AN INVESTIGATION INTO THE RELATIONSHIP BETWEEN KINESTHETIC SENSITIVITY AND BALANCING ABILITY IN PRE-SCHOOL CHILDREN

BY

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ABSTRACT

The purpose of this study was to explore the possibility of a linear relationship between kinesthetic sensitivity and balancing ability in pre-school children. Furthermore, the effects of age on kinesthetic sensitivity and balancing ability were investigated. Finally, the role of gender in kinesthetic sensitivity and balancing ability was examined.

Fifty-one subjects, between the ages of three and six years, executed five trials on each of two kinesthetic sensitivity tests (an arm abduction test and a hip abduction test); two tests for static balance (on a balance board and on a balance stick) and two tests for dynamic balance (a beam walk test and a stepping stones test).

Although the correlations between kinesthetic sensitivity and balancing ability were generally positive, they were very slight. These low correlations are probably an indication that different abilities are required for carrying out the different tasks.

Generally, both balancing ability and kinesthetic sensitivity appeared to improve with age. From analysis of individual test results it was obvious that abilities varied from individual to

individual (Appendix G). This could have been the result of developmental, motivational or experiential differences.

Although the girls generally performed slightly better on most tests than the boys the correlations between test scores for boys were slightly higher than those for girls. A t-test indicated that there were no significant differences between the mean scores of the boys and the girls on the balancing or the kinesthetic sensitivity tasks.

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GLOSSARY

The following explanations and operational definitions are put forward for the sake of clarity and in order to avoid possible confusion in interpretation:

Abduction - lateral movement of the limbs away from the midline of the body.

Ability or **perceptual-motor ability** - The potential an individual has for motor behaviour at any given time during the developmental process.

Behaviour - Reaction - which involves activity, thinking, perceiving, feeling and interest - in response to a task or stimulus.

Cephalocaudal - The direction of growth and development which proceeds from the head to the feet.

Development - Increment in functionality.

Growth - Increment in size; structural changes.

Innate - That which already exists before birth and accounts for particular characteristics.

Joint sensitivity - In this study the focus falls on all possible receptors which function in joint movement.

Kinesthesis - For the sake of uniformity, the American forms of spelling "kinesthesis" and "kinesthetic" are used throughout the text, except where quotes are taken from English texts, where the original form of "kinaesthesis" (kinaesthetic) is maintained.

Kinesthetic acuity - The ability of kinesthetic receptors to transmit to the central nervous system accurate and precise information about the body's position in space.

The terms **kinesthetic sensitivity, kinesthetic awareness** and **kinesthetic perception** are used interchangeably throughout the text and should, in this context, be interpreted as the ability of an individual to perceive the degree of abduction at the shoulder or hip.

Kinesthetic memory - The ability to accurately duplicate a movement or position.

Maturation - Developmental changes proceeding towards full potential.

Ontogenetic development - Development of an individual due to experience.

Performance - The behaviour an individual displays during the execution of a task.

Phyletic - Pertaining to a line of descent according to the species.

Phylogenetic development - Genetically determined development.

Proprioceptors - Mechano-receptors, reacting specifically to mechanical energy and constantly providing the brain with information about the movements and positions of the various parts of the body.

Proximodistal - The direction of growth and development which proceeds from the trunk to the extremities.

Readiness - The principle referring to structural, neurological and psychological traits in attending to relevant stimuli.

Sensory integration - The ability of the individual to accurately interpret sensory information from the various proprioceptors.

Selective attention - The readiness of the organism at any moment to receive and process information.

CHAPTER ONE

PURPOSE AND ORGANISATION

The thrill of new mastery often springs from the confirmation of potential the child did not believe it had.

Scheffler (1985:66)

1. INTRODUCTION

The perceptual-motor development and behaviour of young children has received a great deal of attention from child psychologists and physical educators for many years. This interest has often been associated with the enhancement of scholastic achievement, but has also led to concern for identifying the contribution perceptual-motor development makes to the overall development of children. Godfrey and Kephart (1965:7) explain that,

> The motor activities of the child ... become important not only for their own sake, but for the contribution which they must make to the more complex activities which he will be required to perform at later stages.

