AN INVESTIGATION INTO THE RELATIONSHIP BETWEEN THE DEVELOPMENT OF ROTATION OF THE HIP MOTOR CONTROL

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TABLE OF CONTENTS

TABLE OF CONTENTS i

LIST OF TABLES viii

LIST OF FIGURES x

CHAPTER 1: INTRODUCTION 1

CHAPTER 2: THE NATURAL HISTORY OF FEMORAL TORSION 5

2.1 INTRODUCTION 6

2.2 DEFINITION OF ANGLES 7

2.3 DEVELOPMENT OF FEMORAL TORSION 10

2.3.1 Prenatal development 10

2.3.2 Postnatal development 11

2.4 FACTORS INFLUENCING THE CHANGING SHAPE OF THE FEMUR . . 13

2.4.1 General considerations 13

2.4.2 The role of muscle forces acting over the proximal femur 15

2.4.3 The mechanism of prenatal torsion 16

2.4.4 The mechanism of postnatal detorsion. 17

CHAPTER 3: IDIOPATHIC MEDIAL FEMORAL TORSION SYNDROME 23

3.1 INTRODUCTION 24

3.2 X-RAY STUDIES OF ANTEVERSION OF THE FEMUR 25

3.3 INTOEING GAIT 26

3.4 HIP ROTATION 27

3.5 MANAGEMENT 29

CHAPTER 4: DEVELOPMENT OF THE MOTOR TESTING PROTOCOL 30

4.1 FACTORS THAT INFLUENCED THE SELECTION OF TEST ITEMS . . . 31

4.2 SELECTION OF TASKS FOR INCLUSION IN THE TEST BATTERY . . 33

4.3 DEVELOPMENT OF DESCRIPTIVE CATEGORIES 35

4.3.1 Development of the test protocol for standing on one leg 35

4.3.2 Lower limb component 36

4.3.3 Upper limb and trunk components 37

4.4 DESCRIPTION OF TESTS AND SCORING CATEGORIES 38
4.4.1 Standing tasks 38
4.4.1.1 Standing on one leg 38
4.4.1.2 Hopping on the spot 39
4.4.2 Bridging tasks 41
4.4.3 Standing up from long sitting 43
4.4.4 Trunk tasks 44
4.4.4.1 Prone pivot 44
4.4.4.2 Flexion in supine 45
4.4.4.3 Sitting up in supine 46
4.5 SUMMARY OF TEST SCORING PROCEDURES 46
4.5.1 Standing on one leg 46
4.5.2 Hopping on the spot 47
4.5.3 Bridging tasks 48
4.4.3 Standing up from long sitting 49
4.4.4 Trunk tasks 49
4.4.4.1 Prone pivot 49
4.4.4.2 Flexion in supine 50
4.4.4.3 Sitting up in supine 51

CHAPTER 5: METHODOLOGY 52

5.1 CHOICE OF TESTING PROCEDURES AND PILOT STUDY 53

5.2 SUBJECTS 54

5.3 PARENTAL PERMISSION 55
5.4 TESTING PROCEDURES 55
5.4.1 Height, weight and age. 56
5.4.2 Footprints 57
5.4.3 Hip external and internal rotation 58
5.4.4 Passive straight leg raising 58
5.4.5 Movement tests 59

CHAPTER 6: RESULTS 60

6.1 TEST-RETEST RELIABILITY 61
6.1.1 The 6-year-old group 61
6.1.2 The 7-year-old group 65

6.2 CHARACTERISTICS OF THE 6- AND 7-YEAR-OLD GROUPS 69
6.2.1 Age, weight, and height 69
6.2.2 Passive range of movement 70
6.2.2.1 Differences between boys and girls . . 71
6.2.2.2 Differences between right and left legs 71
6.2.2.3 Differences between 6 and 7-year-old group 73
6.2.3 Angle of gait 73
6.2.4 Relationships between passive hip movements and gait angle. 74

6.2.5 Movement tests 75

6.2.6 Standing up from longsitting 79

6.3 THE RELATIONSHIP BETWEEN CLINICAL MEASURES OF ANTEVERSION AND PERFORMANCE ON THE MOTOR TASKS 79

6.3.1 Division of the samples into subgroups 85

6.3.2 Characteristics of the subgroups 87

6.3.2.1 Age, weight and height of subgroups . . 85

6.3.2.2 Passive range of movement and gait angle 89

The 6-year-od group 89

The 7-year-old subgroups 91

6.3.3 Movement tasks 94

CHAPTER 7: DISCUSSION 99

7.1 PASSIVE RANGE OF MOVEMENT 100

7.1.1 Test reliability 100

7.1.2 Distribution of scores 100

7.2 RELATIONSHIP BETWEEN PASSIVE MOVEMENTS 103

7.3 PERFORMANCE ON MOTOR TASKS 104

7.4 THE RELATIONSHIP BETWEEN PASSIVE MOVEMENTS AND PERFORMANCE ON THE MOTOR TASKS 105

7.5 THE INTERACTION BETWEEN MOTOR DEVELOPMENT AND SKELETAL GROWTH 108

7.6 MUSCLE FORCES ACTING ON THE HIP STRUCTURES DURING GROWTH 110

CHAPTER 8: CONCLUSIONS AND RECOMMENDATIONS 113

8.1 DEVELOPMENT OF MOVEMENT TESTS TO MEASURE THE DIFFERENCES IN THE LEVEL OF CONTROL OF HIP POSTURE AND MOVEMENT . . 114

8.1.1 Recommendations 114

8.2 THE RELATIONSHIP BETWEEN PERFORMANCE OF THE MOTOR TESTS AND MEASURES OF CLINICAL ANTEVERSION (HIP INTERNAL AND EXTERNAL ROTATION) 115

8.2.1 Recommendations 116

8.3 FOLLOW UP STUDY 116

CHAPTER 9: CONSTRAINTS 118

9.1 SAMPLE 119

9.1.1 Sample of convenience 119

9.1.2 Differences between the two samples 119

9.2 MEASUREMENT TECHNIQUES 119

9.2.1 Measurement of range of movement 119

9.2.2 Hip rotation as a measure of femoral anteversion 120

9.2.3 Division of samples into subgroups 121

ACKNOWLEDGEMENTS 122

REFERENCES 123

APPENDIX A 137

APPENDIX B 140

LIST OF TABLES

6.1 Comparison of means of test - retest measurements (in degrees) for passive range of movement for the 6-year-old group 62

6.2 Comparison of test (T) and retest (R) scores on the movement tasks or the six year old group (N = 5) 63

6.3 Comparison of test (T) and retest (R) means and SD on the movement tasks for G6. 64

6.4 Comparison of means of test (T) and retest (R) measurements (in degrees) for passive range of movement and gait angle for the 7-year-old group 66

6.5 Comparison of test (T) and retest (R) scores the movement tasks or the 7-year-old group. 67

6.6 Comparison of test (T) and retest (R) scores and means for the movement tasks for the 7-year-old group. 68

6.7 Weight, height, and age of G6 69

6.8 Weight, height, and age of G7 69

6.9 Range of passive hip rotation and straight leg raising (SLR) of G6 and G7 70

6.10 Range of passive hip rotation and SLR for G6 72

6.11 Range of passive hip rotation for G7 72

6.12 Angle of gait (in degrees) for the 6 and 7-year-old groups 74

6.13 Division of 6 and 7-year old groups into LR, MR, and SR subgroups. 86

6.14 Means (in degrees) of hip rotation and straight leg raising of the 6-year-old subgroups. 89

6.15 Angle of hip rotation and straight leg raising of the 7-year-old subgroups 91

7.1 Comparison of data (median, interquartile range and range) for passive hip movements with the finding of Sutherland et al[78] 101

LIST OF FIGURES

2.1 The angles used to define the angle of anteversion 8

2.2 The angle of inclination and the anteversion angle of the acetabulum 9

2.2 In the crouched position the head of the femur is covered completely by the acetabulum. 18

5.1 Construction of angles to measure gait angle 57

6.1 Distribution of scores on standing tasks for G6 and G7 . . 76

6.2 Distribution of scores for the bridging tasks for G6 and G7 77

6.3 Distribution of scores for trunk tasks for G6 and G7 78

6.4 Performance of standing tasks related to range of hip movements in G7 subgroups. 81

6.5 Performance of bridging tasks related to range of hip movements in G7 subgroups. 82

6.6 Performance of standing tasks related to range of hip movement in G6 subgroups. 83

6.7 Performance on the bridging tasks related to the range of hip movements in G6 subgroups. 84

6.8 95% confidence intervals for factor means for age, height and weight for G6 87

6.9 95% confidence intervals for factor means for age, height and weight for G7 88

6.10 95% confidence interval for factor means for passive range of movement and gait angle for G6 90

6.11 95% confidence intervals for factor means comparing passive range of movement and gait angle of the G7 subgroups. . . . 93

6.12 Dstribution of scores on the standing and bridging tasks for the G7 subgroups 95

6.13 Distribution of scores on the trunk tasks for the G7 subgroups 93

6.14 Distribution of scores on the standing and bridging tasks for the G6 subgroups 97

6.15 Distribution of scores on the trunk tasks for the G6 subgroups 98

CHAPTER 1

INTRODUCTION

At birth the angle of anteversion of the femur is 35° - 40°; during growth the process of gradual physiological detorsion reduces this angle to the average adult value of 12°.[1] In some children the degree of detorsion is inadequate, resulting in a severely reduced range of external hip rotation, excessive internal hip rotation, squinting knees and intoeing gait[2,3,4,5,6]. This syndrome, termed idiopathic medial torsion, is a common problem in orthopaedic practice[3,7]. The cause is unknown[4,8]. Conservative management (in the form of orthopaedic appliances) has been shown to be ineffective in changing the degree of anteversion of the femur[3,9,10].

Because most children develop compensatory external tibial torsion it is generally stated that idiopathic femoral torsion corrects itself with time and that no treatment is needed[3,9,5,11,12]. In some children, however, the intoeing and resultant disturbances of gait are considered severe enough to warrant derotation osteotomy[4,5,12,13].

The long term significance of persistent medial femoral torsion has not been well documented although a number of secondary problems have been

attributed to it including flat feet[4,5], knee problems[14,15] and functional disability due to intoeing[4,5]. Several studies[16,17] have found an association between increased anteversion and degenerative osteoarthritis of the hip. The statistical validity of these earlier studies has been questioned in a recent study which found no such association[18].

Brouwer[19] in an extensive review of the literature found support for the following concepts concerning the mechanisms involved in the normal physiological process of torsion and detorsion of the human femur:

-"External mechanical factors are of prime importance for the physiological process of femoral torsion and detorsion, occurring during prenatal and postnatal stages of development."

- "Normal weightbearing in childhood tends to change the position of the proximal end of the femur in axial projection until its normal position in the full grown femur has been reached. Therefore normal weightbearing exerts an adjusting effect on torsional deformities, regardless of their cause."

Bleck[20] hypothesizes that the torque strain needed to reduce the anteversion of the femur is provided by the hip extension and lateral rotation forces acting on the hip during development[14]. It would thus seem that the development of good control of the hip musculature plays an important role in the development of femoral alignment.

Although the relationship between increased anteversion and abnormal motor control in children with cerebral palsy is well documented[20,21,22], there are no published studies that look at the possible links between motor control and femoral anteversion in children without neurological deficits. Children with intoeing gait are reported to be clumsy; but this clumsiness is usually ascribed to the gait angle[3,5].

The **aim** of this study, therefore, is to explore the possible relationship between detorsion of the femur during growth and the development of hip posture and movement. Hip internal and external rotation are commonly used as a clinical measure of anteversion of the femur[3,4,5,6,8]. In this study the range of hip internal and external rotation (as a clinical measure of anteversion) was related to performance of motor tasks requiring control of the posture and movement of the hip.

If the degree of femoral anteversion is linked to the development of motor control, the next step would be to investigate the effectiveness of exercise programmes on the process of detorsion of the femur in children with excessive medial femoral torsion.

Null hypothesis: There is no relationship between clinical measures of medial femoral torsion (hip internal and external rotation) and the development of control of hip posture and movement.

Objectives:

1 To develop a battery of tests to measure the differences in the quality of control of hip posture and movement.

2 To investigate the relationship between performance on the motor tests and measures of clinical anteversion (hip internal and external rotation).

CHAPTER 2

THE NATURAL HISTORY OF FEMORAL TORSION

2.1 Introduction

2.1 Definition of angles

2.3 Development of femoral torsion

- 2.3.1 Prenatal development
- 2.3.2 Postnatal development

2.4 Factors influencing the changing shape of the femur

- 2.4.1 General considerations
- 2.4.2 The role of muscle forces acting on the proximal femur
- 2.4.3 The mechanism of prenatal torsion
- 2.4.4 The mechanism of postnatal detorsion

2.1 INTRODUCTION

The term anteversion (or femoral torsion) refers to the degree to which the axis through the head and neck of the femur deviates from the frontal plane. Usually this axis points slightly forward, known as anteversion or antetorsion. In some cases the axis deviates posteriorly, known as retroversion or retrotorsion. Anteversion of the femur is thought to be an expression of torsion within the femur as a whole, resulting not only from the direction of growth of the proximal femur but also from torsion in the shaft[23].

The torsion in the femur is important for the mechanical efficiency of the lower limb in the upright position. The combination of anteversion of the acetabulum and anteversion of the femur means that a spinning movement of the head of the femur in the acetabulum brings the leg into a position of flexion and some adduction in such a way that the knees stay close to each other and facing forward when walking[24].

There are dramatic changes in the degree of femoral torsion between the time of completion of the cartilage anlage and skeletal maturity. At 2-3 months the angle of anteversion of the foetus is slightly negative, increasing during the prenatal period to reach a maximum average value 35° in the perinatal period[25]. From birth to maturity a gradual process of detorsion occurs reaching an average adult value of between 12° and 16°.

The factors that influence the process of torsion and detorsion of the femur are poorly understood[26,28]. In this chapter the changes in the angle of anteversion that occur with growth and the factors influencing these changes are reviewed.

2.2 DEFINITION OF ANGLES

The angle between the frontal plane and the axis of the head and neck is known as the anteversion angle (AV-angle). According to Brouwer[29], who did an extensive survey of both the European and English literature, the most commonly used definition of the AV-angle is:

The angle of anteversion is the angle between the collar plane and the condylar plane.

collar axis, head and neck axis: axis through the centre of the femoral head and neck

collar plane, anteversion plane: plane through the collar axis and the femoral shaft axis;

condylar axis: functional axis through the knee joint

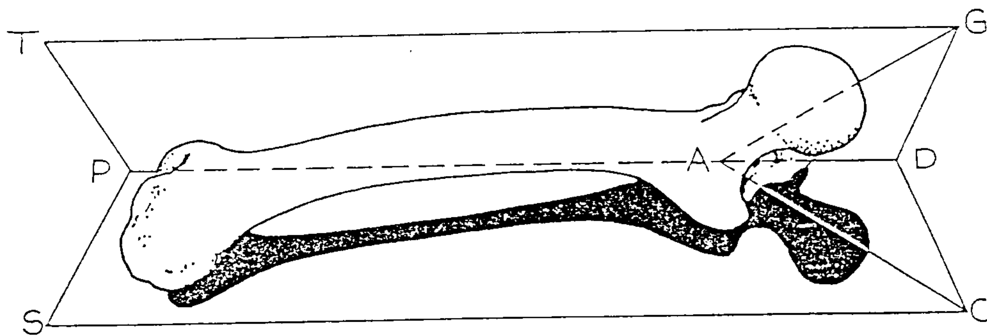
condylar plane: plane through the condylar axis and parallel to the femoral shaft axis.

retro-condylar plane: a plane parallel to the condylar plane which touches the femoral condyles posteriorly.

The angle between the longitudinal axis through the femoral shaft and the axis through the head and neck of the femur is known as **the angle of inclination**.

The function and stability of the hip joint is ultimately determined by the relationship between the orientation of the femur and the ventral orientation of the acetabulum related to the sagittal (acetabular anteversion).

These angles are illustrated in Figures 2.1 and 2.2.



GDC	=	angle of anteversion
PD	=	longitudinal axis through the femoral shaft in its projection in the condylar plane
AG	=	collar axis
TGDP	=	collar plane
PDCS	=	retrocondylar plane

Fig 2.1 The angles used to define the angle of anteversion

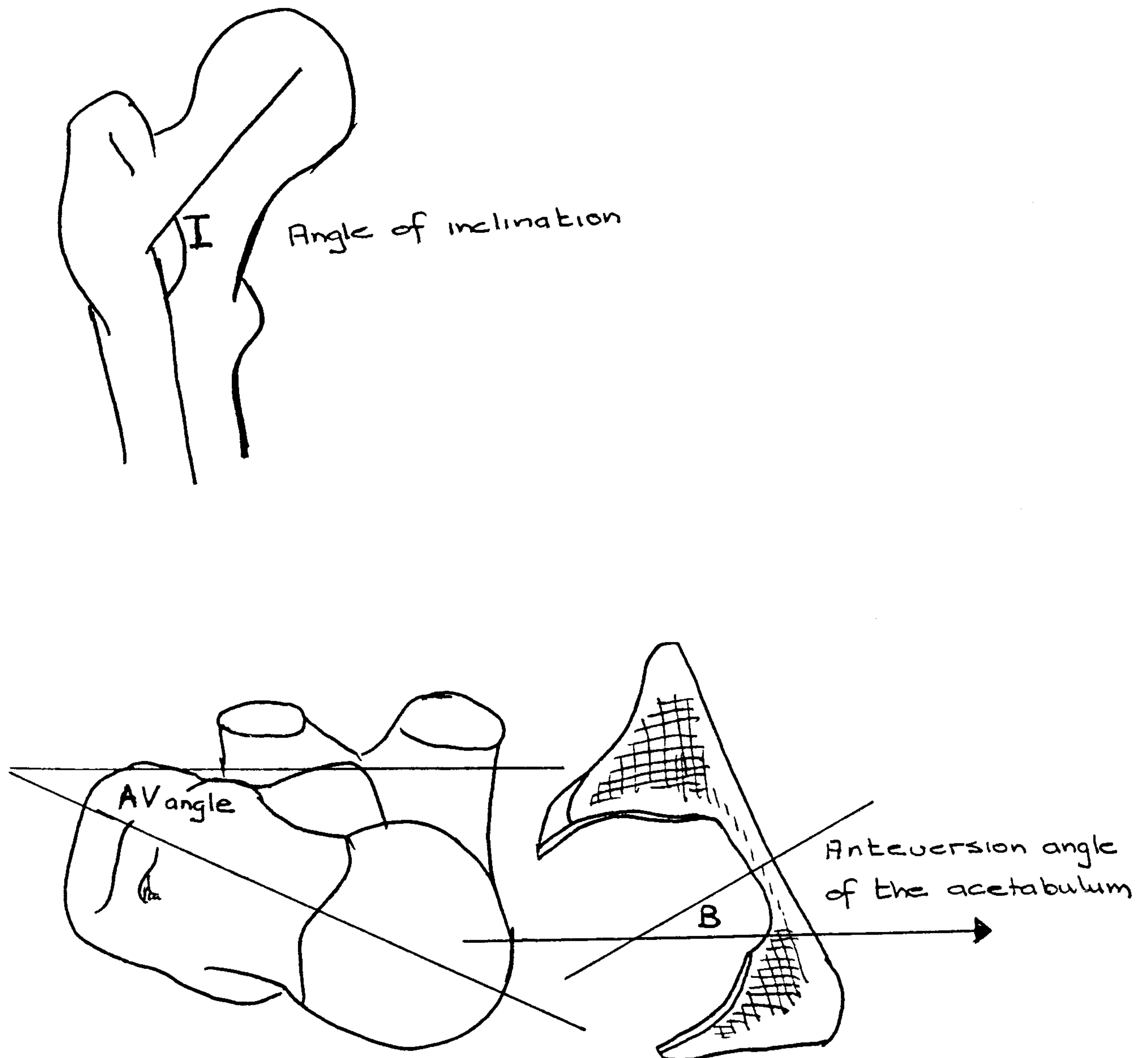


Fig 2.2 The angle of inclination and the anteversion angle of the acetabulum. (Reproduced from Kapandji[55])

2.3 DEVELOPMENT OF FEMORAL TORSION

2.3.1 Prenatal development

By the end of the embryonic period of 8 weeks the femur is well established as a cartilaginous anlage, the centrally placed primary bone collar is forming and the hip and knee joints have begun to form by cavitation[30]. Ossification of the shaft extends proximally and distally so that it is largely ossified at birth. By the end of the fetal period the secondary ossification centre in the distal end of the femur has also appeared[31]. The prenatal femur does not have a femoral neck separating the head from the greater trochanter. These two areas are contiguous and are grossly separated by anterior and posterior intertrochanteric indentations[32].

Torsion of the femur increases gradually during the prenatal period, starting with slightly negative values in the embryo and increasing to average values reported to lie between 18° and 40° in the perinatal period[9,25,26,27]. At birth anteversion appears to be highly variable. Watanabe[33] has reported values of -30° to +40°. The commonly accepted angle at term is 35° with a reported range of 64° of anteversion to 2° of retroversion[32].

The lack of femoral neck in the prenatal femur makes measurement of the angle of anteversion difficult and the large range of values reported may reflect differences in measurement technique. More recent detailed studies using multiple measurements and statistical analyses probably give a more reliable measure of anteversion at birth. These studies suggest that maximal anteversion appears at approximately 32 weeks with

values of 30° on the right and 32° on the left, and that this anteversion decreases by term to 18° and 24° respectively[32].

2.3.2 Postnatal development

At term the neonatal hip is characterized by a spherical head, variable anteversion and virtually no femoral neck with the trochanter at the same level as the femoral articular surface[25]. Changes in the shape of the proximal femur during growth are brought about by changing relationships between the planes of the longitudinal growth plate (which contributes to the longitudinal growth of the femur) and the trochanteric growth plate and femoral neck isthmus (which broaden the neck)[34].

During postnatal growth there is a gradual detorsion of the femur reaching a generally accepted average of between 12° and 16°.[9,35,36]

There have been numerous studies using different radiological techniques that have documented the average degree of anteversion of the femur at different ages. The exact figures tend to differ slightly; this is probably due to differences in techniques used, different anatomical definitions, different definitions of "normal" and differences in populations[35].

Two studies by Fabry et al[36] and Shands et al[37] gives figures for different ages. These studies are well documented and make use of radiological techniques that have been shown to be reliable. The

figures given in these studies coincide with those of other studies[36,37,38] as well as earlier anatomical studies reported by Brouwer[38] and can be accepted as being a good reflection of the values for anteversion found at different ages.

