISION

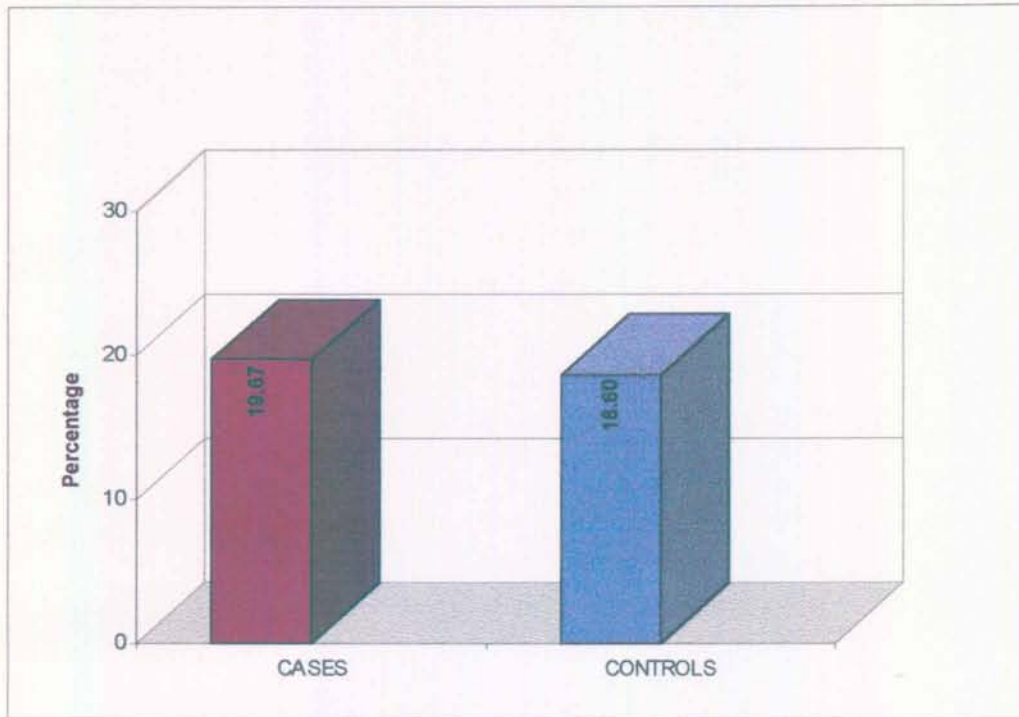


Figure 51: Percentage of case and control subjects who presented with defective vision.

Table 14: Side of defective vision in all affected subjects

Side	Left	Right	Both	Not sure
Cases	16,7%	8,3%	41,7%	33,3%
Controls	11,1%	0%	33,3%	55,6%

Table 15: Age at which defective vision was first noticed

Age	<1 year	1-5 years	5-10 years	> 10 years	Could not remember
Cases	0%	16,7%	16,7%	58,3%	8,3%
Controls	0%	11,1%	44,4%	44,4%	0%

Table 16: Type of visual problem in the affected subjects

Type	Far sighted	Short sighted	Both	Did not know	Other
Cases	41,7%	25%	8,3%	8,3%	16,7%
Controls	55,6%	33,3%	0%	0%	11,1%