Recognising this, Broadhead and Church (1985) and Cratty (1986) stress the need to establish, with greater certainty, the movement characteristics of pre-school children. In order to do this, those systems which are involved in, and important for, the development of skilled movement need to be identified and studied. This implies a need for a better understanding of the rate at which the various systems develop and their relationships to each other. An important component of this is kinesthesis.

Kinesthesis has been the topic of several studies but, except in a few where specific receptors were named, it has often been assumed that individuals possess some kind of general kinesthetic ability. The kinesthetic system allows for perception of the body's position in space and the relationship between its parts. This process is facilitated by the reaction to movement by different types of proprioceptors in the different structures within the body. These proprioceptors, either individually or collectively, supply information about different types of movement and the resulting body positions. Richardson and Tandy (1973) are among those who report that the kinesthetic sense is the first sensory system to develop in children and is in fact already operating before birth.

Singer (1982) points out that various proprioceptors in different parts of the body contribute to the maintenance of equilibrium, but stresses the role of the stretch reflex in this regard. Gibson (1966) includes the articular subsystem of kinesthesis as one of the modalities which gives essential information of postural adjustments (e.g. in the maintenance of balance). It is still not clear, though, which of the proprioceptors are involved and to what extent they contribute to the control of movement and the maintenance of balance in young children.

Bressan and Woollacott (1985/86) found that a child's balance control is among the earliest maturing of the motor control capacities. They explain that between the ages of one and three years the child's ability to balance accelerates, but remains dependent on visual cues. It is known that, prior to this, there is a shift from proprioceptive to visual dominance in perceptual tasks, but at exactly what stage this shift takes place and how kinesthetic sensitivity is influenced by this is not yet clear. The same authors suggest that between the ages of four and six years a transition phase in control of balance occurs: there is then a shift back from the visual to include the kinesthetic and vestibular systems. It appears, then, that there could be a shift from visual dominance to an integration of visual and kinesthetic control in balance.

Questions to which answers may emerge from this study are: Which proprioceptors contribute to the maintenance of balance? Are the same systems that are involved in the control of static balance also involved in dynamic balance control? Do all balance tasks which are classified as static balance involve the same proprioceptors? The present study is an attempt to contribute to this field of knowledge in child development.

2. PURPOSE OF THE INVESTIGATION

The purpose of this investigation is to determine whether a relationship exists between kinesthetic sensitivity and balancing ability in young children.

Taking into consideration the early development of both balance control and kinesthetic sensitivity there is some probability that development in both may follow a similar course and that there may even be a connection between the development of the two capacities.

Gibson (1966:35) suggests that "position registration seems to depend on the sensitivity of the joints, ...not on the sensitivity of the muscles". It is this suggestion which prompted concentration on joint sensitivity as a measure of kinesthetic sensitivity in young children in the present study (especially since no evidence could be located in the literature to suggest that studies regarding such a relationship in young children have been done). For this, shoulder and hip joints were isolated as they are both proximal joints and, according to developmental theory, should be among the first joints to reach maturity. They also appear to be the joints most likely to assist with balance. It was hoped that this investigation's focus on joint sensitivity could contribute to our knowledge of the possible role the kinesthetic system plays in the child's balancing ability.

Further, it could contribute to our knowledge about the rate at which different systems develop, and their relationships to each other.

Several researchers have come to the conclusion that balancing ability improves with age (Morris et al 1982, Ulrich and Ulrich 1985, and others). However, Erbaugh (1984) argues that the level of maturation is a more reliable indicator of developmental status and that it is not enough to rely merely on chronological age to determine this. Others (Espenschade and Eckert 1980) argue that development does not rely only on maturation, but that experience also plays an important part.

Although age is recognised as not being an accurate indicator, it would appear to be the best available means for the researcher to estimate a child's developmental level. Another of the aims of this study, then, was to establish to what degree kinesthetic sensitivity and balance improves between the ages of three and six years.

The theory that there is a shift from visual dependence to include the kinesthetic and vestibular systems at a certain stage suggests that there could be some changes in kinesthetic sensitivity during the process of this shift. Whether these changes would indicate increased or decreased sensitivity remains questionable.