Fabry et al[36] evaluated 846 hips on 432 normal children between the ages of 1 and 16 years. The average angle of anteversion was 24.14° ranging from 30° at age 1 to 16° at age 16 with an average standard deviation of 7.3°. This study gives a value of 25° for children aged 6 - 8 years.

A study by Shands et al[37] showed similar trends - they found an average angle of 39° anteversion in a group of children age 3 months to 1 year. There was a sharp decrease between the age of 1 and 2 years to 30° Thereafter there was a decrease of 1° to 2° degrees every two years. Between the ages of 14 and 16 years there was another sharp drop from 21° to 16°. Shands et al[37] give a value of 20° for children aged 6 - 8 years.

Brouwer[38] in an extensive review of the literature supports these findings. Most of the 28 studies on the angle of anteversion in the adult cited by Brouwer give an average angle of between 10° and 16°. The range is however very large (-25° to 47°). Brouwer[38] adds the following comment: "Another significant finding is that the size of the AV-angle during childhood shows the same wide variation as during adult life. Finally there is no consensus when the process of detorsion commences, but the majority of investigators agree that the detorsion

takes place throughout the period of ambulation until the closure of the growth plates."

There are no significant differences between average values for left and right femora but differences in individuals are reported to be considerable. Reikeras et al[39,40] found a difference of up to 11.8° in a study of normal femora.

The correlation between anteversion angles and the angle of inclination is poor in normal adult femora[39].

2.4 FACTORS INFLUENCING THE CHANGING SHAPE OF THE FEMUR

2.4.1 General considerations

The position and basic shape of the bone is defined by the shape and position of the anlage. However cartilage growth and chondro-osseous development is very sensitive to extrinsic factors such as the influence of adjacent tissues, vascularity, the concentration of nutrients and hormones, as well as compression and tension loading acting across the bone[41,42,43]. The final shape of the bone therefore may vary significantly.

It is generally accepted that physical forces acting on the body make a major contribution to the final contours of the skeleton[44,45]. Using a modelling process Carter et al[41] have shown that the site and timing

of ossification of cartilage can be explained by the changing areas of maximal stresses within the developing bone.

Growth is promoted by physical forces within the physiological range for each bone. Increased loads within the physiological range will accelerate growth, compression eliciting a more rapid growth than tension. Increasing loads beyond the physiological range first retard then stop growth[42]. (These principles are referred to as the Heuter-Volkman Law of cartilage growth response[42].)

The epiphyseal plate may respond to loads in four ways:

1 growth can increase longitudinally
2 growth can decrease longitudinally
3 growth can be deflected by shearing
4 torsional growth can occur from continual or intermittent shearing[42].

Most epiphyseal plates are aligned perpendicular to the time averages resultant of loads acting across them[42]. The two forces acting over joints are muscular forces and gravity. The muscle forces are usually greater and seem to have the greatest influence on joint alignment[42,46]. This conclusion is supported by studies (reported below) of the effect of muscle paralysis and imbalance on the shape of the femur.

2.4.2 The role of muscle forces acting over the proximal femur

Ogden[47] states that in the later fetal stages and postnatally there is an increasing interdependence between hip joint development, muscular development and function. Cavitation of the hip joint occurs concomitantly with the establishment of innervation and function of the muscles around the hip. Paralysis of muscles in the fetus results in a failure to cavitate the hip joint[47].

Frost[48] has postulated that the defects in growth seen in congenital dislocation of the hip (CDH) are caused by an imbalance in muscle forces in the fetus due to delays in central nervous system maturation. The manoeuvres used to correct CDH by realigning the hip in the acetabulum correct the forces acting over the hip. He proposes that the femur tends not to redislocate after treatment because the muscle forces tend to normalize with time.

More direct evidence for the role of balanced muscle forces in the development of the femur come from studies of the effects of paralysis and cerebral palsy on hip development[20,21,22].

Normal hip abductor mechanisms are essential for growth of the trochanter as well as the normal development of the contours of the neck of the femur. Paralysis of the abductor muscles is associated with coxa valga[49,50]. Overactivity and shortening of the hip adductors in cerebral palsy, especially gracilis and the medial hamstrings, inhibit the action of the hip abductor muscles and are thought by Baker et al to be a major cause of hip deformity[49].

2.4.3 The mechanism of prenatal torsion

In utero mechanical forces acting on the hip play an important role in determining the shape of the femur[51]. Muscular forces influence joint position and movement of the fetus within the intrauterine cavity. By the sixteenth week of gestation the hip musculature is fully developed and active hip motion can be observed[52]. The period of accelerated growth in the third trimester is associated with the development of increasingly coordinated neuromuscular activity that permits movement and position changes. In most cases the fetus has flexed the knees by the 6th to 7th month and is able to kick and move more freely as well as turn in the uterus[53].

Extrinsic forces such as intrauterine space, decreased amniotic fluid and the presence of another fetus are potentially deforming forces[45,51]. Dunn bases this conclusion on a major study in which 7500 infants were examined perinatally. He also found an increased presence of congenital postural deformities in cases where the infant was unable to kick properly and change position in utero. Based on this study Dunn[45] also postulates that the increased incidence of congenital dislocation of the hip in first born children is due to flattening of the uterine cavity by the greater tone in the abdominal muscles.

Dunn's [45] observations are in line with le Damany's conclusions concerning prenatal torsion of the femur. Brouwer[54] states that Le Damany's early hypothesis on the mechanism of torsion of the foetal femur has been confirmed by later studies:

"Because of the length of the femoral shaft in the limited space available in the pregnant uterus, the femur is pressed against the prominent iliac crest of the fetal pelvis forcing the hip joint into a position of maximal flexion. This pressure from the uterine wall acts as a levering force on the femoral head, using the distal half of the upper leg as the lever arm and the iliac crest of the foetal pelvis as the axis. In this way, Le Damany assumes that the femoral head would be lifted completely out of the hip joint, were it not that the supporting ligaments of the joint were resisting such movement. The result of these counteracting forces is a moment of axial torsion, exerted on the femur which forces the axis of the femoral head and neck into the sagittal plane. Complete anteversion (AV-angle 90°) is not reached due to the fact that the hip is not only in extreme flexion but also in lateral rotation as another consequence of the ovoid shape of the uterine cavity."

2.4.4 The mechanism of postnatal detorsion.

The anteverted position of the foetal femur brings the head of the femur into maximal contact with the acetabulum in the flexed foetal position. The gradual extension of the hips postnatally changes the relation of the head and acetabulum again causing the antero-superior part of the head to lie outside of the joint. The process of detorsion corrects this situation to a certain extent only, for it is only in the crouched position that the acetabulum covers the head of the femur completely[55] (Fig 2.3).

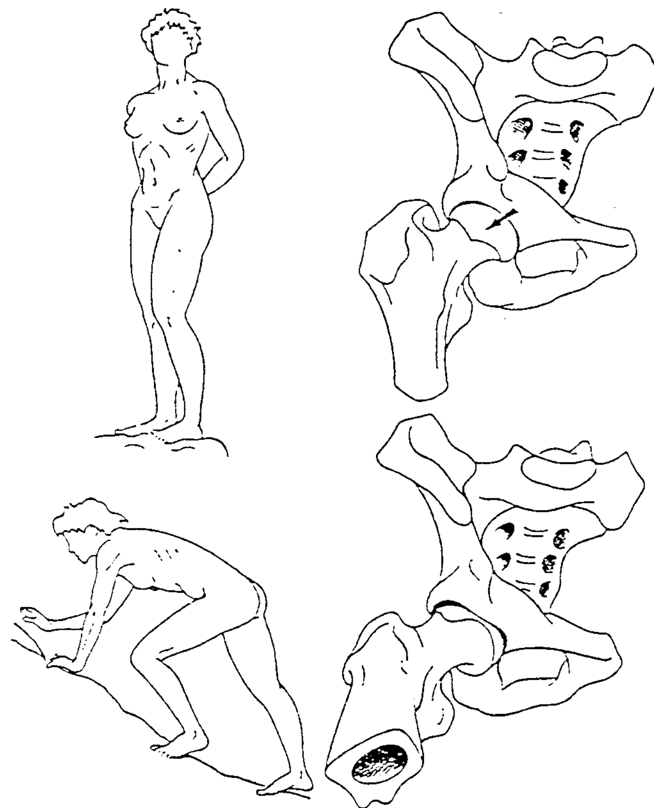


Fig 2.3 In the crouched position the head of the femur is covered completely by the acetabulum. (Reproduced from Kapandji AI. The Physiology of Joints, Volume 2. Edinburgh: Churchill Livingstone, 1970.)

The forces responsible for detorsion of the femur during growth are not generally discussed in the literature. Morscher[56] and Bleck[58] both speculate that lateral torque forces in extension provided by active muscle action during walking are important in the molding of the femur.

Morscher[56] has proposed that the normal process of detorsion is dependent on the torque forces acting on the proximal femur during ambulation. At the end of the swing phase the hip joint is medially rotated with regard to the pelvis which is rotated forward on the same side. This medial rotation of the swing leg is brought about by the action of gluteus medius and the medial hamstrings[57].

During standing the pelvis rotates forward on the non-support side producing a lateral torque at the support hip which is fixed distally at the foot. The forward rotation of the pelvis is brought about by contraction of the gluteus medius and minimus on the support side. According to Morcher[56] the active medial rotation of the hip during the support phase is the primary force responsible for detorsion of the femur. Morscher bases his conclusions on electromyographic gait studies which showed that the medial rotation of the support hip is brought about by active contraction of the gluteus medius muscles and clinical observations that increased anteversion is found in children with "weak muscles"[56].

There is little change in the stance phase dynamic action of the gluteus medius between the ages of one and seven years.[58] There is a trend towards reduction in the swing phase activity after 4 years[58].

Activity in the gluteus medius and minimus is decreased in children with anteversion[57].

Bleck[58] (based on the work of Lee) has also hypothesized that detorsion is brought about by lateral torque forces on the extended hip. "Lee studied the possible mechanisms of derotation of the proximal femur in the hips of fresh stillborn specimens. The muscles were dissected from the hips leaving only the capsule intact; the newborn hip flexion contracture was entirely in the capsule and not in the muscles. He found that 2° -4° of external torque strain was needed to derotate the proximal end of the femur at the cartilaginous osseous junction. This derotation occurred as the hips were extended and externally rotated. The torque strains in external rotation were absent when the hip was flexed 90°." Somerville[4] similarly has noted that the anterior capsule of the hip is taut in extension and postulates that extension of the hip places a torsional strain on the neck of the femur that gradually molds away the anteversion.

These conclusions are further backed by clinical case studies that have shown that paralysis of hip muscles leads to abnormal development of the proximal end of the femur associated with cerebral palsy[20,21,22].

A review of the development of lower limb motor control during the first year shows very clearly that the hip is constantly exposed to abduction, lateral rotation forces even before the child starts to walk. In fact if one observes normal children the degree of active control of hip abduction and lateral rotation during most non-support tasks is striking.

At birth the young child has a physiological flexion abduction contracture and increased tone in the hip flexors[59]. The flexion contracture spontaneously reduces as the child gains increasing control over extension in prone and supine during the first 18 months[60].

In prone the ability to extend the hips against gravity develops at 4-6 months when the child assumes the prone pivot position with the hips in abduction and lateral rotation[61]. In supine the baby starts to bridge at about 3 months of age. When the child starts to sit at 6 months he or she also keeps the hips in flexion, abduction, lateral rotation and tends to maintain the abduction actively when the weight is transferred laterally as well as when balance is disturbed. When the child first moves from prone kneeling she actively controls hip abduction and lateral rotation as she moves from prone kneeling to sitting. When the infant first stands, it is with a broad base and the legs slightly laterally rotated. The lateral rotation of the hips is also seen when the infant who is still standing with support, moves from standing to sitting on the floor.

Some children do not seem to develop the same degree of control over hip abduction and lateral rotation. The author has observed this most clearly when the child moves from prone kneeling into sitting. Instead of rotating the pelvis and moving into half cross legged sitting, the child simply lowers the pelvis posteriorly and end up sitting between the feet (some times called M-sitting or reverse tailor sitting). In this position the child is quite stable but cannot reach sideways effectively. The child who sits in M-sitting does not have the opportunity to practice balance reactions in sitting and thus misses

out on developing active control of non weight-bearing abduction and lateral rotation of the hip.

Conclusion

There is no direct evidence for the hypothesis that motor development plays an important role in the shaping of the femur post natally. Indirect evidence however points to an important role for muscle forces in the postnatal detorsion of the femur.

General theories of bone and cartilage modelling point to the important role that muscle forces play in the shape of any bone. Circumstantial evidence from studies of the effects of muscle imbalance and paralysis on the shape of the femur lend further support to the hypothesis. Bleck[58] and Morscher's[56] theories attempt to specify the forces affecting detorsion of the femur. The authors personal observation of the differences the development of motor patterns of children (discussed earlier) could explain some of the variability in the degree of detorsion reported in the literature.

CHAPTER 3

IDIOPATHIC MEDIAL FEMORAL TORSION SYNDROME

3.1 Introduction

3.2 X-ray studies of anteversion of the femur

3.3 Intoeing gait

3.4 Hip rotation

3.5 Management

3.1 INTRODUCTION

Idiopathic medial femoral torsion with intoeing gait and associated clumsiness and stumbling is a very common paediatric orthopaedic problem[3,7]. For some reason the gradual decrease in the angle of anteversion that should occur with growth does not happen. As a result the child has to rotate the femur medially to gain maximal coverage of the head and so walks with an intoeing gait. In older children a compensatory lateral torsion of the tibia may develop so that the feet face in the line of progression[4,9,14].

In addition to the intoeing gait the older child also presents with an associated decrease in the range of lateral rotation and an increase in medial rotation of the hip[2,3,4,5,8,9,14]. These children are also reported to sit in the reversed tailor position[3,9].

Staheli notes that clinically the effect of medial femoral torsion does not appear until the age of three[3]. This delay in appearance is thought to be due to the masking effect of the functional lateral rotation contracture of the newborn[3]. The effect of medial femoral torsion on the gait angle is most severe at approximately 5 to 6 years of age, after which in most children it is reported to improve spontaneously[3]. Improvement is thought to be due to spontaneous reduction in the angle of anteversion, compensatory lateral tibial torsion, dynamic compensation and acetabular retroversion[3]. Each of these possible mechanisms is discussed below.

Some children with intoeing gait are described as clumsy and non-athletic[3,9]. Alvik reports that gait and balance difficulties are usually the reason for seeing the doctor[5]. Some children complain of pain in the hip and buttock, especially when they are tired. This is ascribed to overactivity in the external rotators of the hips in walking[5,9]. No evidence is put forward to support these claims.

3.2 X-RAY STUDIES OF ANTEVERSION OF THE FEMUR

The clinical literature tends to state that femoral torsion in many cases corrects itself with time[3,5]. This conclusion is based on the observation that children cease to walk with an intoeing gait as they get older. X-ray studies have shown that this conclusion is false as there is little regression in abnormal angles of anteversion[9,39]. In Reikeras' study of 24 children with medial femoral torsion the average angle decreased about 15° (from 47° to 31°) from the age of 8 to 16[39]. A study by Fabry et al[9] also found no significant decrease after an average follow up period of 5 years and 6 months. (The average decreased from of 42.68° to 39.48°)

Ultimately the congruity of the hip, the alignment of the lower limb and the range of external rotation of the hip depend on the relationship between anteversion of the femur and the acetabulum. Reikeras et al[40] used computer tomography to study this relationship in 34 children with increased anteversion. They found no correlation between the sizes of the anteversion angle of the femur and acetabulum. This finding could be the basis for the lack of correlation between the

angle of anteversion and the degree of functional disability found in the same study[39]. It also questions Staheli's[3] hypothesis that the spontaneous decrease in intoeing gait could be due to a compensatory acetabular retroversion.

3.3 INTOEING GAIT

The child with idiopathic medial femoral torsion typically has an intoeing gait[3,5,8,9,14] which is first noticed in late infancy or early childhood[3]. The intoeing is usually bilateral and symmetrical[3].

The degree of intoeing is dependant on all the torsional elements in the limb (femoral anteversion, acetabular anteversion, tibial torsion, foot alignment) which are additive. The child may develop a compensatory external tibial torsion in which case the line of progression will be normal[3,9]. In other cases the medial torsional deformities may be additive in which case the degree of intoeing will be severe. The child may also compensate for the medial torsion of the limb by rotating the limb laterally. It is interesting to note that the child's intoeing tends to be worse when he or she is tired[2,3,9].

In most children spontaneous resolution of intoeing gait is reported to occur without concomitant decrease in the AV-angle[3,8,9,14]. Of particular interest is the large and well documented study by Fabry et al[9]. In this study of 175 children from 2 to 16 years of age with intoeing gait were found to have an average angle of anteversion 42.68° (SD 6.7). In a follow-up study 154 hips in 77 of these children were re-evaluated

after an average follow up time of 5 years and 6 months. Comparison of the degree of anteversion of the initial study showed no significant decrease in anteversion in this period of time.

Fifty percent of these children had gait angle within the normal range associated with compensatory external torsion of the tibia[9].
A cadaver study by Kobylianski et al[63] showed a significant negative correlation between femoral and tibial torsion. This finding is in line with the clinical observation that in most cases the intoeing gait spontaneously decreases due to compensatory external tibial torsion discussed earlier.

3.4 HIP ROTATION

Clinically idiopathic medial femoral torsion is reported to be associated with an increase in the range of medial rotation and a decrease in the range of lateral rotation of the hip[3,4,8,9,39].

Changes in the range of hip motion are used clinically to diagnose medial femoral torsion. There is, however, no agreement on what ranges should be used to indicate abnormal torsion that is serious enough to warrant active intervention. Somerville[4] considers an external rotation limited to 15° or less to indicate severe deformity. Alvik[5] regards a range of medial rotation of more than 80° degrees in young children and 70° in older children to be pathological. A range of internal rotation greater than 70° is considered by Staheli et al[62] to be indicative of abnormal femoral torsion. A total range of rotation

of 100° is considered to indicative of a stable hip. If the range is greater than 100° it is considered to be hypermobile and therefore unstable due to overstretching of the anterior capsule[5]. None of these authors state how or why they consider these ranges to be indicative of abnormal femoral torsion. Fabry et al[9] compared hip rotation with x-ray studies of the hips of 324 normal children between the ages of one and sixteen years. They concluded that if the range of internal rotation exceeded the range of internal rotation, a torsional deformity of the hip should be suspected. However they do not state how hip rotation was measured or why they come to this conclusion.

Reikeras et al[40] measured the range of movement of the hips of 40 children with an average AV angle of 46°. The average range of hip movement is given as 77° (SD 9). They report that the correlation between AV-angle and the range of hip internal and external rotation was poor. The method used to measure the range of movement of the hips is not given .

In a study of 68 children between the ages of 1 and 8 years with toeing-in gait Crane[8] estimated the range of hip rotation with the hip in extension. He found a mean angle of external rotation between 10° and 30° and internal rotation of 60° to 80°.

One of the problems of using hip rotation to gauge the degree of abnormal femoral torsion is the wide range in the reported values for hip rotation in the normal population. The range of movement of the newborn hip is limited by the adaptive shortening of the anterior structures of the hip. Extension and internal rotation are limited

while external rotation is as much as 90° [62]. During the first three years extension and internal rotation increase while external rotation decreases. External rotation remains greater than internal rotation until 3 years of age; after this internal rotation is slightly greater than external rotation until about 14 years[62]. Between 4 and 13 years the mean range of external rotation has been reported as 45° (range of 25° - 65°); internal rotation is reported to be 40° - 50° (range of 20°-65°)[62].

3.5 MANAGEMENT

The reason why detorsion of the femur with growth does not occur in some children is not discussed in the literature. A follow up X-ray study has shown that intervention strategies such as changes in sitting posture, heel twister cables, lateral heel wedges and Dennis-Browne splints make no difference to the angle of anteversion[9]. It is generally stated that since the intoeing tends to correct itself with time, no intervention is necessary except in extreme cases where derotation osteotomy is recommended[3,9,11].

CHAPTER 4

DEVELOPMENT OF THE MOTOR TESTING PROTOCOL

4.1 Factors that influenced the selection of test items

4.2 Selection of tasks for inclusion in the test battery

4.3 Development of descriptive categories

- 4.3.1 Development of test protocol for standing on one leg
- 4.3.2 Lower limb componen
- 4.3.3 Upper limb and trunk component

4.4 Description of tests and scoring categories

- 4.4.1 Standing tasks
  - 4.4.1.1 Standing on one leg
  - 4.4.1.2 Hopping on the spot
- 4.4.2 Bridging tasks
- 4.4.3 Standing up from long sitting
- 4.4.4 Trunk tasks
  - 4.4.4.1 Prone pivot
  - 4.4.4.2 Full flexion in supine
  - 4.4.4.3 Sitting up in supine

4.5 Summary of test scoring procedures

To test the hypothesis that derotation of the femur during growth is linked to the development of hip muscle control, a battery of tests that would assess qualitative differences in hip control in weightbearing and non-weightbearing movement tasks, was needed. This involved selecting a number of suitable tasks and creating descriptive categories that identified differences in the proficiency with which the children performed the tasks.

4.1 FACTORS THAT INFLUENCED THE SELECTION OF TEST ITEMS

All children without neurological deficits learn to perform the basic motor tasks. The sequence and age of attainment of different milestones has been well documented[65,66,67], as has been performance outcomes for gross motor tasks such as jumping, hopping, running, throwing[68,69,70,71].

Children's performance of individual motor tasks (intratask development) also show quantitative and qualitative changes over time[69,71]. These changes reflect changes in body size and proportions, increased muscle strength as well as changes in the structure and functional relationships of the neurophysiological systems subserving movement[72,73]. When a child is first able to perform a task, the performance lacks coordination and efficiency; over time the performance becomes smoother and more consistent, the child learns to control a greater number of degrees of freedom and to coordinate the action of different components of the task. Intratask development exhibits predictable changes in body actions although the rate of

development differs markedly, with some children attaining a mature quality of performance at a very late stage or not at all.

Robertson and Halverson[74] who have done the most detailed studies in the qualitative and quantitative changes in movement tasks have shown that different components of a task do not develop in a lockstep fashion, but that each component develops at its own pace and is not necessarily related to rate of development of other components. Descriptive categories that classify movement stages for a task cannot be done for the total body configuration but must be done for individual components of the movement ie upper limb, lower limb, trunk[74].

Measures of performance outcome (such as distance covered, speed of movement, length of time a position can be held) do not give an indication of the pattern of movement used to perform the task. In addition changes in performance outcomes do not necessarily reflect improvements in the quality of the pattern used to perform the task. Robertson[75] has shown that young children increase the distance they can throw without changes in the pattern of movement. Test batteries such as the Bruininks-Oseretsky that measure quantitative differences have been shown to be ineffective in differentiating between children with good and poor motor control[76].