The role sex difference plays in balancing ability and kinesthetic sensitivity - and the possible relationships between them - will also be examined. Some researchers (Ulrich and Ulrich 1985) have found no gender difference in balancing ability among young children (three to five years of age) while others (e.g. DeOreo and Wade 1971, Morris et al 1982) found girls to be superior in balancing ability. Laszlo and Bairstow (1985) found no gender difference in kinesthetic sensitivity.

3. RESEARCH QUESTIONS AND HYPOTHESES

The main question under investigation is: what is the relationship between kinesthetic sensitivity and balancing ability in pre-school children? This led to two related questions: what is the influence of age and sex on balancing ability; and what is the influence of age and sex on kinesthetic sensitivity? Finally, this would lead to the question: do age and sex have an influence on the relationship between kinesthetic sensitivity and balancing ability?

The following hypotheses were formulated:

1 There is a positive linear relationship between pre-school children's kinesthetic sensitivity (to shoulder and hip abduction) and their ability to perform balancing tasks.

2(a) There is a positive linear relationship between kinesthetic sensitivity and balancing ability when considered separately for the various age groups.

2(b) There is a positive linear relationship between age and ability in (i) kinesthetic sensitivity, (ii) static balance and (iii) dynamic balance.

3(a) There is a positive linear relationship between the kinesthetic sensitivity and balancing ability of girls.

3(b) There is a positive linear relationship between the kinesthetic sensitivity and balancing ability of boys.

In addition a generalised discussion of gender differences and/or similarities between scores will be included.

4. SCOPE OF THE STUDY

Sixty subjects, ranging in age from three years to six years, originally participated in the study. A convenience sample was used (Cohen and Manion 1985), consisting of pre-school children newly involved in a movement development programme plus a few volunteers from local pre-primary schools. The subjects were all white and came from similar socio-economic backgrounds. In order for the researcher to gain the confidence and trust of the subjects they were all integrated into the movement development programme prior to being tested. None of the tasks employed in the test formed part of the activities in the programme.

Six test items (two each for kinesthetic sensitivity, static balance and dynamic balance) were administered. Each subject completed five trials on each test. The total number of errors on the five trials on each of the six test items made up the raw data.

Each subject was tested on the whole battery in a single session, which lasted approximately twenty minutes. Measurements were all objective and could be taken easily and accurately. The number of errors a subject made on each trial was noted on individual score sheets. Where necessary, comments about unusual performance were noted on the appropriate score sheet. In order for the subjects to focus on kinesthetic cues, vision was eliminated, where necessary, throughout the test battery by means of a blindfold.

These totals were converted to T-scores. The Statgraphics 4.0 computer programme was used for statistical analysis of data. Correlation coefficients were computed to determine relationships and one-way analysis of variance was used to establish whether significant differences existed between the mean scores of the different age groups. In order to establish whether significant differences existed between the mean scores of the boys and girls t-tests were computed.

5. LIMITATIONS

Although several limitations were taken into account during the planning stages, some were unforeseen and needed to be dealt with, where possible, during the testing or scoring procedures.

One limitation which always exists when working with young children, is the unpredictability of their reactions to various circumstances. A deliberate attempt was made to reduce this limitation by: the researcher gaining the confidence and trust of the subjects and personally conducting all tests while continuously motivating subjects to do their best; and introducing an element of play into the procedure and keeping the tests as simple as possible. This appeared to reduce nervousness, timidity, poor motivation and over-sensitivity to failure. An attempt was also made to eliminate the possible effects the fear of height may have had on performance by using a low beam for the Beam Walk Test.

The success of the data collection depended on each subject's successful completion of the whole battery. Incomplete tests, exaggerated and inappropriate or impulsive reactions resulted in the scores of 15% of the original sample being unsuitable for use.

Because it is known that the interest span of young children is limited, tests were carried out with the least possible delay between trials. Another time-factor which could have influenced results was identified during the pilot study and concerned the duration of static balance trials. The maximum duration of 15 seconds per trial was accepted as being suitable, for even the youngest in the group was able to maintain concentration for this period of time. A longer period (e.g. twenty seconds) was found to lead to loss of concentration, interest and motivation, especially among the younger subjects.

Very closely related to interest is attention. Cratty (1986:364) suggested that much of the success of pre-school children in any motor and perceptual task is partly due to maturation of the nervous system, "particularly that component aiding attention and control capabilities". Stratton (1978) believed that pre-schoolers have difficulty concentrating their attention on a single stimulus for more than a few minutes and classified this as the over-exclusive mode of attention.

In order to come as close as possible to determining kinesthetic perception, visual perception, which appears to play an important part in both balancing ability and kinesthetic ability, was eliminated when and where possible, without placing the subjects under undue stress. To reduce possible stressful effects, a colourful mask was used in the place of a blindfold. Subjects appeared to be enthusiastic about wearing this mask, while those participating in the pilot study showed some resistance to wearing an ordinary blindfold.

One limitation which was not taken into account during the planning stages, was the different ways which subjects used to traverse the length of the beam. Detailed notes describing the method employed by each subject were made on individual score sheets. In order to reduce the effect this would have on the scores a factor was developed by which scores were adjusted in an attempt to prevent one subject having a score advantage over another. This appeared to be successful, but the validity of the specific factors is still open to debate.

The influence of the involvement of memory represented another limitation. It has been suggested that kinesthetic memory (or the memory regarding movement and position) is of brief duration (Posner 1967). Inaccuracies in reproducing positions have been ascribed by Gentile and Nacson (1976) to two theories about motor memory: (1) the interference or trace-decay theory and (2) an inability to recall detail, due to events preceding or following instructions. In an attempt to minimise these, instructions were kept simple, environmental interference was minimised and trials were repeated with as little delay as possible.

It is realised that a history of involvement in tasks similar to those involved in test items could have affected scores, but it would have been an impossible task to determine each subject's prior experience in this regard. It was assumed that if a relationship existed between kinesthetic sensitivity and balancing ability, the two abilities would have developed linearly in spite of, or due to, prior experiences.

Gaps and weaknesses in research concerning kinesthetic sensitivity testing in pre-school children was a limiting factor which could not be controlled. Most of the research in the areas covered in this investigation have previously been conducted, but mainly on adults and older children. Thus, there was a lack of comparable material for use in the interpretation of results.

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The purpose of the investigation was to determine whether relationships exist between joint sensitivity and balancing ability in pre-school children, and to what extent age and sex influence these possible relationships.

Chapter Two of the study takes an in-depth look at the various factors as they would affect and determine performance in young children, especially as it pertains to balance and kinesthetic perception. This is followed by an examination of various factors in the child's life which are likely to affect the development of kinesthetic sensitivity and balance control. Finally, the theoretical underpinnings of kinesthesis and balance are examined, in an attempt to clarify concepts as they relate to the study.

A detailed description regarding the methodology in this study is presented in Chapter Three. This includes a description of the subjects, the test battery and how it was developed, testing equipment and procedures, the six test items and statistical procedures.

Chapter Four deals with the analysis of the data. This is followed by the final chapter in which results are discussed, conclusions drawn and recommendations made for possible further research in similar fields.

CHAPTER TWO

REVIEW OF LITERATURE

As they play, the children are the careless agents of their learning, about both the outer and the inner world.

Pickard (1965:83)

1. INTRODUCTION

The present study is concerned with the possible relationship between the capacity of pre-school children to perceive joint position and movement, and their ability to execute simple balancing tasks. The theory on which this study is based is that control of all perceptual-motor activities, of which balance is one, depends on the integrity of both the motor and sensory processes (Laszlo and Bairstow 1985). This involves receiving, processing and reacting to sensory information. The success with which this occurs thus influences the proficiency of performance.

More pertinently, it was necessary to examine in detail the available literature on factors that influence motor development, the development of perceptual-motor control and motor behaviour in pre-school children, with particular reference to balance control and kinesthetic sensitivity. In addition, tests designed to measure balance and kinesthesis were examined.

Development takes place in stages and several researchers have attempted to identify corresponding ages during which children appear to become maturationally ready to perform certain perceptual-motor tasks. The maturational level of the child's sensory system, his emotional condition, his physical status, and the selected response to specific conditions at a given stage of development will determine the child's performance potential.

Consequently perceptual-motor development involves changes that take place in ability and performance as a result of growth, maturation and experience (Schmidt 1988).