To effectively identify differences in the quality of motor development, the motor test battery needed to identify qualitative differences in task performance. Although there are a number of standardized motor test batteries available none of them

differentiate movement quality of lower limb function. Clinically, developmental physiotherapists assess the quality of numerous movement tasks but, for the most part, judgements are based on clinical experience rather than on standardized tests.

4.2 SELECTION OF TASKS FOR INCLUSION IN THE TEST BATTERY

In order to identify differences in the quality of performance of the youngest and oldest subjects included in the test sample, the tasks chosen for inclusion in the test battery needed to be appropriate for the age of the children to be tested and needed to accommodate the large individual differences in the rate at which children develop specific motor skills.

The test battery was designed to give a general impression of the quality of weightbearing motor control of the lower limbs. No attempt was made to develop definitive tests of motor control or changes in control over time. As I had originally planned to use a sample of children in the 5-6 age group to test my hypothesis that the range of hip rotation is associated with motor control, the test battery was developed on children of this age.

As a first step in selecting tasks for inclusion in the test battery I chose a number of tasks used clinically to test lower limb motor control. Initially I observed (and in some cases video filmed) 20 normally developing boys and girls aged 5-6 performing the following tasks:

1 bridging on one leg in crook lying

2 bridging on one leg in supine, feet raised on a stool

3 standing on one leg

4 hopping on the spot

5 standing up from long sitting

6 standing up from sitting on a low stool

7 standing up from half kneeling

8 stepping up onto a stool

9 walking on the toes

10 walking on the heels

Of these activities the first four showed a great deal of variation in this age group. Some of the children could perform these activities efficiently, some performed them very poorly or could not do the task. Most children fell somewhere in-between. Standing up from long sitting was included in the test battery because I had observed that children with clinical signs of anteversion of the hip tended to rotate the hips internally when standing up and wished to explore this observation further.

Items 6 - 8 were all performed well by all the children; qualitative differences in performance were not detectable on observation. Most children still had definite associated reactions when walking on the heels and toes (tasks 9 and 10). This meant that these tasks did not differentiate between good and slow development between the ages of 5 and 7.

In addition I chose 3 tasks commonly used to test trunk control: sitting up in supine, full flexion in supine and prone pivot. These tests were included to investigate whether performance on weightbearing lower limb tasks is associated with performance of commonly used trunk control tests.

4.3 DEVELOPMENT OF DESCRIPTIVE CATEGORIES

The next step was to develop descriptive categories that would identify differences in the quality of performance of the selected tasks. To illustrate this procedure I will describe the steps I used to develop the testing protocol for standing on one leg.

4.3.1 Development of the test protocol for standing on one leg

I video filmed 15 children of both sexes between the ages of five and eight years performing the task. The child was asked to stand on one leg and maintain the position for 20 seconds. If the child had difficulty maintaining the position, she was asked to try a second time. The video films were reviewed and the pattern of movement for the upper and lower limb components were described for each child. The descriptive categories were refined by reviewing of the video films several times until the performance of each child could be easily categorized. Categories were ranked according to degree of skill displayed and given a score of between 1 (for the most proficient performance) and 3 for the poorest quality. A score of 4 was assigned

if the child could not perform the test at all. Based on the observation that the youngest children tended to perform the activities at the lowest skill level, I have assumed that the levels of skill reflect levels of maturity of task performance.

4.3.2 Lower limb component

At the most skilled level of performance the lower limb was held steady with intermittent small medio-lateral adjustments of the foot and ankle to maintain balance. Less control was evidenced by more frequent and larger range of medio-lateral foot adjustments as well internal rotation of the hips and fixing in internal rotation. In some cases the non-support foot touched the floor intermittently to regain balance. At the poorest level of control the child was unable to stand still, the foot moved on the supporting surface and the non-support foot frequently touched the floor in an effort to regain balance.

The final descriptive categories for the lower limb component were:

1 Lower limb remains steady. Some foot action to maintain balance.
2 Intermittent medial rotation of the support and non-support hips. Regular movements of the ankle. Non-support foot placed on floor once or twice.
3 Unable to maintain balance for more than 5-6 seconds. Moves support foot around on floor.

4.3.3 Upper limb and trunk components

At the most skilled level the child holds the trunk upright and steady. The arms are relaxed next to the body. At lower levels of skill the child moves the arms and sideflexes the trunk using either small range intermittent movements to regain balance or larger range uncontrolled movements to try and preserve balance.

The upper limb and trunk component was also divided into three categories:

1 Upper limbs relaxed and still. The trunk remains upright and steady.
2 The upper limbs move intermittently. Small range intermittent trunk sideflexion.
3 Large range uncontrolled upper limb and trunk movements all the time.

A review of the video recordings showed that this classification could successfully be used to classify all the children that had been filmed. At the most skilled level the child scored a 1 for the upper limb and lower limb components each. At the least skilled level he scored a total of 6 (3 for the lower limb and 3 for the upper limb components). Intermediate levels of performance scored a combination of 1 and 2, 2 and 2 or 2 and 3.

A similar process was followed for each of the tasks.

4.4 DESCRIPTION OF TESTS AND SCORING CATEGORIES

4.4.1 Standing tasks

4.4.1.1 Standing on one leg

Test action: standing on one leg for 20 seconds.

If the child had difficulty standing on one leg on the first attempt, he or she was encouraged to try again.

Rationale: Standing on one leg requires adequate control of hip extension and abduction, as well as an ability to balance the centre of gravity of the body over a small base. At the most skilled level of control the child is able to position the centre of gravity over the base and compensates for small shifts in the centre of gravity by adjusting the position of the leg relative to the foot - this is seen as small range lateral movements of the foot. Anterior-posterior adjustments also take place but are not easily observed.

Children with less control of standing on one leg seem to have difficulty stabilizing the pelvis on the lower limb. They tend to rotate the support and non-support lower limbs internally in what looks like an attempt to fix the legs in a more secure position. They also have problems balancing the centre of gravity over the small base. Compensatory movements of the arms and trunk are used to try and restore balance. At the poorest level of control these arm and trunk movements are quite large.

Young children are very dependent on visual cues for maintaining balance and cannot stand on one leg with the eyes closed.

Scoring categories

Arm component

1 The arms remain relaxed and steady. The trunk stays upright and still.
2 Intermittent controlled movements of the arms and trunk.
3 Large range uncontrolled movements of the arms and trunk.

Leg component

1 The leg remains steady. There is some intermittent ankle action to maintain balance.
2 Large range movements of the ankle to maintain balance. Occasional fixing in internal rotation of the support and non-support leg to maintain balance. Support foot does not move on the floor.
3 Unable to maintain balance for more than 5-10 seconds - puts non-support foot down to regain balance, moves support foot about.
4 Cannot stand on one leg.

4.4.1.2 Hopping on the spot

Test action: hopping on one leg on the spot 20 times.

The subject was asked to hop on the spot staying inside a circle with a 30 cm diameter.

Rationale: Skilled hopping on one leg involves propelling the body upward using forceful extension of the ankle and knee. The hip extensors work to stabilize the trunk and pelvis on the lower limb. A skilled hop on the spot is characterized by a smooth push-off movement at the ankle with the trunk upright and the arms relaxed and next to the body. The first attempts to hop are characterized by flexion of the support leg and forward tilting of the trunk - the child as it were pulls the support foot off the supporting surface[74].

At the most skilled level of hopping on the spot the arms are not involved in the hopping action. At a lower level the arms move up and down rhythmically in time with the hopping, presumably to assist with the upward thrust of the centre of gravity. At the least skilled level of hopping the arms move about in an uncontrolled and asymmetrical fashion and seem to be involved in crude attempts to maintain the centre of gravity over the base.

Scoring categories

Arm component

1 Arms relaxed next to side, do not move about.
2 Arms move up an down rhythmically in time with hopping - serves to provide extra momentum. Movements usually symmetrical.

3 Arms move up and down, but movement not rhythmical or timed to assist jumping. Arm movements not symmetrical.

Leg component

1 Hops rhythmically in circle with trunk upright. Hops by extending the leg. Completes 15 consecutive hops.
2 Hops rhythmically but tends to move out of circle.
3 Tilts trunk forward, flexes leg rather than pushing off. Moves about.
4 Cannot hop consecutively.

4.4.2 Bridging tasks

I included two bridging tasks in the test battery:

Test actions:

Hip extension in supine: supine lying with heels resting on 20 cm high stool; buttocks raised off the supporting surface and one foot lifted off the stool, shoulders flexed to 90 degrees with elbows extended, position maintained for 10 seconds.

Bridging in crook lying: bridging in crook lying, the left foot lifted off the supporting surface with the left knee extended; the shoulders flexed to 90 degrees with the elbows extended; position maintained for 10 seconds.

The positions were demonstrated to the subject. The child was requested to maintain the position for 10 seconds and encouraged to keep the supporting hip in extension.

Rationale: When I first started to look at tasks that would give an indication of hip control I included bridging on one leg because it was a novel task for the children and gave an indication of hip extensor strength. During the early stages of developing the test battery the children seemed to find hip extension in supine a much easier task than bridging in crook lying. I surmised that this difference may be due to the more efficient length of the hamstrings in the hip extension in supine task. In bridging in crook lying the hamstrings are in the shortened position; hip extension is brought about mainly by the gluteus maximus muscle.

In addition to demands made on the hip extensor muscles, bridging on one leg also requires a degree of hip rotation to keep the pelvis level. At the most skilled level the child is able to maintain the position without obvious effort; full hip extension is maintained and the pelvis stays level and steady. At lower levels of skill the child cannot maintain full hip extension and the pelvis starts to tilt down on the non-support side - the pelvis "wobbles". In some cases the child cannot maintain the position for more than a few seconds before falling over to the non-support side.

Stretching the arms forward means that the child is not able to use the arms to stabilize the trunk, making the task more difficult. In

addition the degree of effort used to maintain the position is reflected in associated reactions in the arms.

Scoring categories

1 Maintains the position with ease for 10 seconds, supporting hip fully extended, trunk and arms steady.

2 Maintains the position but hip not fully extended for full 10 seconds, pelvis not held steady, tilts to non-support side intermittently (wobbles).

3 Maintains with effort, arms abduct and are tense, non-support leg internally rotates, pelvis and shoulder girdle tilt to non-support side.

4 Cannot maintain the position.

4.4.3 Standing up from long sitting

Action: standing up from long sitting.

The child was requested to stand up from long sitting without pushing on the hands. Three patterns of movement were observed. In the case of standing up from longsitting, the scoring indicates the pattern used and does not relate indicate any relative quality of movement.

1 The child would flex the hips and knees, drawing the feet closer to the trunk with the hips externally rotated and then stand up.

2 The child would flex the hip and knees, but in this case he or she would internally rotate the hips so that the knees were together and feet wide apart and stand up from this position.

3 Some children stood up through side sitting or half kneeling.

4.4.4 Trunk tasks

Three trunk tasks were included to see if there was a relationship between performance on the standing and bridging task and trunk muscle efficiency.

4.4.4.1 Prone pivot

Test action: maintain the prone pivot position (arms in elevation, trunk extended with shoulders and legs lifted off the floor) for 10 seconds.

The position was demonstrated to the subject. The subject was asked to take up the same position and I corrected the position. After a short rest the subject was instructed to take up the position again and hold it for 10 seconds.

Scoring categories

1 Maintains the position for 10 seconds with ease. The thighs kept off the supporting surface.

2 The thighs touch supporting surface intermittently.

3 Holds position with difficulty, thighs not lifted of supporting surface.

4 Cannot hold the position at all.

4.4.4.2 Flexion in supine

Test position: supine with both lower limbs fully flexed and the head and shoulders lifted so that the head touches the knees. The shoulders flexed to 90° with the elbows straight.

The subject was asked to take up the position and I corrected the position if necessary. The subject was instructed to maintain the position for 10 seconds.

Scoring categories

1 Maintains head close to knees, with arms steady for 10 seconds.

2 Holds steady for 10 seconds but cannot maintain head in contact with the knees. Holds steadily without a lot of effort.

3 Holds position steady for 10 seconds but cannot bring head to knees.

4 Holds position with effort, arms abduct or elevate, wobbles or falls to the side.

4.4.4.3 Sitting up in supine

Test action: sitting up from supine with shoulders flexed and elbows extended.

The subject was instructed to sit up 3 times starting in supine with the arms stretched out forward.

1 Sits up 3 times easily and smoothly without using the arms. Feet remain on the floor
2 Sits up without pushing on arms, feet lifted high off supporting surface.
3 Cannot sit up without pushing on hands.
4 Cannot sit up

4.5 SUMMARY OF TEST SCORING PROCEDURES

4.5.1 Standing on one leg

Arm component

1 The arms remain relaxed and steady. The trunk stays upright and still.
2 Intermittent controlled movements of the arms and trunk.
3 Large range uncontrolled movements of the arms and trunk.

Leg component

1 The leg remains steady. There is some intermittent ankle action to maintain balance.

2 Large range movements of the ankle to maintain balance. Occasional fixing in internal rotation of the support and non-support leg to maintain balance. Support foot does not move on the floor.

3 Unable to maintain balance for more than 5-10 seconds - puts non-support foot down to regain balance, moves support foot about.

4 Cannot stand on one leg.

4.5.2 Hopping on the spot

Test action: hopping on one leg on the spot 20 times.

The subject was asked to hop on the spot staying inside a circle with a 30 cm diameter.

Arm component

1 Arms relaxed next to side, do not move about.

2 Arms move up an down rhythmically in time with hopping - serves to provide extra momentum. Movements usually symmetrical.

3 Arms move up and down, but movement not rhythmical or timed to assist jumping. Arm movements not symmetrical.

Leg component

1 Hops rhythmically in circle with trunk upright. Hops by extending the leg. Completes 15 consecutive hops.

2 Hops rhythmically but tends to move out of circle.

3 Tilts trunk forward, flexes leg rather than pushing off. Moves about.

4 Cannot hop consecutively.

4.5.3 Bridging tasks

Test actions:

<u>Hip extension in supine</u>: supine lying with heels resting on 20 cm high stool; buttocks raised off the supporting surface and one foot lifted off the stool, shoulders flexed to 90 degrees with elbows extended, position maintained for 10 seconds.

<u>Bridging in crook lying</u>: bridging in crook lying, the left foot lifted off the supporting surface with the left knee extended; the shoulders flexed to 90 degrees with the elbows extended; position maintained for 10 seconds.

The positions were demonstrated to the subject. The child was requested to maintain the position for 10 seconds and encouraged to keep the supporting hip in extension.

1 Maintains the position with ease for 10 seconds, supporting hip fully extended, trunk and arms steady.

2 Maintains but hip not fully extended for full 10 seconds, pelvis not held steady, tilts to non-support side intermittently (wobbles).

3 Maintains with effort, arms abducts and tense, non-support leg internally rotates, pelvis and shoulder girdle tilt to non-support side.

4 Cannot maintain the position.

4.4.4 Standing up from long sitting

Action: standing up from long sitting.

The child was requested to stand up from long sitting without pushing on the hands. Four patterns of movement were observed.

1 The child flexes the hips and knees, drawing the feet closer to the trunk with the hips externally rotated and then stand up.

2 The child flexes the hip and knees, but in this case he or she would internally rotate the hips so that the knees were together and feet wide apart and stand up from this position.

3 The child stands up through side sitting or half kneeling.

4.5.5 Prone pivot

Test action: maintain the prone pivot position (arms in elevation, trunk extended with shoulders and legs lifted off the floor) for 10 seconds.

The position was demonstrated to the subject. The subject was asked to take up the same position and I corrected the position. After a short rest the subject was instructed to take up the position again and hold it for 10 seconds.

1 Maintains the position for 10 seconds with ease. The thighs kept off the supporting surface.
2 The thighs touch supporting surface intermittently.
3 Holds position with difficulty, thighs not lifted of supporting surface.
4 Cannot hold the position at all.

4.5.6 Flexion in supine

Test position: supine with both lower limbs fully flexed and the head and shoulders lifted so that the head touches the knees. The shoulders flexed to 90° with the elbows straight.

The subject was asked to take up the position and I corrected the position if necessary. The subject was instructed to maintain the position for 10 seconds.

1 Maintains head close to knees, with arms steady for 10 seconds.
2 Holds steady for 10 seconds but cannot maintain head in contact with the knees. Holds steadily without a lot of effort.
3 Holds position steady for 10 seconds but cannot bring head to knees.

4 Holds position with effort, arms abduct or elevate, wobbles or falls to the side.

4.5.7 Sitting up in supine

Test action: sitting up from supine with shoulders flexed and elbows extended.

The subject was instructed to sit up 3 times starting in supine with the arms stretched out forward.

1 Sits up 3 times easily and smoothly without using the arms. Feet remain on the floor
2 Sits up without pushing on arms, feet lifted high off supporting surface.
3 Cannot sit up without pushing on hands.
4 Cannot sit up

CHAPTER 5

METHODOLOGY

5.1 Choice of testing procedures and pilot study

5.2 Subjects

5.3 Parental permission

5.4 Testing procedures

- 5.4.1 Age, weight and height
- 5.4.2 Footprints
- 5.4.3 Hip external and internal rotation
- 5.4.4 Passive straight leg raise
- 5.4.5 Movement tests

5.1 CHOICE OF TESTING PROCEDURES AND PILOT STUDY

Children aged six to eight years were used as subjects for the study as this is the age when the clinical manifestations of medial femoral torsion are reported to be the most apparent[77]. A pilot study was done to test the reliability of the measurements and scoring of the motor tasks. Nine 6-year-old children were recruited from the University of the Western Cape Pre-primary School. All these children were tested on two occasions by myself with the assistance of the same physiotherapist on both occasions to establish test-retest reliability.

The pilot study included the following:

* recording the age of the child;
* measurement of height and weight to ensure that the children fell within the normal range for their age;
* passive range of hip internal and external rotation as a clinical measure of medial femoral torsion;
* passive range of hip abduction, adduction, extension and straight leg raising to compare with the range of hip rotation;
* measurement of tibial torsion;
* gait angle measured from footprints;
* movement tests.

In the pilot study the measurement of hip rotation and straight leg raising was found to be repeatable to within 5°. (See p 58 for

method of measurement.) Hip abduction, adduction and extension could not be repeated reliably because of the difficulty of fixing the pelvis and defining the end of range. They were therefore excluded from the final testing protocol.

Tibial torsion was measured according to the method described by Staheli[77]. These measurements were found to be unreliable and were not included in the final protocol.

The scoring of the movement tests was found to be practical to administer and test-retest repeatable was found to be acceptable. Tables 6.2 and 6.5 give the raw scores for each motor test.

5.2 SUBJECTS

Two groups of children were recruited from two convenient schools in Stellenbosch. The two schools were selected on the basis of previous personal contact with the principals which made access to the schools easier. Permission to conduct the research was sought from the Cape Education Department before the principal of the primary school was approached.

Sample 1: A 6-year-old group (G6) of children were recruited at a pre-primary school. Out of a total of 41 children in two classes, 38 participated in the study. One child was excluded due to a recent foot injury. Permission to include another two children was refused by their parents.

Sample 2: Sixty four (out of a possible 73) Sub B children at a primary school in Stellenbosch formed a second group - the 7-year-old group (G7). One child was excluded due to poor co-operation on the movement tests. A second child was excluded because she was much older than the other children and a third child was ill during the testing. The parents of 6 children refused permission to include their children in the study.

5.3 PARENTAL PERMISSION

The parents were informed about the study in a letter and requested to complete and return a consent form to the class teacher. (Appendix A)

5.4 TESTING PROCEDURES

All the testing was carried out by myself assisted by one of two qualified physiotherapists whom I had trained to carry out the testing procedures. One physiotherapist helped to test all the pre-primary group (G6) while the other physiotherapist assisted with the Sub B group (G7).

Testing of each child, which was done during class time, took 25 - 30 minutes to complete. The order that the children were tested depended on the convenience of the teacher. All the children participated very willingly and, except for one child who was later excluded from the study, were very co-operative.

The data was recorded on a form by the assistant (Appendix B).

5.4.1. Height, weight and age.

Each subject's weight was recorded on a calibrated bathroom scale. Height was measured against a tape measure attached to the wall. Date of birth was taken from the class register and age calculated from date of birth to date of testing.

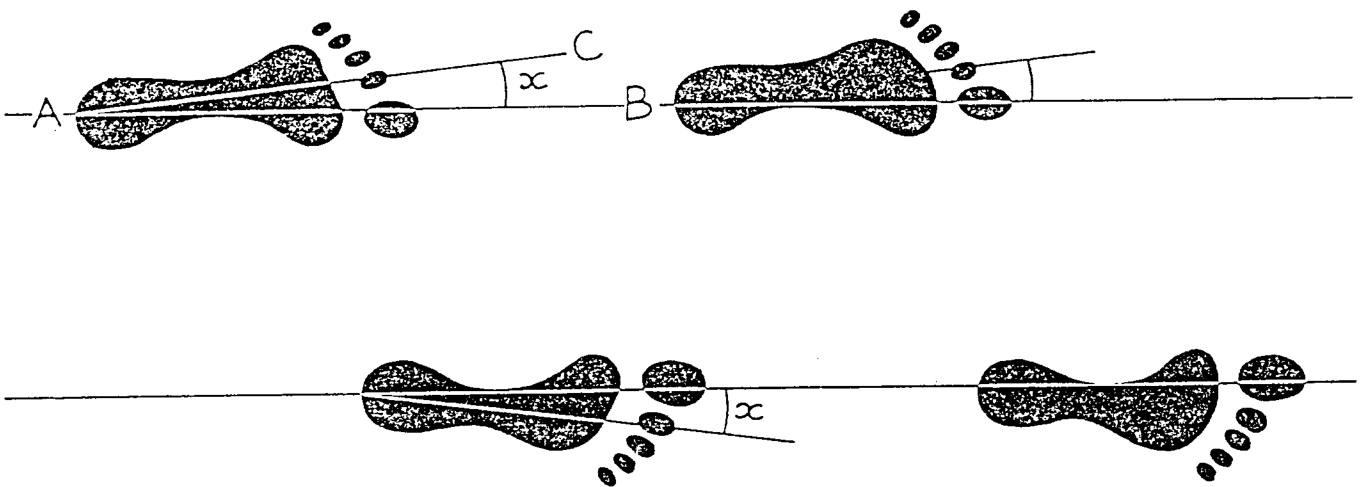
5.4.2 Footprints

Footprints were recorded to measure gait angle by asking the child to walk with bare feet on adhesive contact paper covered with carbon paper. The contact paper was laid on the floor and the wax paper covering removed. The adhesive surface of the paper was dampened to reduce stickiness and layer of carbon paper was laid on the adhesive paper. After the child had walked over the paper, the carbon was removed and the protective covering replaced on the adhesive paper. The footprints showed clearly through the wax paper covering.

The subjects were asked to walk a distance of 5 metres with 3 metres of recording paper placed in the middle. This recorded 6-7 footprints, of which the angle of progression of 4 prints could be calculated.

To measure the angle of gait two lines were constructed on each footprint (Fig 5.1). One line from the mid-point of the back of the

heel of the foot through the second toe to mark the long axis of the foot. A second line was drawn from the midpoint of the back of the heel to the midpoint of the back of the heel of the following footprint of the same foot to mark the line of progression. The angle between the long axis of the foot and the line of progression was measured.



AC = long axis of the foot

AB = line of progression

CAB = angle of gait

Fig 5.1 Construction of angles to measure gait angle

5.4.3 Hip external and internal rotation

Internal and external rotation of the hip was measured in prone lying with the knee flexed. I stabilized the pelvis with one hand and grasping the ankle rotated the hip internally (or externally) until the pelvis started to tilt. This point was easy to identify as long as the child relaxed. In some cases it was necessary to move the leg through the range a number of times to encourage the child to relax. The assistant measured the range of movement using a standard goniometer with the pivot positioned over the distal tip of the patella. Two readings were taken to ensure accuracy. If there was a discrepancy of more than a 2 - 3° the measurements were repeated for a third time and the two that were the same were recorded.

The method used was the same as that described by Sutherland et al[78] in their major study on the development of walking.

5.4.4 Passive straight leg raising

For this test the subject lay supine with both legs extended. For right leg raising, the right leg was passively elevated until the knee started to flex. The goniometer was positioned with the pivot over the greater trochanter, one arm was aligned parallel to the supporting surface, the other arm pointing to the lateral femoral condyle. The angle between the goniometer arms was designated the straight leg raising angle.

The angle was measured twice. If there was a discrepancy in the measured angle, the measurements were repeated.

5.4.5 Movement tests

For the motor tests the child was given instructions and the action demonstrated to the child. The quality of movement was judged according to the criteria that had been laid down and was recorded by the assistant. In some cases the correct classification was unclear and the child was requested to repeat the task. During the testing of the 6-year-old group it was sometimes found that the subject's performance fell between two designated levels of performance. In such cases the lower score (ie the higher level of performance) was assigned for the test. Because of the difficulties encountered during the testing of the 6-year-old group, an intermediate score (ie a 1+ or a 2+) was included when testing the 7-year-old group to cover instances where the child's performance seemed to fall between two adjacent scoring categories.

CHAPTER 6

RESULTS

6.1 Test - retest reliability

- 6.1.1 The 6-year-old group
- 6.1.2 The 7-year-old group

6.2 Characteristics of the six and 7-year old groups

- 6.2.1 Age, weight and height
- 6.2.2 Passive range of movement
  - 6.2.2.1 Differences between boys and girls
  - 6.2.2.2 Differences between right and left legs
  - 6.2.2.3 Differences between G6 and G7
- 6.2.3 Angle of gait
- 6.2.4 Relationship between passive range of movement and gait angle
- 6.2.5 Movement tests
- 6.2.6 Standing up from long sitting

6.3 Relationship between measures of anteversion and movement tests

- 6.3.1 Division of samples into subgroups
- 6.3.2 Characteristics of the subgroups
  - 6.3.2.1 Age, weight and height
  - 6.3.2.2 Passive range of movement
- 6.3.3 Comparison of performance of subgroups on the movement tests

6.1 TEST-RETEST RELIABILITY

The subjects in each group were numbered sequentially in the order they were tested. After I had completed the testing of all the subjects in a sample, I selected every 10th child for retesting. If the child was not available at the time, the next child on the list was tested. Six of the 7-year-old group were retested, and 5 of the 6-year-old group were retested by myself and the same assistant who had assisted with the testing for each group. A one sample Student t-test was used to test for differences in means.

6.1.1 The 6-year-old group

Measurement of height was accurate to 0.5 cm and weight to 1 kg. Since the measurement of height and weight were only used to ensure that the children fell within the normal range for their age, this measurement error was considered to be acceptable.

Twenty eight out of the thirty passive movement measurements were within 5° of each other. The other two measurements were within 10°. As there was no significant difference in the means for the test and retest measurements of each movement, it was assumed that there was no bias towards greater or lesser reading in the retest data. (Table 6.1).

The retest footprint data were unfortunately lost, so reliability could not be tested. The gait angle data for the 6-year-old group were therefore not used for this study.

TABLE 6.1
Comparison of means of test - retest measurements (in degrees) for passive range of movement for the 6-year-old group (N = 5)

		Test Mean	Retest Mean	T-statistic	p	DF
Internal	L	58.2	58.8	-0.09	-	4
rotation	R	50.6	51.4	-0.06	-	4
External	L	21	24.6	-1.30	-	4
rotation	R	25.6	26.4	-0.12	-	4
SLR	L	69.2	67.6	0.38	-	4
	R	66.8	66.2	0.14	-	4

Table 6.2 gives the raw scores for the movement tasks. Except for the scores for hopping and standing on one leg of subject number 1 the scores on the retest are very close to the test scores. As there is no significant difference on a one sample student t-test in the means of the test and retest scores for each task, it was assumed that there was no bias towards a greater or lesser score in the retest data. (Table 6.3).

TABLE 6.2
Comparison of test (T) and retest (R) scores on the movement tasks for the 6-year-old group (N = 5)

		Possible score	Subjects				
			1	2	3	4	5
Standing on 1 leg	T*	4-14	4	12	10	7	7
	R**		9	12	9	6	8
Hopping	T	4-14	12	11	14	10	10
	R		8	12	12	11	12
Hip extension	T	2-8	4	5	4	4	5
	R		4	4	4	5	6
Bridging	T	2-8	6	6	4	6	6
	R		4	6	5	6	6
Prone pivot	T	1-4	1	2	1	1	1
	R		1	1	1	1	2
Full flexion	T	1-4	2	3	3	3	3
	R		3	3	2	2	3
Situp	T	1-4	3	2	2	1	3
	R		3	2	1	1	3

* = Test score ** = Retest score

TABLE 6.3

Comparison of test (T) and retest (R) means and SD on the movement tasks for six-year-old group (N = 5)

DF		Possible score	Mean	SD	T-statistic	p	
Standing	T*	4-14	8	3.1	-0.76	-	4
on 1 leg	R**		8.8	2.2			
Hopping	T	4-14	11.4	1.7	0.36	-	4
	R		11	1.7			
Hip	T	2-8	4.4	0.5	-0.53	-	4
extension	R		4.6	0.9			
Bridging	T	2-8	5.6	0.9	0.40	-	4
	R	2-8	5.4	0.9			
Prone	T	1-4	1.2	0.4	0	-	4
pivot	R		1.2	0.4			
Full	T	1-4	2.8	0.4	0.53	-	4
flexion	R		2.6	0.5			
Situp	T	1-4	2.2	0.8	1	-	4
	R		2	1.0			

* = Test score ** = Retest score

6.1.2 The 7-year-old group

All the scores for internal rotation of the left and right hips and external rotation of the left hip were within 5° of each other. There was however a 10° - 15° difference in the scores for external rotation of the right hip. This discrepancy could be due to the fact that when we measured the ranges of hip rotation, I positioned the hip joint in external rotation always sitting on the left side of the child. Positioning the right hip while sitting on the left side could have caused errors in positioning. The means for the test and retest scores for hip rotation, including that for external rotation of the hip did not differ significantly (Table 6.4).

Of the 12 scores for left and right straight leg raising, all but one were within 5° of each other. The means for the two groups did not differ significantly on the Student t-test (Table 6.4).

The test and retest means for gait angle of the 7-year-old group did not differ significantly.

TABLE 6.4

Comparison of means of test (T) and retest (R) measurements (in degrees) for passive range of movement and gait angle for the 7-year-old group.

		Test		Retest				
		Mean	SD	Mean	SD	T-statistic	p	DF
Internal	L	53	10.3	52	13.3	0.53	-	5
rotation	R	50	13.0	53	11.6	-3.21	-	5
External	L	37	11.3	36	9.7	0.46	-	5
rotation	R	41	16.6	39	8.6	0.31	-	5
SLR	L	68	6.8	65	4.6	1.05	-	5
	R	64	7.0	65	3.8	-0.22	-	5
Gait	L	8	2.4	8	4.4	0	-	5
	R	7	3.1	6	5.9	0.22	-	5

Movement tasks

Although there were a few (5 out of 42 scores) quite large discrepancies between the test and retest scores for the movement tasks (Table 6.5), there was no significant difference in the means for each task (Table 6.6).

TABLE 6.5
Comparison of test (T) and retest (R) scores the movement tasks for the 7-year-old group (N = 6)

		Possible score	Subjects score					
			1	2	3	4	5	6
Standing	T	4-14	5	5	8.5	5	4	7.5
on 1 leg	R		5	4.5	5	5	5	9
Hopping	T	4-14	6	8	5	4.5	6	12
	R		6.5	7	6	4	4	9
Hip	T	2-8	2	3	2	2.5	2	3.5
extension	R		2	2.5	2	2	2	3
Bridging	T	2-8	2	4.5	5	3.5	2.5	4
	R		2	4	2.5	4	4	5.5
Prone	T	1-4	1	1	1.5	1	1	1.5
pivot	R		1	1.5	1	1	1	1
Full	T	1-4	1.5	1.5	1.5	2.5	1	1.5
flexion	R		1	3	1	2	1.5	1.5
Situp	T	1-4	1	3	2	3	1	1
			1	3	1	3	1	1

TABLE 6.6

Comparison of test (T) and retest (R) scores and means for the movement tasks for the 7-year-old group (N = 6)

		Possible Score	Mean	SD	T-statistic	p	DF
Standing	T	4-14	5.8	1.7	0.03	-	5
on 1 leg	R		5.8	1.7			
Hopping	T	4-14	6.1	1.9	-1.35	-	5
	R		6.9	2			
Hip	T	2-8	2.5	0.6	2.23	-	5
extension	R		2.2	0.4			
Bridging	T	2-8	3.6	1.2	-0.14	-	5
	R		3.7	1.2			
Prone	T	1-4	1.2	0.2	0.54	-	5
pivot	R		1.1	0.2			
Full	T	1-4	1.6	0.5	0.25	-	5
flexion	R		1.6	0.7			
Situp	T	1-4	1.8	1.0	1.00	-	5
	R		1.7	1.0			

6.2 CHARACTERISTICS OF THE 6- AND 7-YEAR-OLD GROUPS

6.2.1 Age, weight, and height

Tables 6.7 and 6.8 summarise the data for the age, weight and height of the subjects in each of the samples. There was no significant difference on the student t-test in the mean weight or height of the girls and boys in either the 6 or the 7-year-old groups (Tables 6.7 and 6.8). In both groups the boys were slightly older than the girls. This difference was significant in the 7-year-old group (t = 2.59 p < .05 DF 62) but not in the 6-year-old group (t = 1.82 P - DF 36).

TABLE 6.7
Weight, height, and age of G6

	Boys (N = 24)		Girls (N = 14)				
	Mean	SD	Mean	SD	t	p	DF
Age (years)	6.4	0.4	6.26	0.3	1.82	-	36
Height (cm)	120	6.4	121	3.9	-0.42	-	36
Weight (kg)	22	3.3	23	2.8	-0.56	-	36

TABLE 6.8
Weight, height, and age of G7

	Boys (N = 29)		Girls (N = 35)				
	Mean	SD	Mean	SD	t	p	DF
Age (years)	7.6	0.5	7.3	.3	2.59	<.05	62
Height (cm)	130	5.8	128	5.3	1.94	-	62
Weight (kg)	26.7	4.4	25.9	4.7	0.65	-	62

6.2.2 Passive range of movement

Table 6.9 summarizes the data for the passive range of movement of the hips.

TABLE 6.9
Range of passive hip rotation and straight leg raising (SLR) of G6 and G7

		6-year-old group				7-year-old group			
		Boys (N=24)		Girls (N=14)		Boys (N=29)		Girls (N=35)	
		Mean	SD	Mean	SD	Mean	SD	Mean	SD
Internal rotation	L	52	10.4	47	5.0	54	0.7	53	0.0
	R	48	11.8	42	5.9	52	8.9	54	10.0
External rotation	L	23	11.4	25	5.7	39	9.5	38	10.1
	R	26	9.1	26	7.1	40	10	38	9.0
SLR	L	71	7.2	74	5.3	65	6.2	71	6.1
	R	70	8.0	75	4.8	64	7.1	70	5.6

6.2.2.1 Differences between boys and girls

There was no significant difference on a Student t-test in the mean range of left and right internal or external hip rotation of the boys and girls; the data for the boys and girls was therefore pooled for all further analysis.

In both groups the mean angle of SLR is 3°-6° larger for the girls than for the boys. This difference is significant in the 7 year-old-group for right SLR ($t = -3.7$, $p < .001$ DF = 62) and left SLR ($t = -3.6$, $p < .001$ DF = 62).

6.2.2.2 Differences between right and left legs

The mean angle of left and right hip rotation (internal and external) in the 7-year-old group did not differ significantly (Table 6.11) In the 6-year-old group there was a highly significant difference in the mean angle of left and right internal hip rotation ($t = 3.5$ $p < .001$ DF = 37) as well as a significant difference between left and right external rotation ($t = - 2.24$ $p < .05$ DF = 37) (Table 6.10).

There was no significant difference in the mean angle of left and right SLR of both boys and girls in either sample (Table 6.10 and 6.11).

TABLE 6.10

Range of passive hip rotation and SLR for G6

		mean	SD	range	t	p	DF
Internal	L	50	8.9	32 - 70	3.48	< .001	37
rotation	R	46	10.3	26 - 78			
External	L	23	9.7	4 - 65	-2.24	<.05	37
rotation	R	26	8.2	10 - 48			
SLR	L	72	6.6	59 - 85	0.02	-	37
	R	72	7.2	58 - 94			

TABLE 6.11

Range of passive hip rotation for G7

		mean	SD	range	t	p	DF
Internal	L	53	9.8	35 - 760	0.53	-	63
rotation	R	53	9.5	35 - 74			
External	L	38	9.8	12 - 60	0.27	-	63
rotation	R	39	9.5	15 - 55			
SLR (Boys)	L	66	6.2	55 - 75	1.7	-	28
	R	64	7.1	55 - 80			
SLR (Girls)	L	71	6.2	60 - 80	1.3	-	34
	R	70	7.1	60 - 85			

6.2.2.3 Differences between 6 and 7-year-old groups

The mean internal rotation for the 6 and 7-year-old groups did not differ significantly. There was a large difference between the mean external rotation of the 7-year-old group (L = 38°, R = 39 °) and the 6-year-old group (L = 23°, R = 26 °) These differences are highly significant for left ($t = 7.60$ $p < .001$ DF = 100) and right legs ($t = 6.83$ $p < .001$ DF = 100)

There was no significant difference in the range of straight leg raising between the two groups for both boys and girls.

6.2.3 Angle of gait

The angle of gait for the left and right feet of the 7-year-old group are given in Table 6.12 The left gait angle was significantly smaller than the right gait angle for both boys and girls. There was no significant difference between the boys and the girls ($t = -1.5$ p - DF = 62).

Because the reliability of the gait angle data of the 6-year-old group could not be assessed due the loss of the retest footprints, the analysis of this data was not included in this study. The analysis did however show results similar to the 7-year-old groups findings.

TABLE 6.12

Angle of gait (in degrees) for the 7-year-old groups (N = 64)

		Mean	SD	Range		t	p	DF
Boys	Left	3.2	3.8	-7 -	+10	-3.11	< .001	28
	Right	5.1	4.2	-7 -	+10			
Girls	Left	4.8	4.1	-9 -	+12	-2.21	< .05	34
	Right	6.6	4.6	-3	+18			

6.2.4 Relationships between passive hip movements and gait angle.

There was also a moderate correlation between gait angle and range of hip rotation in the 7 year-old group on the left ($r = -41$ $p < .005$), and right ($r = .43$ $p < .001$).

6.2.5 Movement tests

A Wilcoxen signed rank test was used to test for left - right differences on the standing and hip extension tasks. As there was no significant difference between left and right scores on any of the movement tasks, scores for the left and right legs were combined to give a single score for each task. This gave a possible score of 4 - 14 for standing on one leg and hopping and a possible score of 2 - 8 for hip extension and bridging.

The Mann Whitney test showed no difference in the performance of the movement tests between the boys and the girls in either group.

During the testing of the 6-year-old group, the child's performance sometimes fell between two adjacent categories. In such cases I tended to score the task at the more skilled level ie gave the lower of the two scores. During the testing of the 7-year-old group I introduced an intermediate category to cover such cases. This meant that if a child in the 7-year-old group's performance seemed to fall between level 2 and 3, I would give a score of 2.5 compared to a score of 2 that would have been assigned to a child in the 6-year-old group. As a result a statistical comparison of the scores of the two groups cannot be made.

Visual comparison of the distribution of scores for the two groups (Fig 6.1 - 6.3) does give some indication of changes in the performance of the tasks between the younger and older group. Generally, the distribution of scores indicated a higher level of proficiency for the 7-year-old group than the 6-year-old group on the hip extension tasks but not on the trunk tasks. Within each group there was no association between age and performance on individual tasks. Some of the youngest children performed at the highest level of proficiency while some of the oldest children performed very poorly.