As both perceptual and motor factors formed the basis of this investigation it was also necessary to determine how development takes place in the area of perception. Singer (1982) describes the process of perception as being associated with making meaning of information which has been forwarded from the receptors, via the nervous system, to the brain. Perception has also been described as the organisation of the raw material of sensation into a constant "world of experience" in which the senses are co-ordinated with each other (Encyclopaedia Brittanica 1964, 18:684). This suggests that perception is essentially a cognitive process.

The selected response, in turn, depends upon interpretation of the input; the ability to integrate information from the various sensory inputs; the ability to draw on memory; utilisation of feedback and the ability of the musculature to execute the desired action. The author has devised the model in Figure 1. in an attempt to illustrate those factors which affect the perceptual-motor behaviour of an individual on any given task.

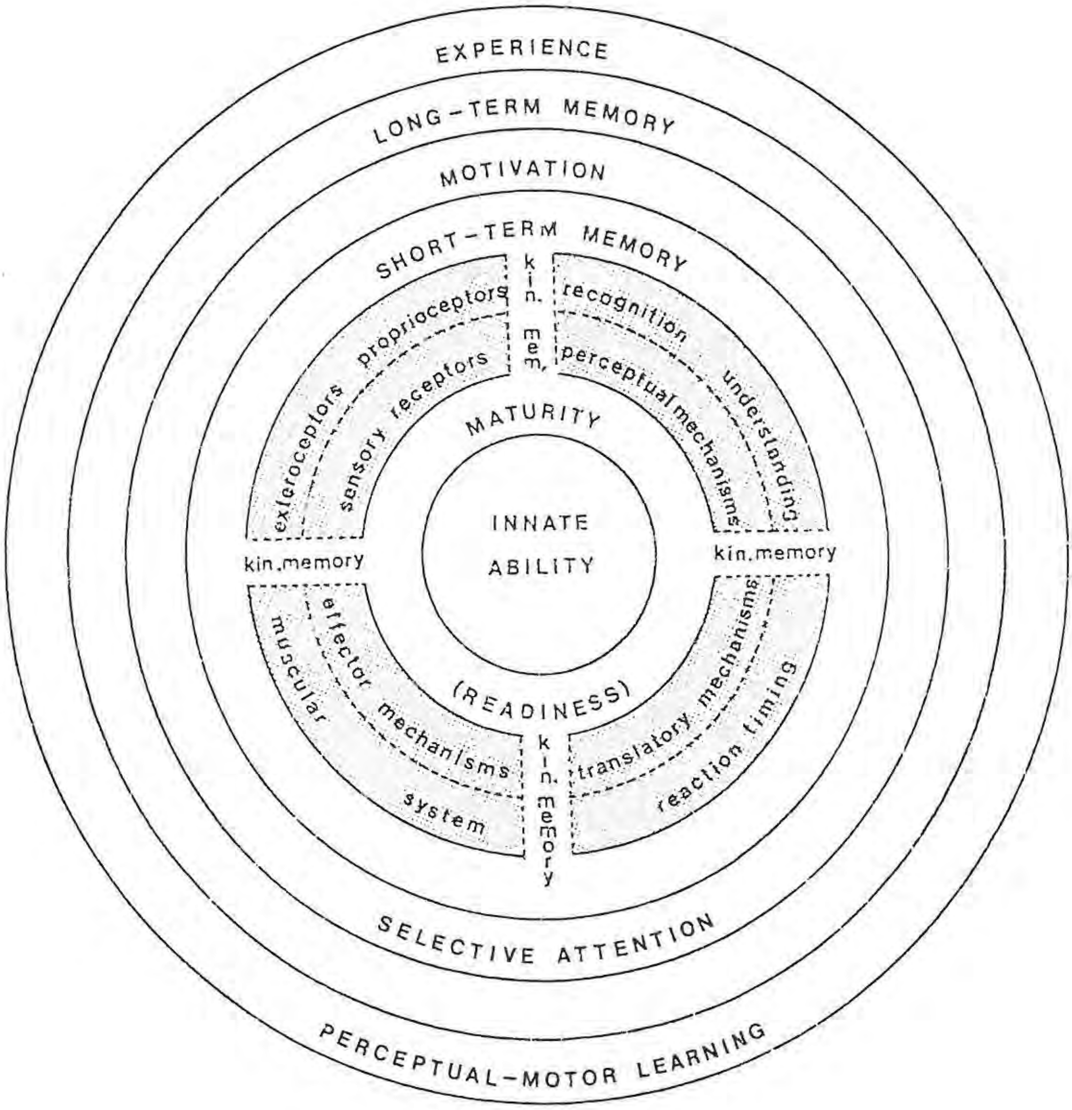

Figure 1. **Model representing systems involved in the perceptual-motor process and factors which influence it.**