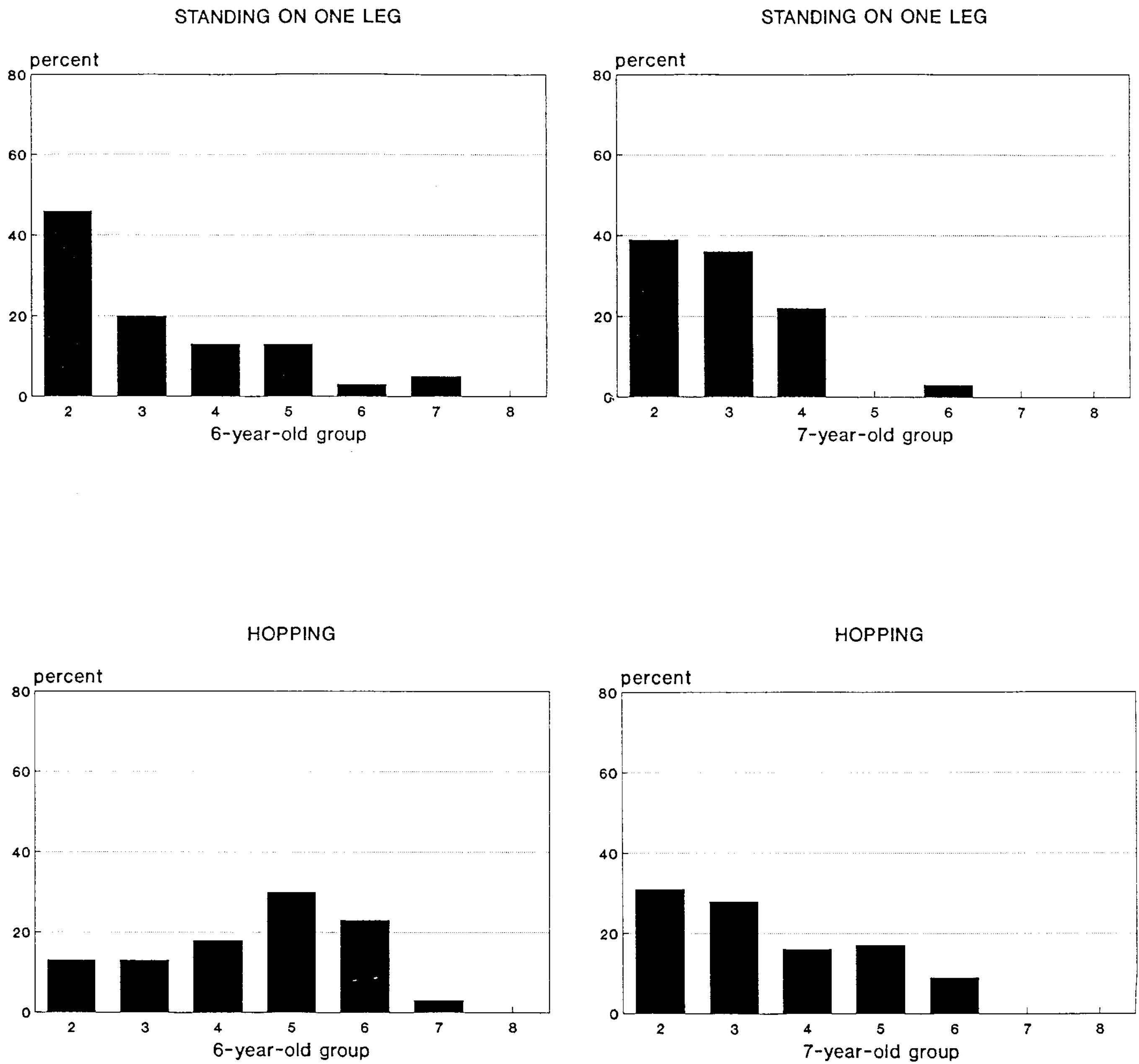


Fig 6.1 Distribution of scores on standing tasks for G6 and G7

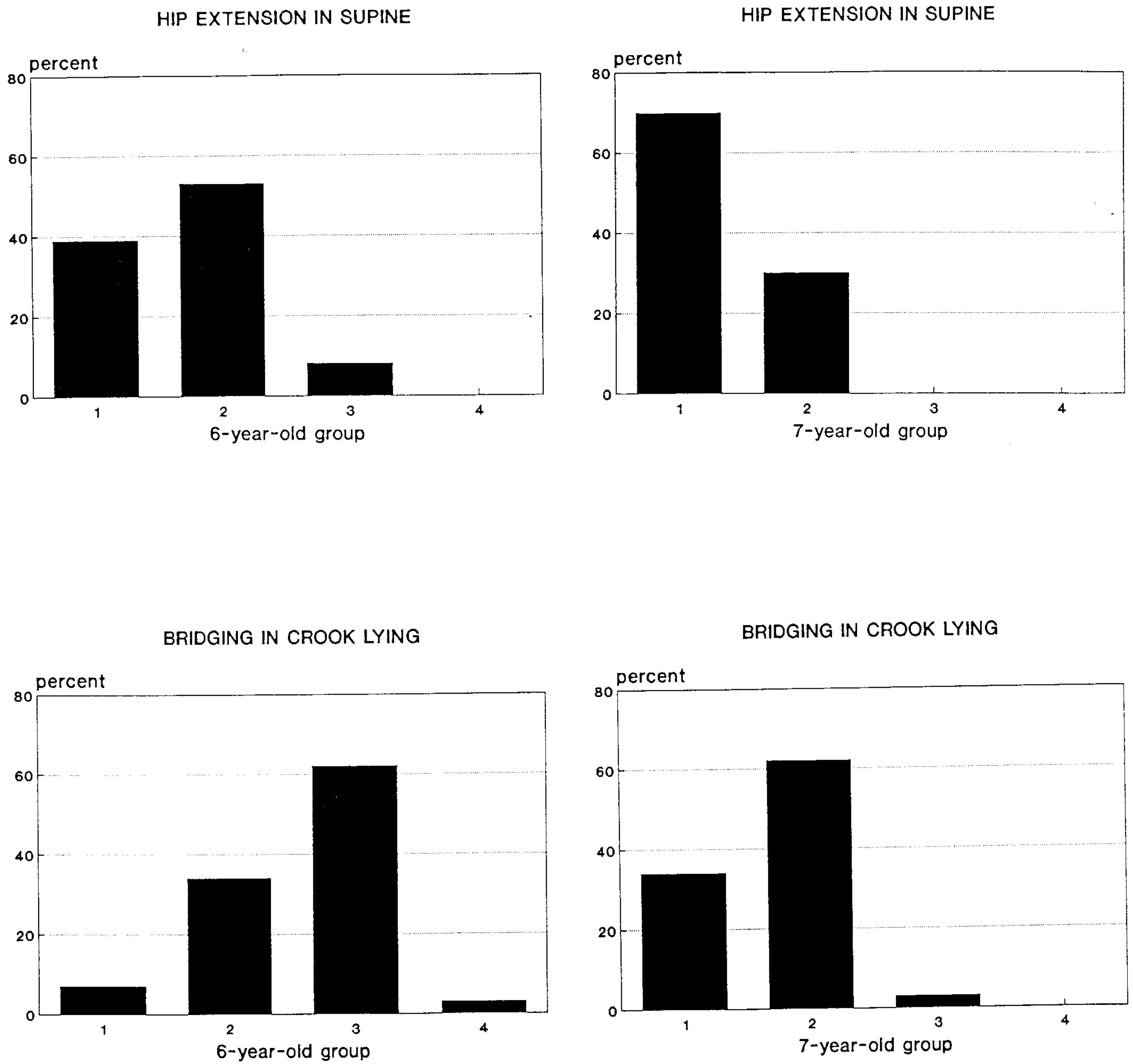
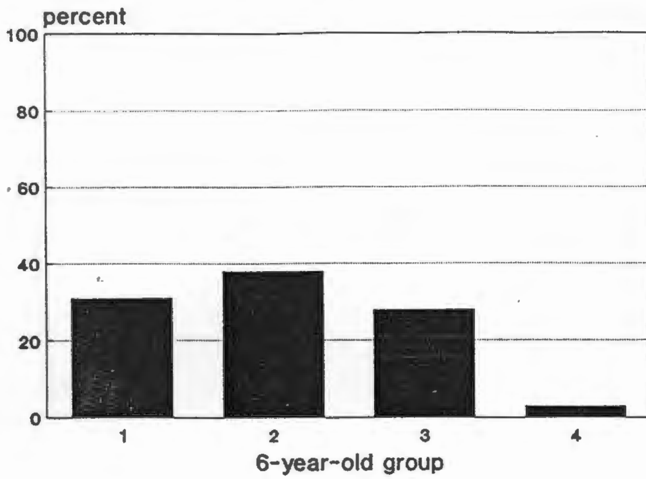
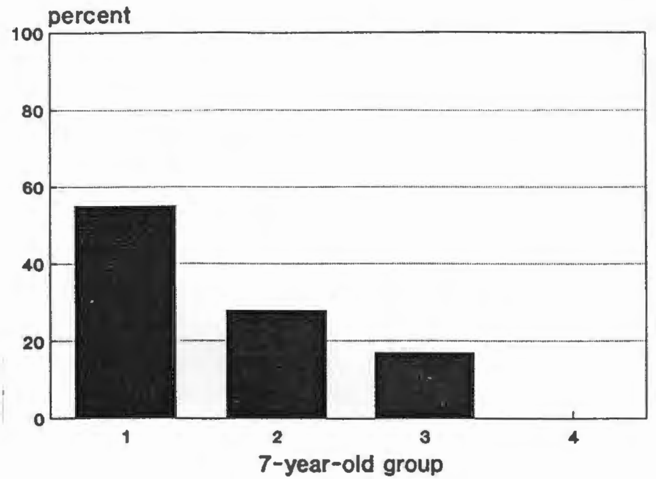
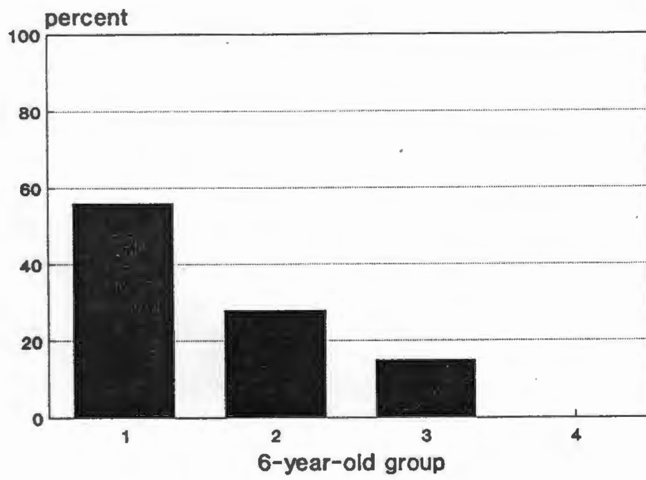
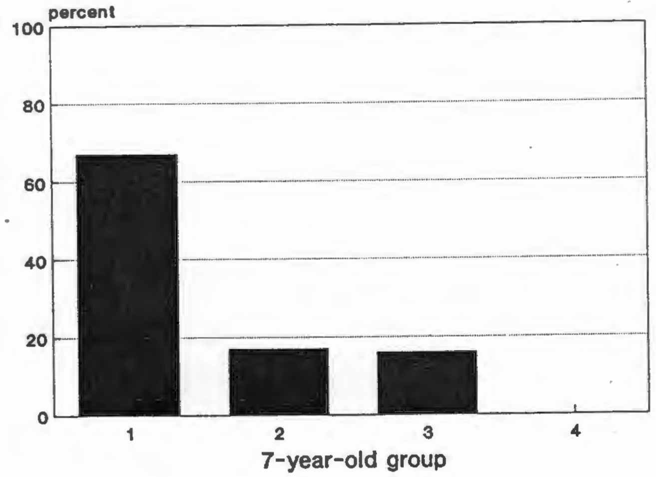


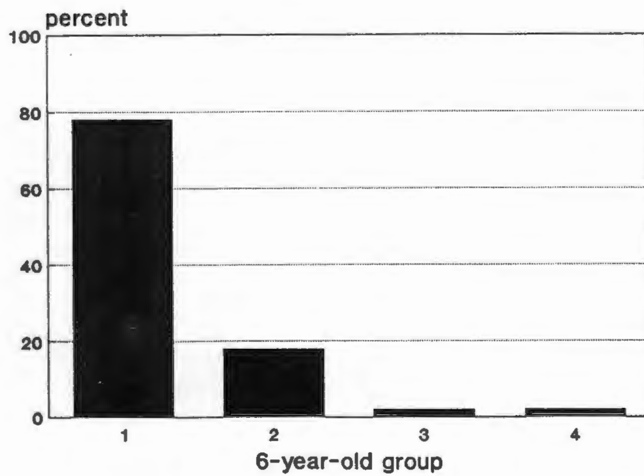
Fig 6.2 Distribution of scores for the bridging tasks for G6 and G7











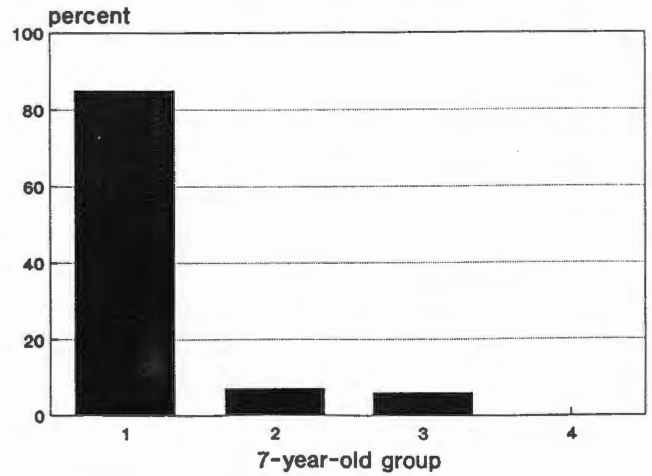


Fig 6.3 Distribution of scores for trunk tasks for G6 and G7

6.2.6 Standing up from longsitting

All the children in both groups could stand up without pushing on their hands. Of the 38 children in the 6-year-old group, 5 children (13 %) stood up with internal rotation of the hips; these 5 children all had more than 60° of internal hip rotation of the left and right hips. In the 7-year-old group, 20 of the 64 children (31%) stood up with internal rotation of both hips; another 5 children (8%) internally rotated the left leg, the remainder (61%) stood up with the hips neutral. Of the 20 children who stood up with internal rotation of both legs, 11 had internal rotation of 60° or more of both legs. Four of the 39 children (10%) who stood up with the legs neutral had a range of internal rotation of 60° or more for both legs.

6.3 THE RELATIONSHIP BETWEEN CLINICAL MEASURES OF ANTEVERSION AND PERFORMANCE ON THE MOTOR TASKS

To explore the relationship between measures of anteversion (hip rotation and gait angle), straight leg raising and performance on the motor tasks, I plotted a number of scattergrams and calculated Spearman rank correlation coefficients.

The association between range of movement of the left and right legs and a composite score for individual movement tasks was explored. It can be argued that movement of the leg should have been compared to performance of tasks using the same leg rather than using a composite score. Spearman correlation co-efficients using movement scores for one leg were much the same as those for a combined score. The combined score however gave a greater spread of points (with less superimposing of individual points) on the scattergram allowing for more effective visual analysis of the data.

In the 7-year-old group there were poor to moderate correlations between hip external and internal rotation (the average for left and right) and scores for standing on one leg and bridging. There were also weak but significant correlations between hip internal and external rotation and hopping and hip extension in supine (Figs 6.4 and 6.5).

There was no significant correlation between gait or straight leg raising (boys and girls) and any of the movement tasks or between the trunk tasks and hip rotation. (Scattergrams not included.)

On the standing tasks (hopping and standing on one leg) children in the 7-year-old group with less than 50° of internal hip rotation tended to cluster on the lower scores. The scores of the children with hip internal rotation of more than 50° were very scattered (Fig 6.4).

In contrast the 6-year-old group showed no significant correlation between left and right hip rotation and the movement tasks except for a moderate negative correlation between right external rotation and standing on one leg (Fig 6.6) and a weak positive correlation between right hip internal rotation and extension in supine. (Fig 6.7).

Surprisingly the strongest correlations in the six-year-old group were found between left ($r = -.51$ $p < .01$) and right ($r = -.60$ $p < .001$) straight leg raising and standing on one leg. There was also a weaker correlation between right straight leg raising and hopping as well as bridging in crook lying (Fig 6.6 and 6.7).

There was no correlation between range of hip movement and the trunk tasks in the 6-year-old group. (Scattergrams not included.)

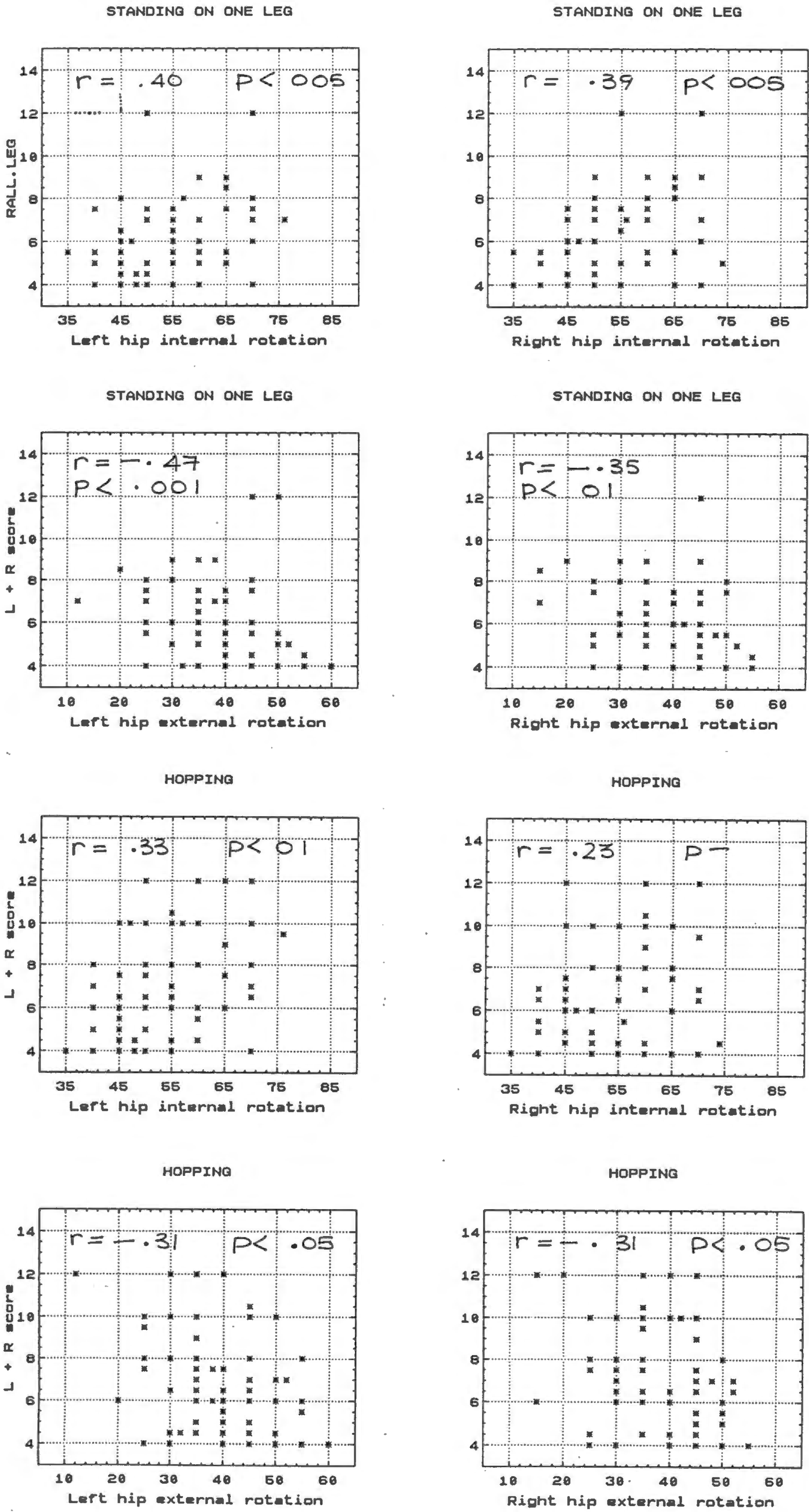


Fig 6.4 Performance of standing tasks related to hip movements in G7 subgroups (with Spearman correlation coefficients).

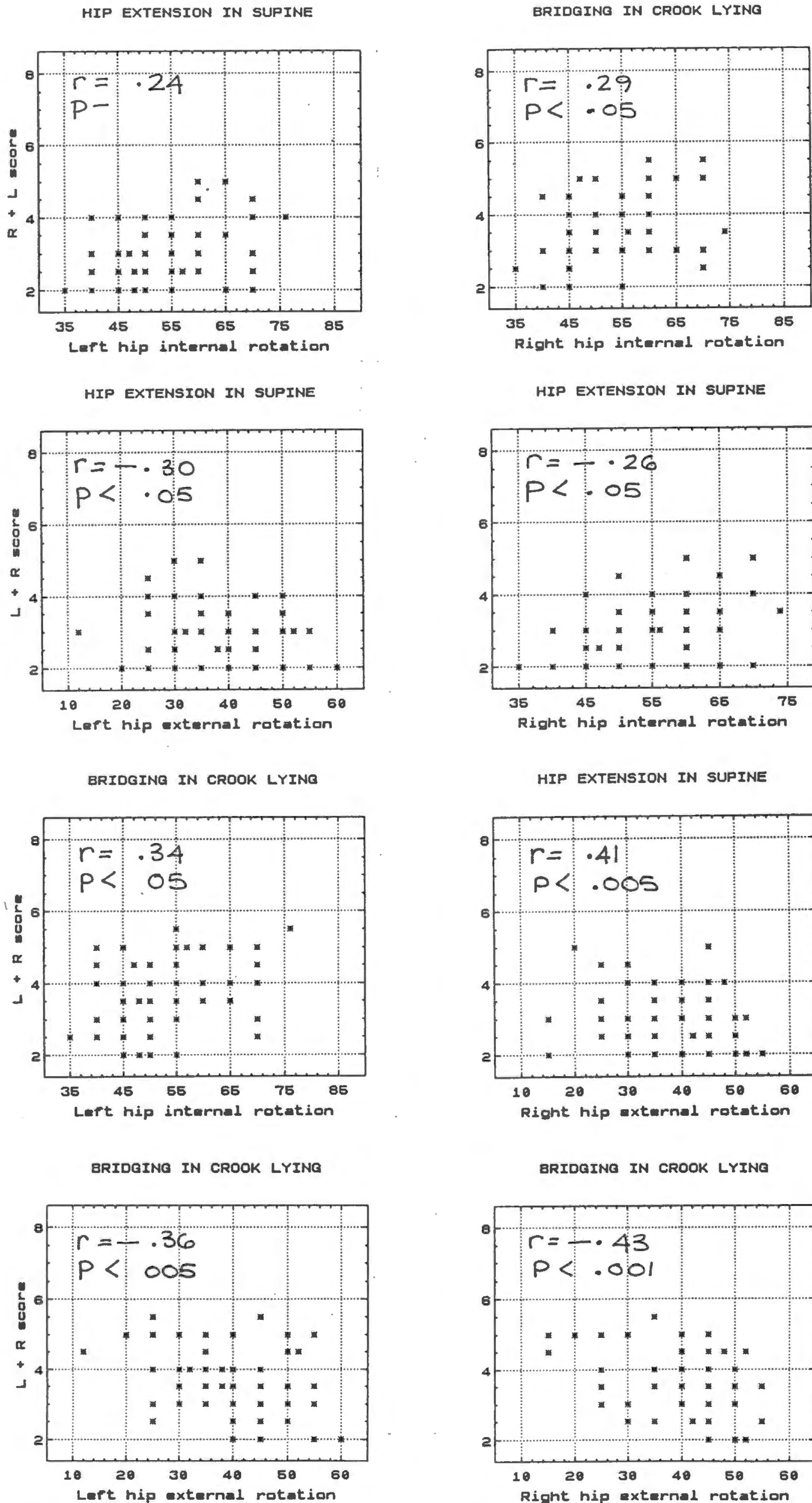
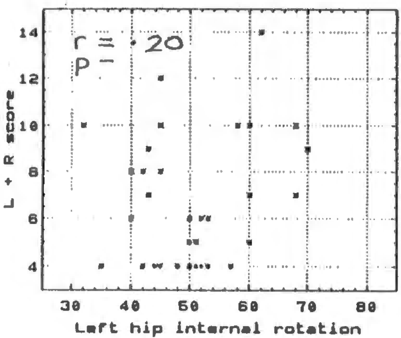
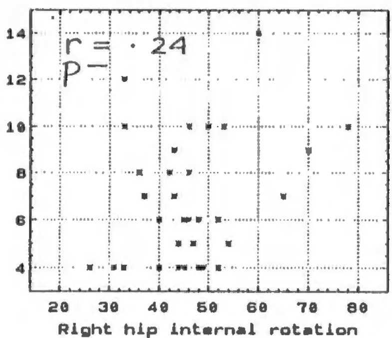
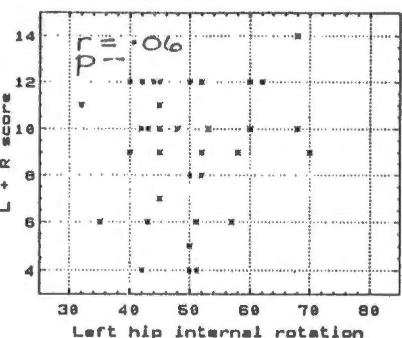
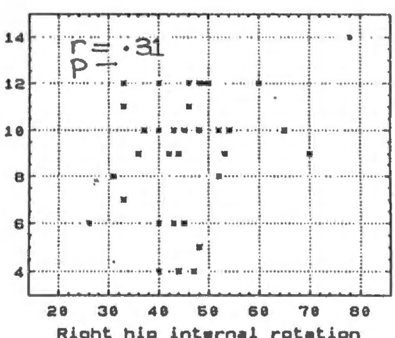


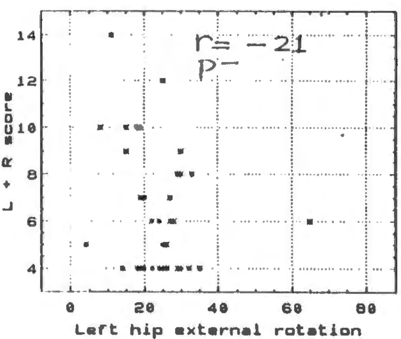
Fig 6.5 Performance on bridging tasks related to hip movements in G7 subgroups (with Spearman correlation coefficients).