As the model indicates, the processing of information gained through the senses, and the subsequent appropriate response, depend on a hierarchy of mechanisms. The model should not, however, be seen to suggest that perceptual systems (the shaded areas) are influenced from one direction only, but that there is an interrelationship between all the factors which would exert an influence. A breakdown in any one area of this system would invariably lead to unsuitable reactions. When this occurs regularly the child is commonly said to be clumsy and is thus thought to suffer, to a greater or lesser degree, from motor impairment. Delay in the maturation of any of the processes has the same effect, although this situation need not be permanent.

Pikunas (1969:53-54) explains that "heredity is the leading factor responsible for individual differences in growth and behavior", especially where ability is concerned. He goes on to explain that "heredity and genetic factors act as a matrix upon which various environmental occurrences exert a stimulating, suppressive, or distorting influence". The individual is thus endowed with certain potentials, but whether or not these develop to the full will depend on the influence his particular environment exerts, i.e. the opportunities the environment presents and utilisation of such opportunities.

The child gains experience through interaction with, and interpretation of, various aspects of the environment. Through repeated experience or practice he learns to cope with the demands made upon him by the environment. In this way learning takes place.

Perceptual-motor learning is thought to cause relatively permanent changes in performance. These occur in particular movement behaviour as a result of practice and experience, which implies an improvement in overt performance (Cratty 1967; Singer 1982). This development, which occurs as a result of experience and learning, is termed ontogenetic development.

Practice and experience contribute to the memory store which forms an essential part of the process of integration and assimilation of information from the senses. The success with which the motor memory contributes towards efficient movement depends on the amount and period of retention of learnt behaviour.

It is clear, therefore, that although there are several factors which contribute to general perceptual-motor development, and specifically to the ability to accurately reproduce movements and to perform balancing tasks, these do not occur in isolation, but rather form part of a network of interrelated processes. For the sake of clarity however these contributing factors and processes are discussed under separate headings. This is done in order to gain some understanding of the young child and that which could influence performance.

2. GROWTH AND DEVELOPMENT

Over the years, motor development in children has been the focus of a great deal of attention. Gesell (1928) and Piaget (1929) recognised that the motor domain is an important early indicator of child development, and Godfrey and Kephart (1965:7) insist that "the first learnings of an infant are motor learnings; the first responses of an infant are motor responses". As a result of growth, maturation and experience the child is able to develop the various fundamental perceptual-motor abilities which will form the foundation for future skill learning (Schmidt 1988).

Several factors contribute towards the growth and development of the child. Some of these factors, the phylogenetic factors, have been genetically fixed and will determine the child's abilities and potentials. Others, the ontogenetic factors, are dependent on the child's experiences within his environment which influence behaviour and response in different ways.

2.1. Phylogenetic factors

Several genetically determined factors decide the innate ability of the child in all areas, including perceptual-motor ability. Perceptual-motor ability - also called motor ability - refers to the potential an individual has for motor behaviour at a given time during the developmental process.

2.1.1. Physical development and growth

Physical development usually follows an orderly and predictable sequence, and motor development appears to follow a similar pattern (Espenschade and Eckert 1967). Two distinct directions of development were suggested in the literature: firstly, it tends to occur in a cephalocaudal direction (i.e. proceeding from the head towards the feet); and, secondly, it follows a proximodistal direction (i.e. development of the trunk precedes that of the limbs) (Pikunas 1969). For this reason a child can perform gross motor skills before being capable of controlling the finer muscles of the extremities.