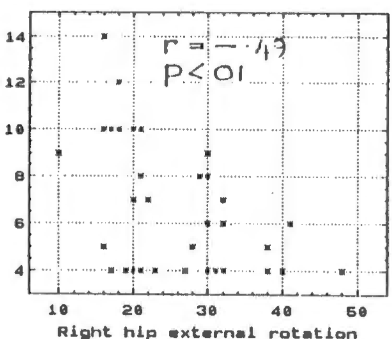


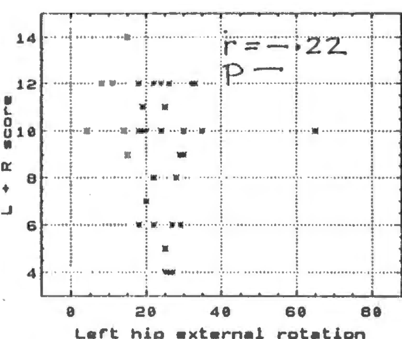


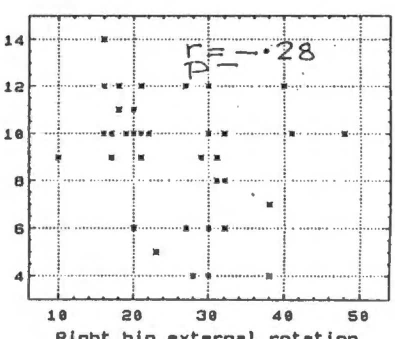


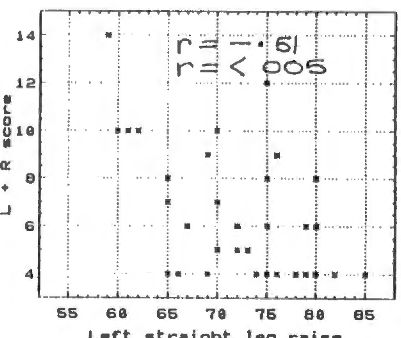


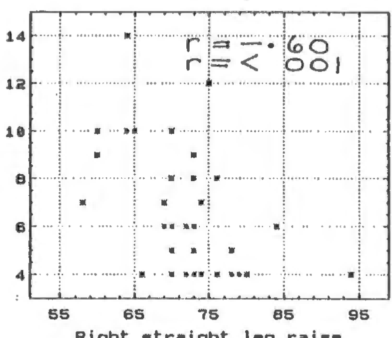


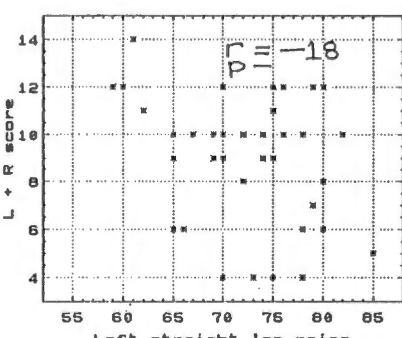












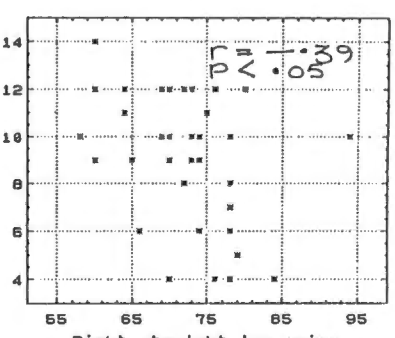
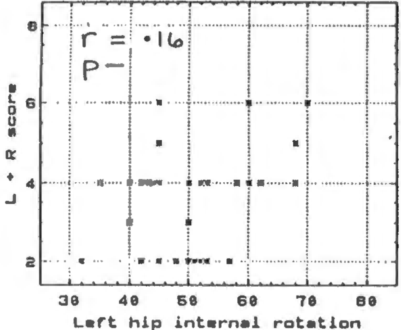
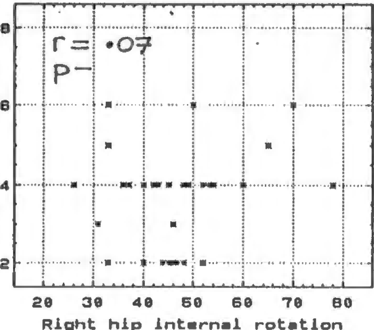
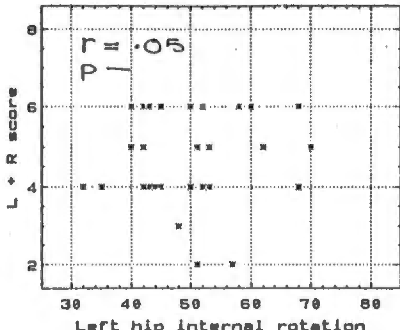
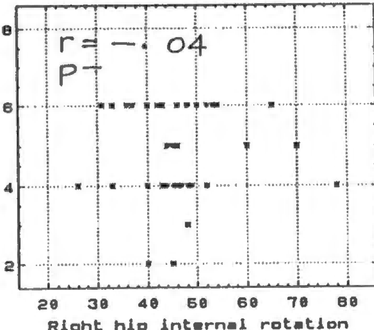


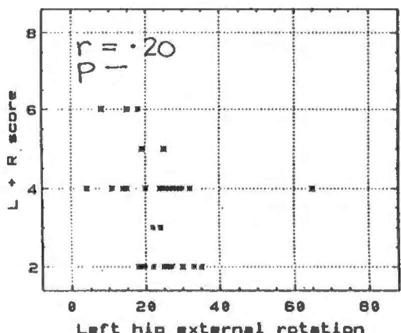
Fig 6.6 Performance on standing tasks related to the range of hip movement for G6 subgroups (with Spearman correlation coefficients.

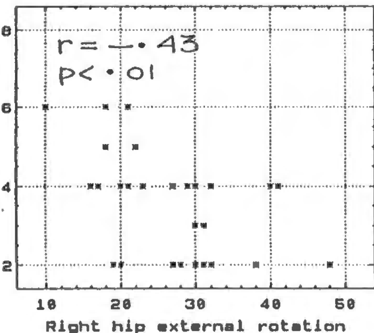


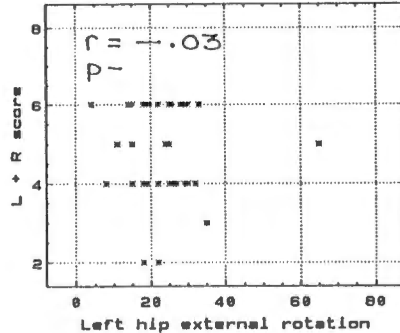


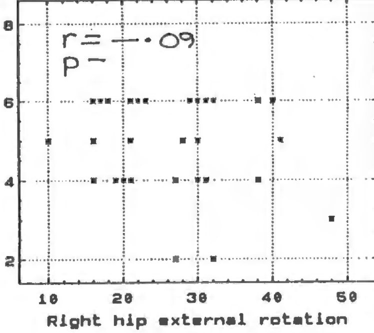


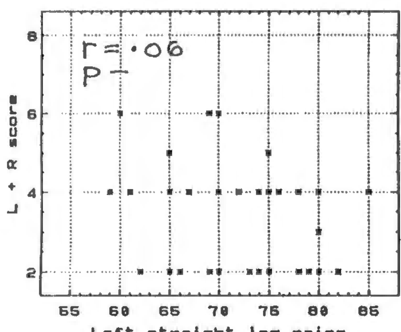


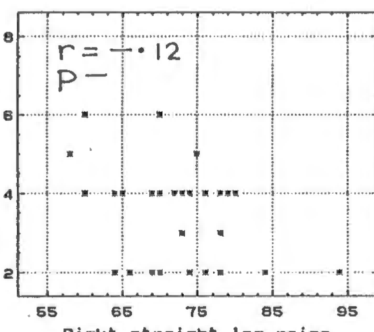


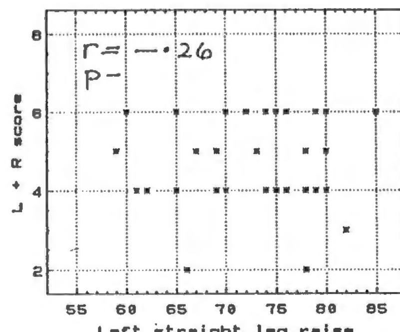












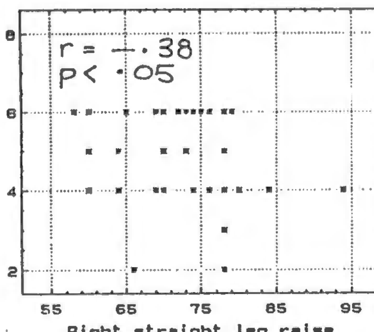


Fig 6.7 Performance on bridging tasks related to the range of hip movement in G6 subgoups (with Spearman correlation coefficients).

6.3.1 Division of the samples into subgroups

Clinically the range of internal rotation is used to assess the degree of abnormal anteversion of the hip. To further explore the correlation seen between range of movement and performance on motor tests of children with smaller and larger ranges of internal rotation I divided each sample into 3 subgroups based on the range of internal hip rotation. I then compared the performance of the three subgroups on the motor tasks.

As there was no difference between the left and right internal rotation of the 7-year-old group, subjects were placed into subgroups on the basis of the average for left and right internal rotation. In the 6-year-old group the mean for right internal hip rotation was significantly less than the mean for left internal rotation, therefore average of left and right could not be used to place subjects in the subgroups. The distribution of ranges of left internal rotation of the 6-year-old group did not differ significantly from that of the 7-year-old group, whereas there was a significant difference in ranges for right internal hip rotation (Section 6.6.6.3). The range of left internal rotation was therefore used to place subjects in the 6-year-old group into subgroups.

The scattergrams of the 7-year-old group indicated that for children with a range of internal rotation of 50° or less the scores on the bridging and standing tasks tended to cluster on the lower half of the y-axis. In the 6 year old group the scores of children with a internal rotation range of around 50° had the lower scores.

These considerations were used to divide each group into a small range (SR) subgroup with a range of internal rotation of 50° or less, a middle range (MR) subgroup with a range of 50° - 59° and a large range (LR) subgroup with a range of 60° or more (Table 6.13).

The possible measurement error of 10° meant that the children in the middle group could erroneously have been put in the middle subgroup instead of the smaller or larger subgroup. The ranges of the children large and small subgroups did not overlap.

TABLE 6.13

Division of 6 and 7-year old groups into LR, MR, and SR subgroups.

	Subgroup	Range	Number of subjects	Girls	Boys
6 year-old-group	LR	60° or more	8	1	7
	MR	50° - 59°	13	6	7
	SR	< 50°	17	7	10
7 year-old-group	LR	60° or more	17	8	9
	MR	50° - 59	23	16	7
	SR	< 50 °	24	11	13

6.3.2 Characteristics of the subgroups

6.3.2.1 Age, weight and height of the subgroups

An analysis of variance showed that there was no difference in the age, height and weight of the LR, MR and SR subgroups of the 6 or 7-year-old samples, except for an age difference in the 6-year-old group ($F_{2/35} = 3.35$, $p < 0.05$). Post hoc analysis (Tukey) performed at alpha 0.05 revealed that the 6LR subgroup was older than the 6MR and 6SR subgroups (figs 6.8 and 6.9).

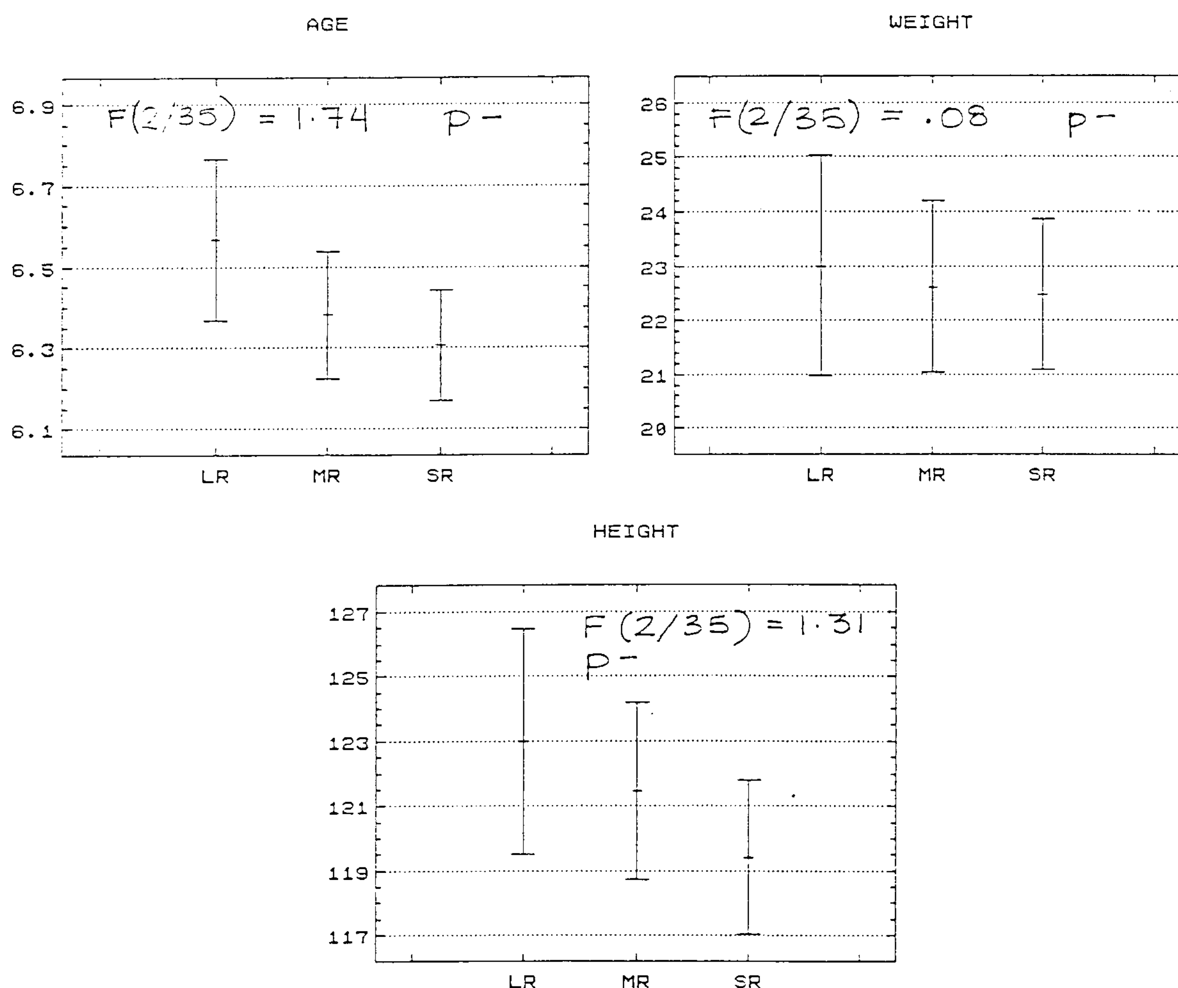


Fig 6.8 95% confidence intervals for factor means for age, height and weight for G6 subgroups.

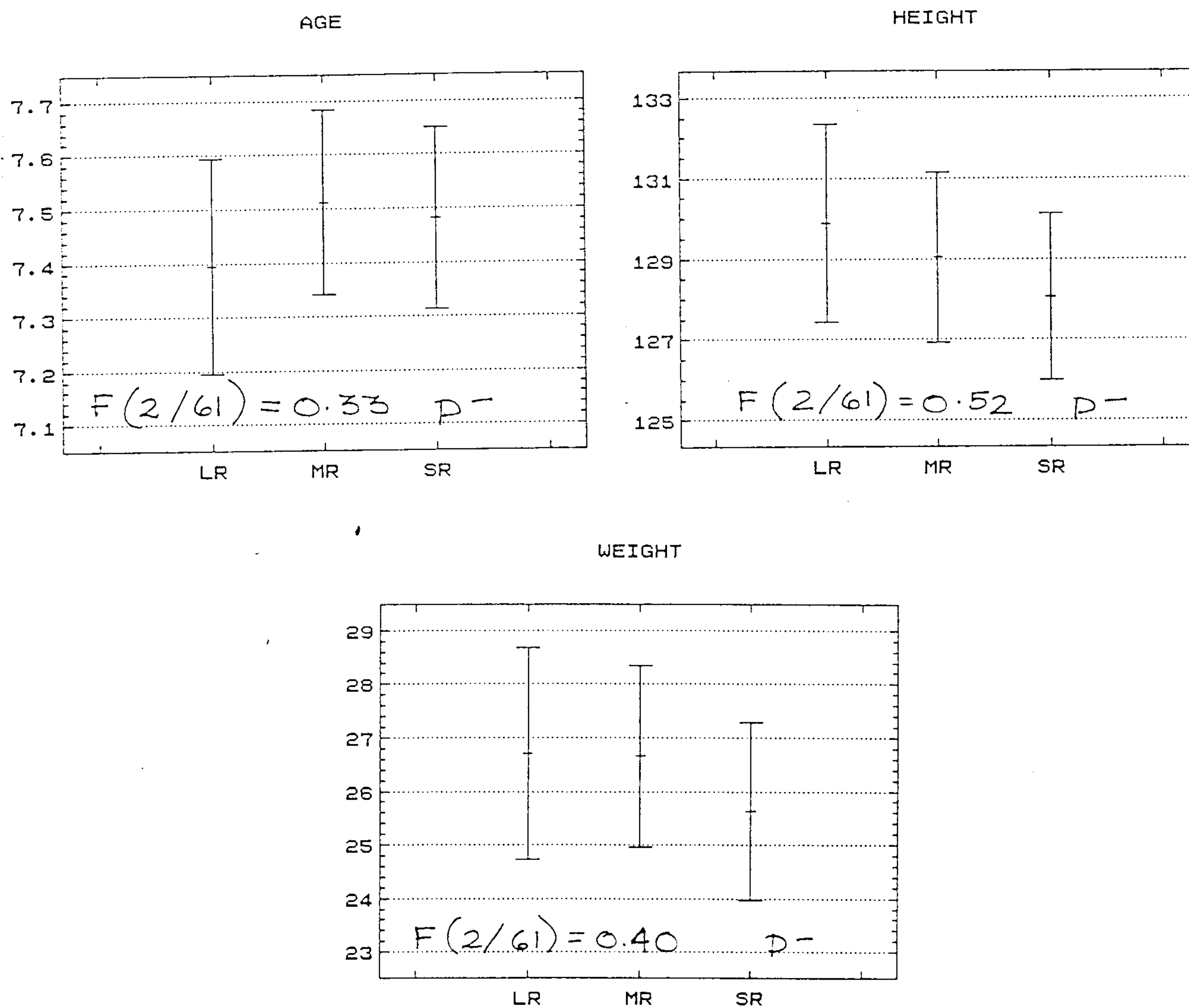


Fig 6.9 95% confidence intervals for factor means for age, height and weight for G7 subgroups.

6.3.2.2 Passive range of movement and gait angle

The 6-year-old group

Table 6.14 gives the ranges of hip rotation and straight leg raising of the 6LR, 6MR and 6SR subgroups.

TABLE 6.14
Means (in degrees) of external hip rotation and straight leg raising of the 6-year-old subgroups.

		6LR (N = 7)		6MR (N = 14)		6SR (N = 7)	
		Mean	SD	Mean	SD	Mean	SD
External rotation	L	14	5.0	28	12.0	23	6.2
	R	7	3.5	31	7.4	26	6.9
SLR	L	65	4.9	73	6.2	74	5.7
	R	62	5.0	73	4.7	75	6.3

An analysis of variance revealed significant differences between subgroups for external hip rotation and SLR. Post hoc analysis showed that for external hip rotation the mean angle of the 6LR subgroup was significantly smaller than the 6MR and 6SR subgroups. Interestingly external hip rotation of the 6MR subgroups was slightly larger than that of the 6SR subgroup but this difference was not significant (fig 6.10).

A post hoc analysis (Tukey) showed that the 6LR subgroup differed from the 6MR and 6SR subgroups but that the latter did not differ from each other (Fig 6.10)

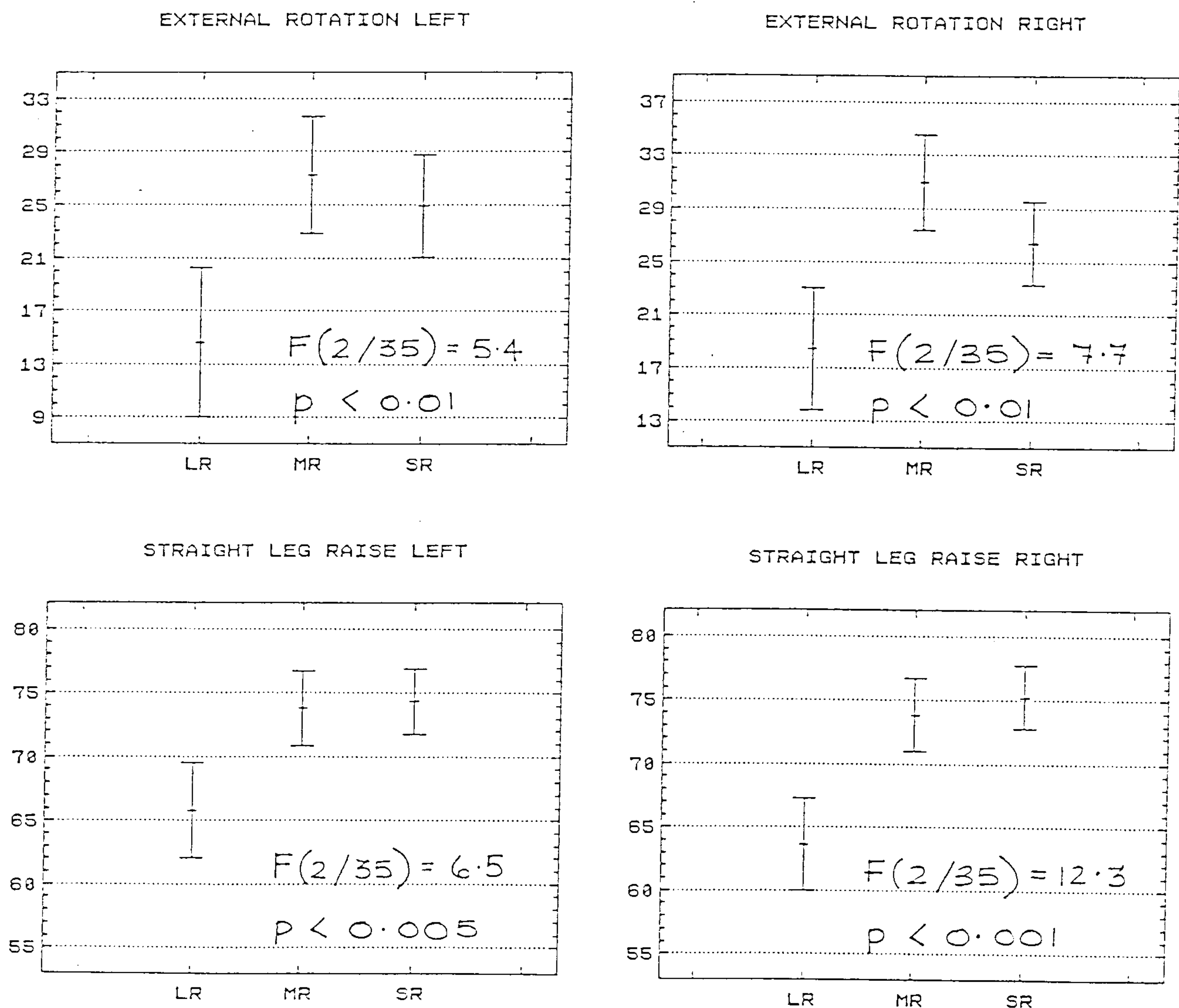


Fig 6.10 95% confidence interval for factor means for passive range of movement the G6 subgroups.

The 7-year-old subgroups

The means for passive range of hip movement and gait angle of the 7-year-old subgroups are given in Table 6.15

TABLE 6.15

Mean angle of hip rotation and straight leg raising of the 7-year-old subgroups.

		7LR (N = 17)		7MR (N = 23)		7SR (N = 24)	
		Mean	SD	Mean	SD	Mean	SD
External	L	30	9.2	40	9.9	44	5.7
rotation	R	31	10.1	38	7.5	45	6.2
SLR	L	69	8.7	69	5.3	68	6.7
	R	66	8.5	68	5.2	68	5.7
Gait	L	1	4.4	5	3.6	6	2.7
	R	3	3.6	6	5.1	8	3.3

An analysis of variance indicated that there was no significant differences between the subgroups on SLR (compared to the 6-year-old subgroups where there was a significant difference). (Fig 6.11)

For external rotation and gait angle the variation between groups was greater than within them (fig 6.11). The mean angle of left and right external rotation of the 7LR subgroup was smaller than the 7MR subgroup which in turn was smaller than the 7SR subgroup. Post hoc analysis showed that for the left hip the 7LR subgroup differed from the 7MR and 7SR subgroups but the latter did not differ from each other. For right external rotation all three subgroups fell into separate classes (fig 6.11).

The gait angle of the 7LR subgroup (left and right feet) fell into a separate class from the 7MR and 7SR subgroups.

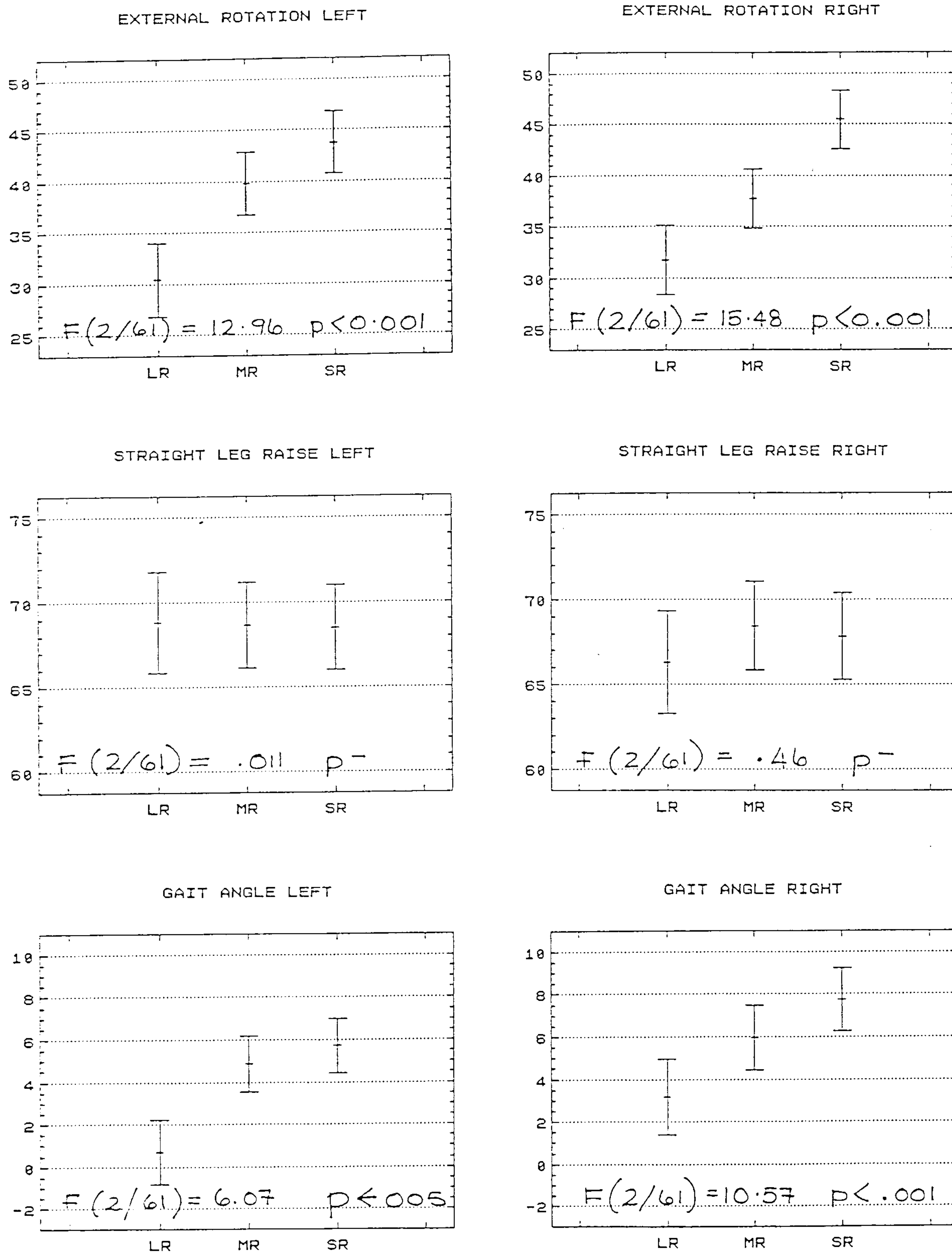


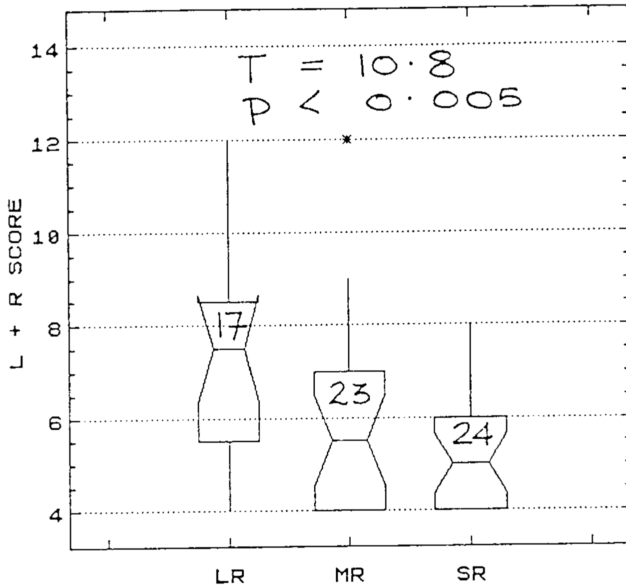
Fig 6.11 95% confidence intervals for factor means comparing passive range of movement and gait angle of the 7-year-old subgroups.

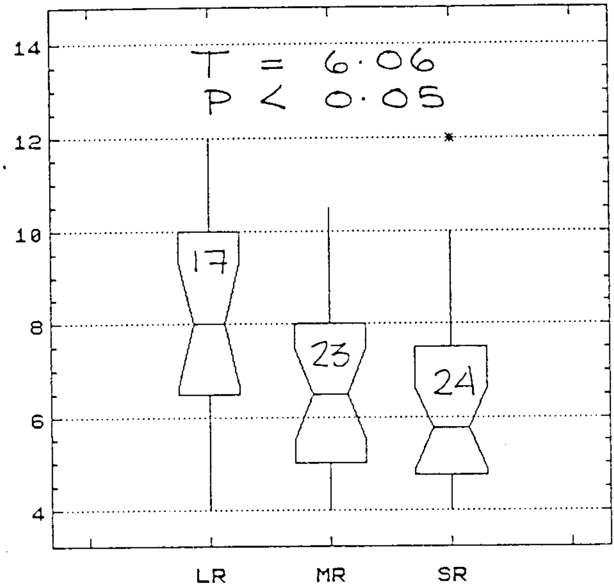
6.3.3 Movement tasks

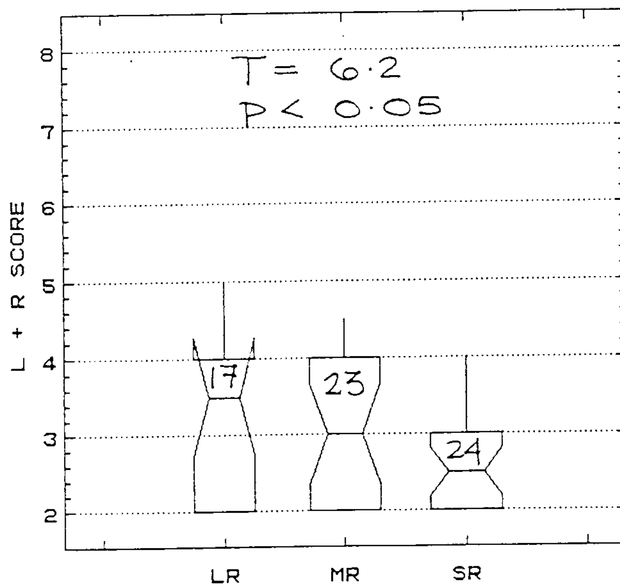
Visual analysis of the distribution of scores of the 7 year-old subgroups on the standing and bridging tasks (fig 6.12) shows that the 7LR subgroup consistently scored less well than the 7MR subgroup, which in turn performed less well than the 7SR subgroup. A Kruskall-Wallis analysis showed this differences to be highly significant for standing on one leg and significant for hopping, hip extension in supine and bridging. Of the trunk tasks only prone pivot showed a significant difference between groups (Fig 6.13).

The distribution of scores of the standing and bridging tasks of the 6-year-old group (Fig 6.14) shows a different trend: the 6MR subgroup performs consistently better than the 6SR subgroup. The 6LR subgroup performs less well than the 6SR subgroup. A Kruskall-Wallis analysis showed that these differences were highly significant for standing on one leg and hip extension, significant for hopping but not significant for bridging. There was no significant difference between the subgroups on the trunk tasks (Fig 6.15).

Notched box plots are used to illustrate the difference in the distribution of scores for the movement tasks (Figures 6.12 - 6.15).







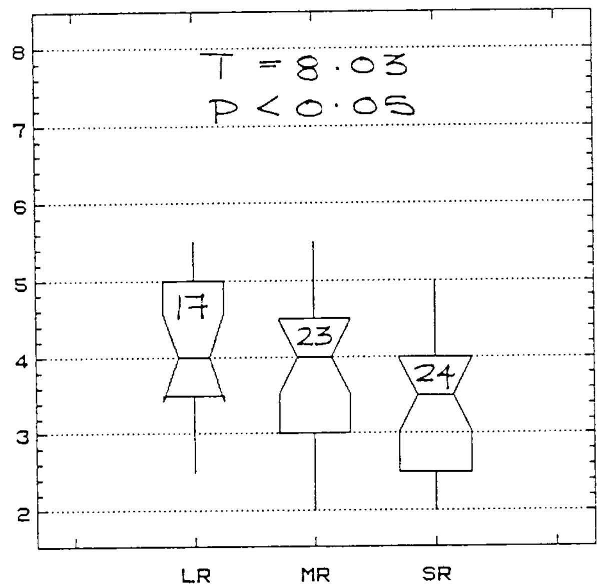


Fig 6.12 Notched box plots showing the distribution of scores on the standing and bridging tasks for G7 subgroups.

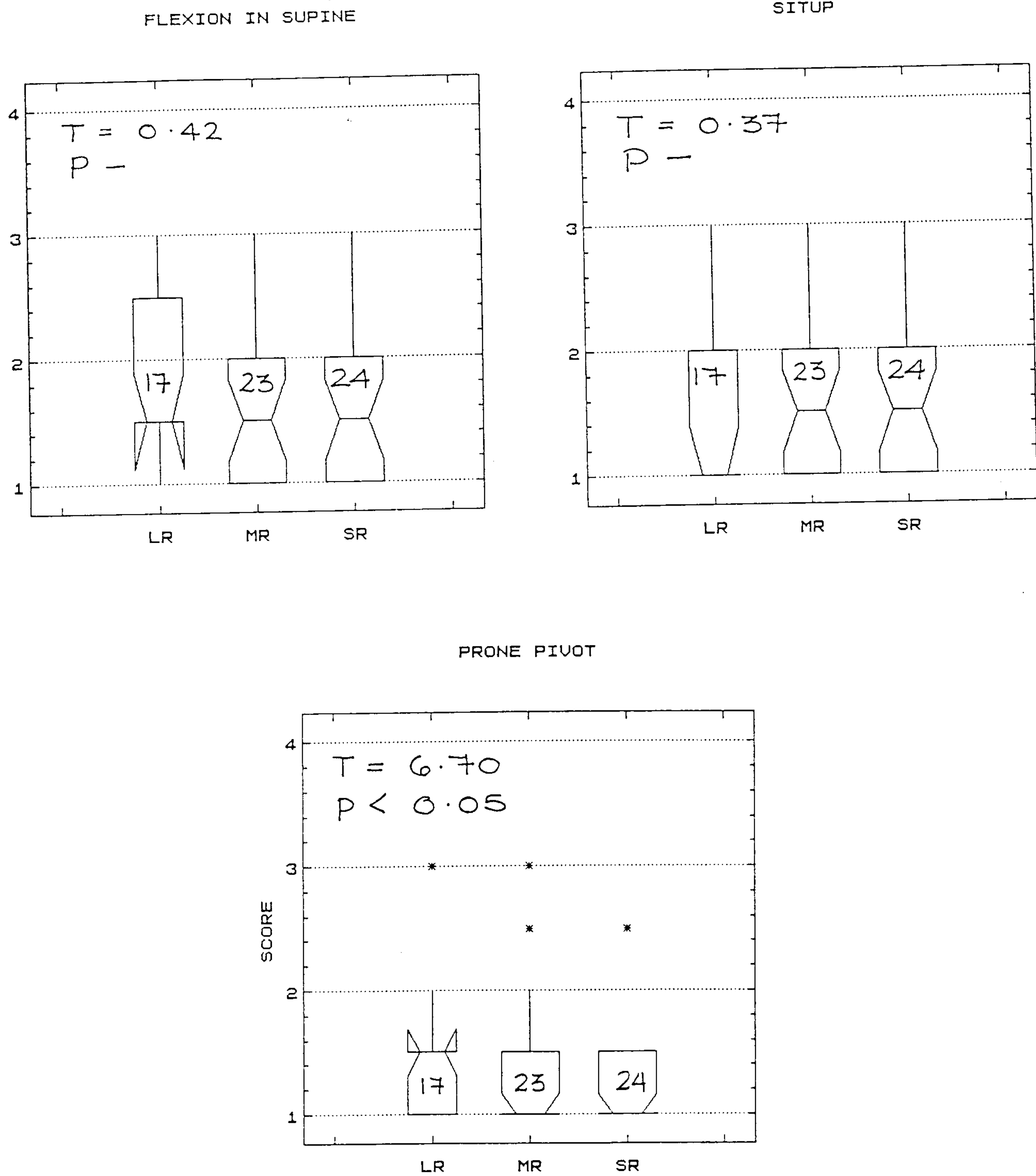


Fig 6.13 Notched box plots showing the distribution of scores of the trunk tasks for the G7 subgroups.

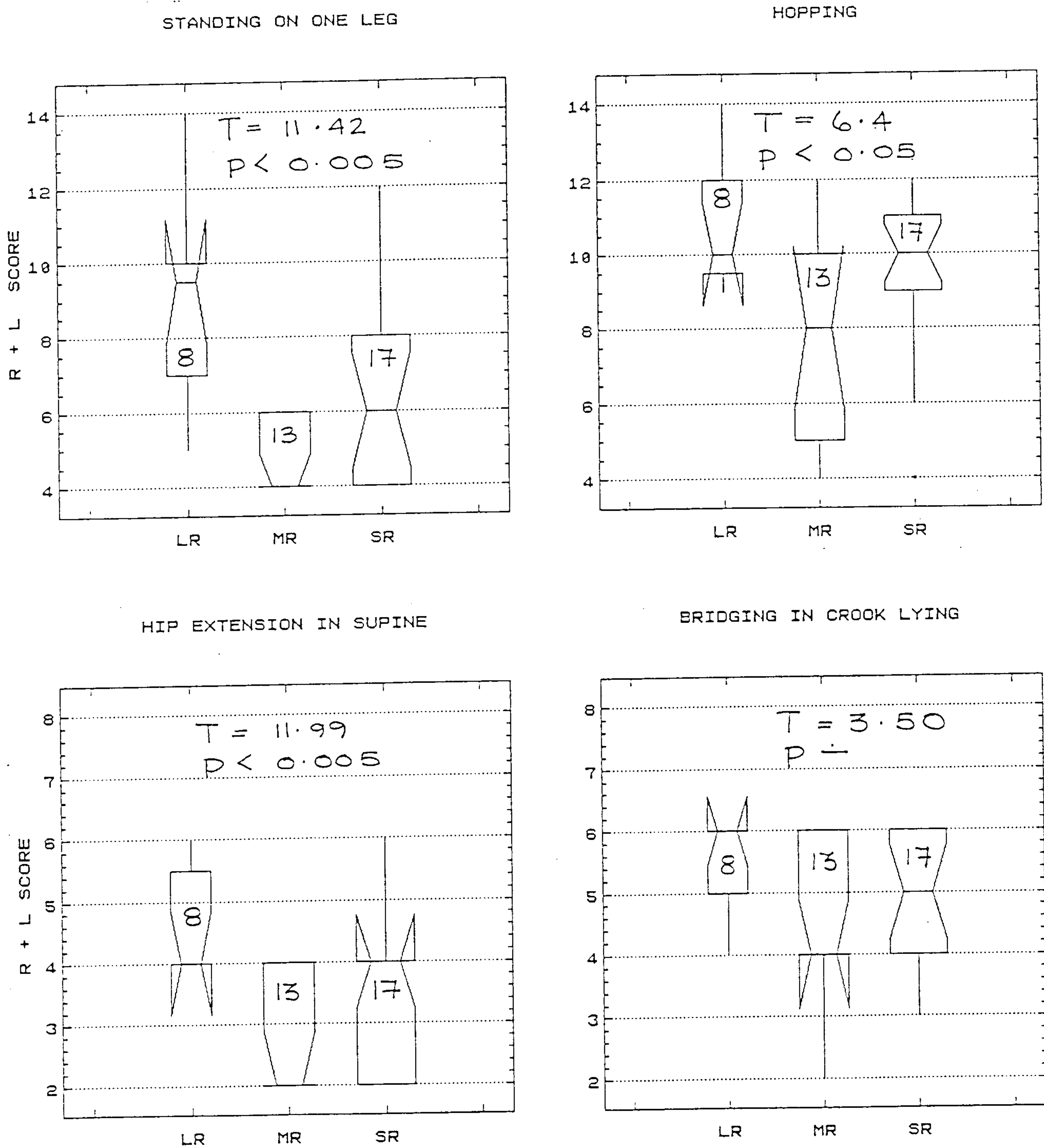


Fig 6.14 Notched box plots showing the distribution of scores on the standing and bridging tasks for the G6 subgroups.

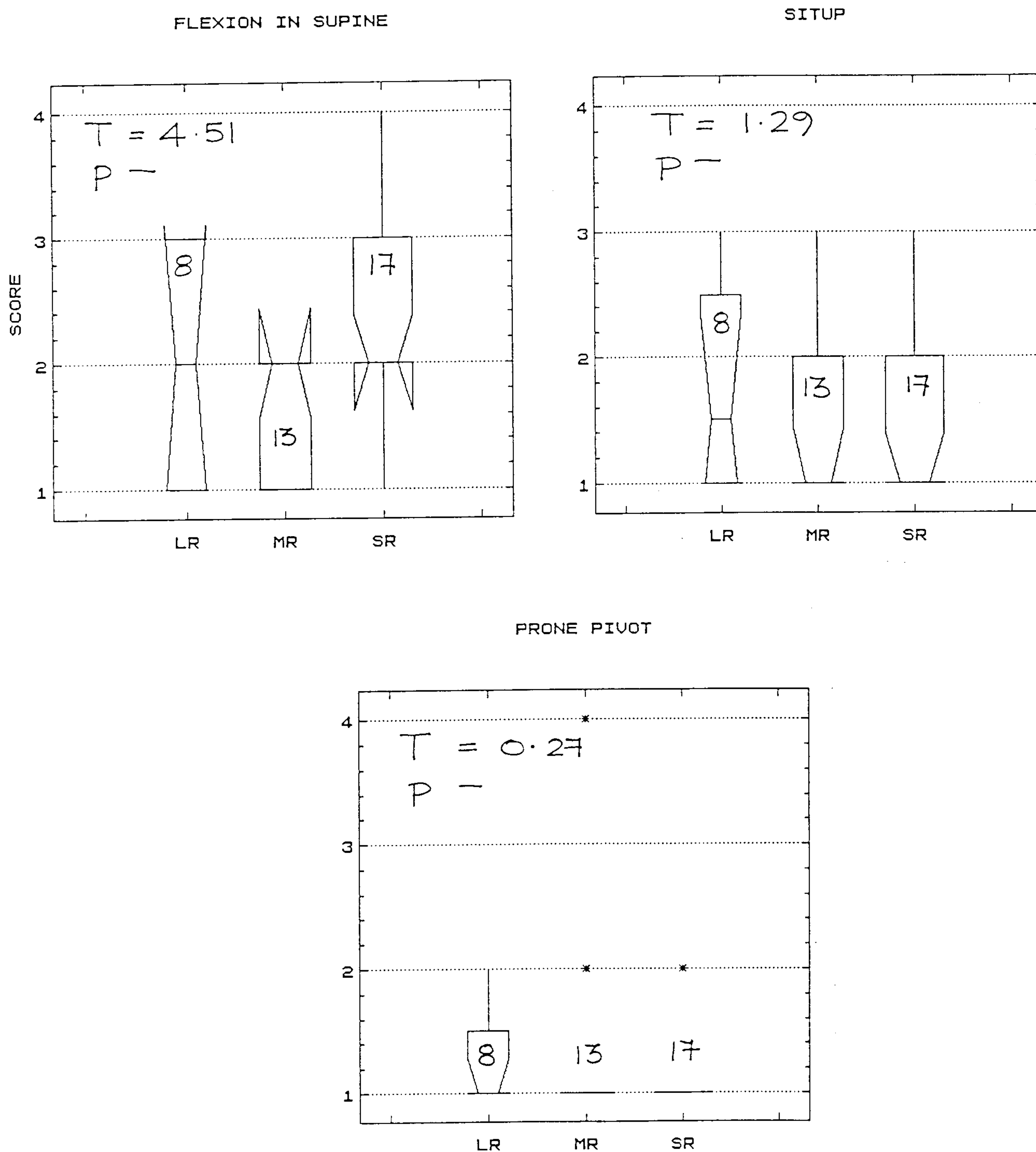


Fig 6.15 Notched box plots showing distribution of scores on the trunk tasks for the G6 subgroups

CHAPTER 7

DISCUSSION

7.1 Passive range of hip movement

7.1.1 Test reliability

7.1.2 Distribution of scores

7.2 Relationship between range of passive hip movements and gait angle

7.3 Performance on the motor tasks

7.4 The relationship between passive range of movement and performance on motor tasks

7.5 How is motor control related to skeletal growth?

7.6 Forces acting on the hip structures during growth

7.1 PASSIVE RANGE OF MOVEMENT

7.1.1 Test reliability

The 5° - 10° difference in the test - retest scores for the passive movement tests (except for the right hip external rotation of the 7-year-old group) was considered within acceptable range for goniometer measurements of range. As there was no difference in the means for the test and retest scores it was assumed that there was no measurement bias towards greater or lesser scores.