Physical growth signifies physiological and anatomical changes within bodily structures. The changes that occur as a result of growth and development of bones, muscles, nerves, etc. follow the same directional sequence as illustrated above (Espenschade and Eckert 1967). There appears to be a dynamic interrelationship between these changes and development, implying that the one affects the other, and that both are continuous and ever changing. Reports of findings which are of special significance for the present study, indicate that there seems to be a stronger relationship between physical growth and motor performance in pre-schoolers than in older children (Cratty 1986). For this reason Herkowitz (1980) maintains that the study of physical growth is basic to the study of motor development, as height-weight ratios, tissue growth, and differences in body proportions undoubtedly affect the individual's motor development.

Although there is a sequential pattern to growth it does not occur linearly: different segments of the body grow at different rates and changes in body proportions occur with age. For example, Herkowitz (1980:11) found that "the head changes from one-fourth of the total length at birth to one-sixth at six years" and while the proportional growth of the head diminishes steadily, the legs and arms grow relatively longer. These proportional changes inevitably have an effect on the child's motor development, and thus his perceptual-motor ability.

Growth, however, involves more than just changes in proportion for it is also responsible for weight gain. Although the ossification process in the bones contributes towards weight gain, Ausubel et al. (1980) claim that muscular development accounts for much of the weight gain during the pre-school years. This could be explained by the fact that the larger muscles of the trunk and limbs develop faster than the finer muscles of the hands and feet. The development of muscles allows the child to experience more complex movements in which more muscles are involved, and through regular involvement the muscles develop in strength, and coordination becomes more precise (op. cit.).

Longitudinal and cross-sectional studies have shown that following the period of rapid growth during the first eighteen months, additional spurts of growth occur during the third and fifth years. These growth periods tend to be followed by periods of levelling off during the second, fourth and sixth years (Cratty 1986). This explains Cratty's claim that the relationship between physical growth and motor performance appears to be stronger in pre-schoolers than in older children. This phenomenon could be explained by the suggestion of Shumway-Cook and Woollacott (1985:145) that "the age range of 4 - 6 may represent a period of disproportionate growth with respect to critical changes in body form".

The main factor responsible for many individual differences in growth and behaviour appears to be heredity (Pikunas 1969). If this is so, it would go some way towards explaining why, when looking at physical growth at a specific age, there tends to be a range of variability about the mean. These variations in growth patterns have a unique influence on the development of the individual child's motor ability. Apart from the genetic determination of the child's physique, factors such as opportunity, diet, or illness could influence growth and subsequently, therefore, motor development. In view of this Hurlock (1978) suggests that a child's physical condition could also influence the way in which he responds to movement tasks. As a result of deficient diet or illness a weakening of muscles often occurs, and this can result in lack of control, and often, fear of attempting certain activities. Selye (1956) found that anxiety, stress and tension caused by fear have a detrimental effect on performance. It would thus appear that stressful conditions related to testing procedures could adversely influence performance, and precautions need to be taken to obviate this, especially when dealing with young children.

Physical growth is thus not an entity which is independent of other factors and it would be impractical to view the physical child without taking into account affective aspects. Body image (the mental picture an individual has of his body) is inextricably involved when it comes to the performance of movement. This is socially determined, and body-build, height, weight, etc. influence the way in which the individual perceives his body in relation to those around him. This perception determines the level of confidence that would be displayed when participating in motor activities (Cratty 1986).

2.1.2. **Age**

A literature search was carried out to: (a) examine explanations of motor behaviour during the developmental stages immediately preceding, including, and following the age group three to six years; (b) examine the literature pertaining to the areas of balance and kinesthesis; and (c) determine trends and opinions in research in these areas.

Research has clearly shown that the first four or five years of a child's life is the period of the most growth and development (Hottinger 1980a; Cratty 1986). However, White (1975: in Hottinger 1980b) concludes that much of the important development in children occurs by the age of three years.