The possible measurement error of 10° was also taken into account when dividing children into the large, middle and small range subgroups. Even with this degree of possible error, the scores of the large and small range groups did not overlap. This allowed comparison of the motor performance of children with the least and the greatest ranges in the spectrum of ranges.

7.1.2 Distribution of scores

The distribution of the ranges of hip rotation of the 7 year-old group (G7) are similar to those given by Sutherland et al[78] (who used the same method to measure hip rotation) (Table 7.1).

The large discrepancy in the distribution of ranges of hip rotation between the 6-year-old group and the 7-year-old group is possibly due to differences in measuring technique used by the two assistants. It is well documented that although test-retest

reliability of goniometry using a standardized method is good (as was the case in this study), inter-tester reliability tends to be less consistent[79]. The abnormal distribution of scores of the passive hip rotation of the six-year-old group brings into doubt the validity of the hip movement data and all findings relating to hip movements of this group need to be treated with caution. Despite these problems, the data for this group were included in the study because of some interesting features, particularly relating to the range of straight leg raising. The differences could also be explained by the variable nature of movement control in this group, as is discussed below.

However since the measurement error was consistent within the six-year-old group, the possibility of comparing the performance of children whose range of movement falls into the lesser and greater thirds of the measured ranges still remains.

The ranges for straight leg raise (SLR) in this study are similar, although slightly lower than those reported by Sutherland et al[78] probably due to slight differences in measurement techniques.

TABLE 7.1

Comparison of data (median, interquartile range and range) for passive hip movements with the finding of Sutherland et al[78] *.

		6 years		7 years	
		Sutherland et al (N = 45)	This study (N = 39)	Sutherland et al (N = 45)	This study (N = 64)
External Rotation	L	40	24	45	40
		32 - 50	18 - 28	28 - 48	31 - 45
		15 - 70	4 - 65	18 - 65	12 - 60
	R	40	27	45	40
		30 - 45	20 - 31	30 - 50	32 - 45
		20 - 70	10 - 48	20 - 70	15 - 55
Internal Rotation	L	55	50	55	50
		45 - 60	43 - 53	45 - 60	45 - 60
		30 - 80	32 - 70	30 - 80	35 - 76
	R	60	45	55	50
		50 - 65	40 - 49	45 - 60	45 - 60
		30 - 80	26 - 78	30 - 80	35 - 74
SLR	R	80	73	80	70
		70 - 85	66 - 78	72 - 88	64 - 75
		60 - 100	59 - 85	62 - 95	55 - 80
SLR	L	75	73	75	68
		70 - 90	69 - 78	70 - 85	63 - 73
		55 - 95	58 - 94	55 - 95	55 - 85

* Interpreted from graphical representation

7.2 RELATIONSHIP BETWEEN PASSIVE MOVEMENTS

The finding that straight leg raising is moderately related to both external and internal rotation as well as to standing on one leg in the 6-year-old group (G6) needs to be explained. The range of straight leg raising is limited by the length of the hamstrings. Abnormal activity in the hamstrings is thought to be a major cause of the internally rotated gait seen in cerebral palsy[80,81,82]. In the normal child the medial hamstrings are active during the last part of swing phase and first part of the stance phase[81]; this action of the hamstrings coincides with internal rotation of the hip at the end of the swing phase. In the cerebral palsied child with an internally rotated gait, hamstring action is prolonged in the stance phase[80,81] and is thought by Chong[80] to be the cause of the internal rotation gait in cerebral palsy. These findings raise the question of whether internal rotation gait of children with medial femoral torsion is also associated with overactivity of the hamstrings. Such overactivity would also lead to shortening of the hamstrings and decreased straight leg raising.

In this study the 6-year-old group children with the smallest range of straight leg raise (i.e. with shorter hamstrings) also performed less well in standing on one leg. At the poorest level of control of standing on one leg, the children tended to rotate the supporting leg medially consistently in an attempt to maintain balance. This relationship between straight leg raising and hip rotation does not exist in the 7-year-old group. This could be attributed to improved postural control in the older group.

Electromyographic studies of gait and other weight-bearing activities are needed to elucidate the role of the medial hamstrings in intoeing gait in neurologically normal children.

7.3 PERFORMANCE ON MOTOR TASKS

The first aim of this study was to develop a method of evaluating qualitative differences in the performance of selected motor tasks involving hip control. The test battery did successfully grade the children's motor behaviour, as well as point to age-related differences in the proficiency of performance of the selected tasks.

In developing the descriptive categories for the tasks, I had assumed that the levels described reflect developmental differences. This assumption is supported by the apparent changes in the distribution of scores of children performing the tasks at different levels of proficiency in the younger and older age groups (bearing in mind that the two groups could not be compared statistically due to a small difference in scoring). Prelongitudinal studies are needed to confirm the accuracy of the descriptive categories and a longitudinal study is needed to verify the developmental nature of the categories and indicate the time span needed to pass from one stage to another[83].

7.4 THE RELATIONSHIP BETWEEN PASSIVE MOVEMENTS AND PERFORMANCE ON MOTOR TASKS

The moderate correlation between the range of hip external and internal rotation and the standing and bridging tasks indicate that there is a relationship between clinical measures of femoral anteversion and development of lower limb motor control. The relationship between internal rotation and performance on the motor tasks is further amplified by the differences in performance of these motor tasks by the children in the 7-year-old small range (SR), middle range (MR) and large range (LR) subgroups.

In the 7-year-old subgroups the scores for the standing and bridging tasks were moderately correlated with the range of hip internal and external rotation. This is also reflected in the distribution of scores of the three subgroups - the 7SR subgroup consistently performing better than the 7MR subgroup and the 7MR subgroup better than the 7LR subgroup. One of the most striking features of the distribution of scores in the three subgroups is the tendency for the motor scores of the children in the 7SR subgroup to fall in the lower half of the distribution while those of the children in the 7MR and 7LR subgroups were spread over the whole range of possible scores. If one accepts that the development of motor control has an influence on the derotation of the femur, an explanation for this distribution is that the children in the 7MR and 7LR subgroups, whose scores were on the lower half of the range, had developed this control fairly recently and the influence on detorsion of the femur (and therefore on hip rotation) would still follow.

Generally the characteristics of the 6-year-old group are less tidy than those of the 7-year-old group. There is a difference in range of left and right external rotation in the 6-year-old group not present in the 7-year-old group. The distribution of scores for hip rotation differ from those given by Sutherland et al[78]. These differences may be due to measurement errors. For these reasons the results of the six-year-old group are problematic and all discussion on this group is very tentative.

In the six-year-old group performance on the hip extension tasks is related to the range of external but not to internal rotation of the right hip. This could explain why the 6MR group tended to perform better on the movement tasks, as the mean range of medial rotation of the 6MR subgroup was larger than that of the 6SR subgroup.

The passive movement scores of the six-year-old group may be due to measurement error but it may indicate a period during which many changes are taking place in motor control and in the morphology of the femur. Woollacott[84] noted a great deal of variability in postural reactions in the 4 - 6 year age range compared to younger and older children.

Shumway-Cook and Woollacott[85] refer to Zellar's work on changes in body form with development which "suggest that the age range 4-6 may represent a period of disproportionate growth with respect to critical changes in body form." [86]

Children aged four to six years also show greater variability in postural responses than either younger or older children. Shumway-Cook and Woolacott write about this period:

"These data suggest that with development there is a shift in the predominant controlling sensory input to posture. It appears that, in the child under three, visual-vestibular inputs primarily control stance balance. Presented with multimodal sensory conflict the child under three finds it difficult to suppress erroneous visual inputs and respond to correct somatosensory inputs."

"Between the ages of four and six somatosensory inputs increase in importance in mediating postural response, suggesting a shift away from visual dominance. The 4- to 6-year-old child's response latencies are slower and more variable than either the young child or the adult; they also sway more in response to situations presenting sensory conflict. This age period may represent a period of transition where children are developing more adult-like sensory integration strategies for organizing redundant sensory input and resolving multimodal sensory conflicts."

"In the 7- to 10-year-olds, response patterns under altered sensory conditions are comparable to adults, suggesting that by this age maturation of organizational processes subsuming integration of sensory inputs has occurred. " [85]

Other neurophysiological subsystems that form the basis of normal posture and movement also seem to mature between the ages of five and eight. There is a dramatic decrease in the intensity of associated hand reactions between 6.5 and 8.5 years suggesting an increase in inhibitory mechanisms[87]. The adult-like pattern of reciprocal recruitment of antagonist muscles during gait begins to emerge at about 2 years of age with the appearance of a true heel-strike. The adult electromyographic pattern, in which the tibialis anterior is electrically silent during most of the stance phase, is only generally established and consistent by the age of five to six years[88].

7.5 THE INTERACTION BETWEEN MOTOR DEVELOPMENT AND SKELETAL GROWTH

Traditional views of motor development see the attainment of motor milestones as an invariant sequence directly reflecting development of the infant's nervous system. As the nervous system reaches new plateaus, the infant performs new behaviours. Environmental factors are thought to influence the rate of development but not the form of development. In such a system the development of the shape of the femur is passively dependent on the unfolding of the neural control of posture and movement. The growth and changing shape of the femur would have no influence on the changing motor behaviour.

The dynamical systems approach to motor development proposed by Thelen[89] gives another perspective. Based on dynamical systems

theory, she proposes that developing organisms are complex systems, observed behaviours being derived from the influence of many interacting subsystems, each having its own course of development and its own timetable. Subsystems involved in motor behaviour include the nervous system, muscles and skeletal growth.

Based on her studies of the development of infant stepping, Thelen[72,73,89] has proposed that the biodynamic properties of the body segments during normal growth may contribute to the evolving character of voluntary limb movement. Whereas many components contribute to a behaviour one or more may be "rate limiting factors" [89].

Thelen [90] explains the concept of rate limiting factors as follows: "That is, when most of the contributing systems are sufficiently developed, a specific behaviour may await the development of one additional subsystem to emerge. At any chosen point in time an infant may, for example, possess the necessary neural substrates and ability to sequence joint actions appropriately to produce a specific movement pattern but may possess insufficient strength or postural control to demonstrate it under normal environmental conditions." [89]

The dynamical systems perspective implies that skeletal development and motor behaviour are interdependent. The pattern of movement used by the child to perform an action at any point in his or her development is the end result of many interacting systems: skeletal structures, muscle strength and neurophysiological maturation. The

degree of anteversion of the acetabulum as well as the shape of the proximal end of the femur will influence the biodynamic properties of the developing lower limb and thus the pattern of movement used by the child to perform an activity. Changing patterns of movement will, in turn, influence the forces acting on the skeletal system.

7.6 MUSCLE FORCES ACTING ON THE HIP STRUCTURES DURING GROWTH

It has been argued that the extension and external rotation forces created during upright gait are important for the detorsion of the femur[56,57]. This argument is supported by the fact that most dramatic reduction in the angle of anteversion is seen between the ages of one and two years when the child first gains control over bipedal gait.

The direction and size of the moment of force acting on the hip during gait depends on the pattern of muscle action. The work of Winter[90] on the kinetics of gait has shown that a "consistent kinematic pattern at the knee and the ankle does not guarantee a consistent motor pattern at each of the joints of the support limb."

The moment of force represents the net effect of all agonist and antagonist activity about a joint[90]. Winter has defined a total extensor pattern, called the support moment as:

$$M_s = M_a + M_k + M_h$$

where Ma, Mk and Mh are the moments of force at the ankle, knee and hip and are positive for extension and negative for flexion. The support moment pattern for stance is always positive and is consistent between individuals and trials. However the moment pattern at the hip and knee has been found to be quite variable. Winter[91] summarizes his findings as follows:

"All the kinematic patterns and the kinetic patterns are quite repeatable. However, the individual joint motor patterns especially the hip and knee, are quite variable and presumably a measure of the flexibility of the individual muscles as they adapt to produce the same kinematic pattern. This adaptation demonstrates the fine motor tuning that takes place over strides in order to correct for minor deviations from the desired kinematic pattern. For example, for one stride the trunk may be leaning 1° or 2° too far forward, thus the hip extensors increase during the stance period to correct the error. Because the upper part of the body represents 2/3 mass of the body and the hip extensors, including the hamstrings, would be significantly more active than normal. The hamstrings, being knee flexors as well, would alter the knee moment pattern but in the opposite direction. Thus the flexibility to make an adjustment at one joint can manifest itself at an adjacent joint, thereby increasing the variability of both joints."

Based on studies of acceleration of the trunk during gait, Winter[91] further argues that the priority of the hip muscles is to control posture and balance during gait. This role for the hip extensors as postural muscles ties in with the work of Lovejoy[92] which shows how the role of the gluteus maximus has changed during evolution from

quadrupedal to bipedal gait. The role of the gluteus maximus has changed from being a powerful hip extensor, used to propel the centre of gravity forward during gait to the role of stabilizer of the trunk on the hip in the bipedal position.

The proximal femur is considered by Ogden[93] to be probably the most complex of all growth regions. The final shape is dependent on the nature of the forces, to which the developing bone is exposed as well as the timing of the forces and the reaction of developing bone to force changes with increasing age[93]. The variability in the degree of anteversion in the normal population can be accounted for if one considers the many factors that play a role in shaping the hip structures during development. An important factor is the development of postural control; variations in the quality and timing of the development of postural control can explain the great variability in the degree of anteversion.

CHAPTER 8

CONCLUSIONS AND RECOMMENDATIONS

8.1 Development of movement tests to measure the differences in the level of control of hip posture and movement.

8.1.1 Recommendations

8.2 The relationship between performance on the motor tests and measures of clinical anteversion (hip internal and external rotation and gait angle).

8.2.1. Recommendations

8.3 Follow up study

8.1 DEVELOPMENT OF MOVEMENT TESTS TO MEASURE THE DIFFERENCES IN THE LEVEL OF CONTROL OF HIP POSTURE AND MOVEMENT

The movement tests developed for this study effectively differentiated between differences in the quality of control of the selected tasks in children aged 5 - 8. They were quick and easy to administer, were reasonably reliable and provided an effective means of measuring children's motor proficiency on selected tasks. Further cross-sectional studies are needed to verify the scoring categories and task stability as well as establish inter - and intra-tester reliability. Longitudinal studies are needed to clarify developmental trends in each of the tasks[83].

Task stability also needs to be established. (Task stability refers to the stability of performance from trial to trial.)

8.1.1 Recommendations

8.1.1.1 That the categories and task stability be verified using a cross sectional study.

8.1.1.2 The performance on these tests be compared to performance on other commonly used test batteries, as well as tests using outcome measures to score proficiency.

8.1.1.3 A longitudinal study be performed to elucidate the nature of the changes in motor control in the selected tasks.

8.2. THE RELATIONSHIP BETWEEN PERFORMANCE OF THE MOTOR TESTS AND RANGE OF HIP INTERNAL AND EXTERNAL ROTATION.

The main aim of this study was to investigate the relationship between the development of motor control and hip rotation as a clinical measures of anteversion of the femur. The finding that motor control on some tasks involving hip extension shows a weak to moderate correlation with the range of internal and external hip rotation, established that such a relationship exists. This finding is further strengthened by the differences in the performance on the standing and bridging tasks of the SR, MR and LR subgroups.

However the limited nature of this study allow one to reject the null hypothesis with any certainty. The limited scope of the study also does not allow one to make any conclusions about a cause-effect relationship between the two variables under consideration. Given the evidence from studies of anteversion of the femur in children with cerebral palsy, it is tempting to hypothesize that the medial torsion syndrome is caused by poor or slow motor development. However dynamical systems theory reminds one that development should be seen as emergent and that different systems are interdependent - motor behaviour influences the shape of the femur and the shape of the femur influences the expression of motor behaviour.

Both the derotation of the femur and changes in the level of motor control are developmental phenomena. The relationship between the two can only be studied effectively in a longitudinal study that investigates the changes over time in motor control, hip range of movement and gait angle.

8.2.1 Recommendations

8.2.1.1 There are many changes in motor control between the ages of 5 and 8. A longitudinal study should be done to investigate the relationship between changing motor control and hip rotation and gait during this period of rapid change. Such a study would elucidate whether improvements in motor control precede changes in hip rotation.

8.2.1.2 Motor behaviour is accessible to modification and could possibly be used as a way of influencing the development of derotation of the femur. Active training of automatic postural responses and weightbearing muscle function should be investigated as a means of influencing anteversion and as a conservative alternative to surgery in cases where surgery is deemed to be necessary.

(Earlier attempts to correct anteversion with exercises used strengthening and non-weightbearing strengthening exercises which did not address specific motor deficits.)

8.3 FOLLOW UP STUDY

The results of this study indicate that detorsion of the femur is linked to the development of motor control. Before recommendations

can be made regarding prevention and management of medial femoral torsion further research is necessary to elucidate the nature of the motor control deficits and how changes over time in motor control are related to changes in the range of movement of the hip.

Further research is planned including the following steps:

8.3.1 A cross sectional study to validate the scoring categories of the movement tasks, to look at stability of performance on repeated testing and to establish intertester reliability;

8.3.2 A longitudinal study following children from the age of 5 to 8 years looking at changes in the range of movement of the hips, gait angle and performance on the movement tasks.

8.3.3 A study of the effect of movement training on the range of hip movement in children with medial femoral torsion using a single case study design.

CHAPTER 9

CONSTRAINTS

9.1 Sample

- 9.1.1 Sample of convenience
- 9.1.2 Differences between the two samples

9.2 Measurement technique

- 9.2.1 Lack of reliability studies
- 9.2.3 Hip rotation as a measure of anteversion
- 9.2.4 Division of samples into subgroups

9.1 SAMPLE

9.1.1 Sample of convenience

Two samples of convenience were used from two different white schools in Stellenbosch. Any generalization of the results to the population as a whole should be made with great caution.

9.1.2 Differences between the two samples

The results show interesting differences between the 6 and 7-year-old groups. Because of possible differences in measuring techniques between the two samples however comparison of performance on the motor tasks and range of movement between the two samples cannot be made.

A follow up study using a single sample of children between the ages of 5 and 8 is planned to verify the findings.

9.2 MEASUREMENT TECHNIQUES

9.2.1 Lack of reliability studies

The lack of test validity and formal reliability studies for the testing of range of movement as well as the movement tasks, is a major constraint in this research.

Test - retest scores for the range of movement tests were found to be within acceptable range. The results of the measurement of range of hip movement of the 7-year-old group are in agreement with other studies of hip range of movement, increasing the confidence with which one can interpret the results of this group.

The measurement of the range of movement of the 6-year-old group differ from both Sutherland et al's[78] study and the results of the 7-year-old group. The results of the 6-year-old group need to be treated with great caution.

The test-retest reliability of the movement tests used in this study was acceptable for the purposes of this study. Inter-tester reliability was not measured as all the testing was done by one researcher.

9.2.2 Hip rotation as a measure of femoral anteversion

Hip rotation as a measure of anteversion is only an approximation of the degree of torsion in the femur. Scanning techniques give a more accurate measure of femoral anteversion but were not practical to use in this study. However hip rotation is used clinically to assess anteversion and has been shown to be related to x-ray measurement of femoral anteversion.

9.2.3 Division of samples into subgroups

The division of the two samples into subgroups was not done on any firm clinical or experimental grounds. It was done to done to highlight the differences in motor control between children with a smaller and a larger range of internal hip rotation.

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APPENDIX A

PARENTAL CONSENT FORM

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Dept. DEPARTMENT OF PHYSIOTHERAPY

Dir. line/lyn ....

Ref./Verwys. ....

Dear Parent

I am a masters student in the Department of Physiotherapy at UCT. My research project involves looking at the relationship between the development of normal alignment of the bones of the legs and the development of the control of movement in children. As part of this research I need to test fifty 7-8 year old children. The Cape Education Department and Mr Niland have kindly given permission to test the Sub B children and I would be grateful if you would allow your child to be included in the research.

Testing will take 20 minutes and will include a number of motor activities such as standing on one leg, hopping, sitting up from lying. I will also be measuring the range of movement of the joints of the legs. I would like to film a number of the children performing the motor tests for detailed analysis.

Please complete the consent form and return it to Mrs ....

If you have any queries please contact me at 78063.

Thank you for your cooperation.

Yours sincerely

P A Versfeld

CONSENT FORM

I GIVE PERMISSION / DO NOT GIVE PERMISSION for ________________
________________ to participate in the research project being conducted by Pam Versfeld.

He/she MAY / MAY NOT be video filmed as part of this research. (Video films made of the children will be used solely for the purpose analysing movement as part of this research.)

To help me with this research could you please answer the following questions:

1 Was the birth normal?
2 Was your child premature?
3 Has he/she had any major illnesses?

SIGNED ________________________

DATE ________________________

APPENDIX B

TEST RECORD FORM

TEST RECORD FORM **NUMBER**

Date of test: day month

Name ________________________________

Date of birth day month year

Height ________

Weight _______

B RANGE OF MOVEMENT

Hip internal rotation L ____ R ___

external rotation L ___ R ___

SLR L ___ R ___

D GAIT ANGLE

left ______ right ______

E HISTORY

Birth normal Yes No

Premature Yes No Weeks

Illnesses Yes No

E MOVEMENT TESTS

standing on 1 leg	ARM	L	1	2	3	4	R	1	2	3	4
	LEG	L	1	2	3	4	R	1	2	3	4
hopping on the spot	ARM	L	1	2	3	4	R	1	2	3	4
	LEG	L	1	2	3	4	R	1	2	3	4
prone pivot			1	2	3	4					
flexion in supine			1	2	3	4					
sitting up in supine			1	2	3	4					
bridging in supine		L	1	2	3	4	R	1	2	3	4
hip extension in supine		L	1	2	3	4	R	1	2	3	4

-

standing up from longsitting	neutral
	int rotation
	through side sitting