As a result of the theory that development takes place in predictable stages, various authors have attempted to link these stages to age equivalents in order to determine their onset and duration. Examples of some of these classifications are:

Pikunas (1969)	Infancy	Birth - 2,5 years
	Early childhood	2,5 years - 5 years
	Middle childhood	6 years - 9 years
Corlett (1973)	Infancy	Birth - 7 years
	Junior	7 years - 11 years
Hurlock (1978)	Infancy	Birth - 14 days
	Babyhood	2 weeks - 2 years
	Childhood	2 years - adolescence
Hottinger (1980a)	Babyhood	1 month - 2 years
	Early childhood	2 years - 6 years
Cratty (1986)	Infancy	Birth - 2 years
	Early childhood	Pre-school years

Since the present study concentrates on the pre-school child, it is important to note that there is no clear cut-off point at which developmental stages start and end. The stages immediately preceding and following the pre-school years need to be taken into account in order to attempt to explain the behaviour of specific children during the execution of tasks during tests. For this reason a combination of the classifications suggested by Cratty and Pikunas has been adopted for this investigation, namely:

Infancy	Birth - 2 years
Early childhood	Pre-school years
Middle childhood	6 years - 9 years

Although chronological age is often used as a variable in tests for motor development, researchers have nonetheless concluded that early patterns of development should be based on maturational status rather than on chronological age (Espenschade and Eckert 1980; Cratty 1986).

2.1.3. Maturation

Arnold Gesell's theory of maturation (1940: in Ausubel et al. 1980: 18) reiterates Rousseau's emphasis on the "internal control of development". In other words, phylogenetic development is determined by biological or functional readiness. Although there is no universally accepted definition for maturation, the term is usually used to describe improvement in functional capacity which can be attributed only to structural growth and physiological development, without dependence on experience.

Maturation is a process in which there is a systematic development of interdependent attributes and, although this process follows similar directional sequences as physical growth, the rate varies from individual to individual. Cratty (1986:136) explains that "marked individual differences exist not only in pre-school children's physical abilities, but in the maturity of the mechanisms they appear to use when performing various skills".

Espenschade and Eckert (1967:79) list the essential characteristics of maturation as follows:

1. the sudden appearance of new patterns of growth and behaviour;
2. the appearance of particular abilities without benefit of previous practice;
3. the consistency of these patterns in different subjects of the same species;
4. the orderly sequence in the manifestation of different patterns;
5. the gradual course of physical and biological growth toward the attainment of mature status.

The same basic maturational process occurs in all humans and for this reason it is possible to make broad predictions about the development of normal children (i.e. those with no known developmental impairment).

While Krogman (1959: in Espenschade and Eckert 1967) concludes that skeletal maturity is an important factor in determining athletic ability during childhood, behavioural development is ascribed to the maturation of the central nervous system (Coghill 1929; and McGraw 1945: in Wade 1976). Rarick and Oyster (1964: in Espenschade and Eckert 1980) found, however, that skeletal maturity was of little consequence in differences in individual motor performance. Contradictory findings such as these could possibly be attributed to differences between the specific tests used in the different studies, or differences in the populations that were tested.

2.1.4. **Sensory development**

The senses, together with the perceptual mechanisms, are responsible for picking up information and making meaning of it. Perceptual-motor development is thus dependent upon the development of the sensory system, and Laszlo and Bairstow (1985:121) imply that maturation of the motor and sensory systems parallel each other "at least from five years of age". Burns (1986), however, postulated that the motor area develops ahead of the sensory area. This seems a feasible explanation for young children's lack of ability when attempting some activities for which they appear to be physically ready.

Burns (1986) explains that during brain development the cerebellum is the last to reach maturity. The primary role of the cerebellum is to control posture and balance, but it is also involved in coordinating body movements. The motor area therefore develops ahead of the sensory system, but it is the maturity of the sensory system which would set limits on ability.

Behavioural development, then, is dependent on the maturation of the central nervous system (Coghill 1929 & McGraw 1945: in Wade 1976), which, in turn, depends on myelination of the nerves. A myelin sheath which develops around nerve fibres prevents impulses from spreading from one fibre to the next, and thus allows for better control of movement. Rapid myelination of nerve fibres occurs between birth and the age of two years (Burns 1986), and it was found that myelination is actually "stimulated and accelerated by function" (Longworthy 1933: in Espenschade and Eckert 1967:41). Maturation of the central nervous system thus appears to be favourably influenced by experience in a variety of motor activities.

2.1.5. **Gender determined differences**

During the pre-school years it would appear that there is little difference in growth rate between boys and girls, except on an individual basis. At this stage of physical development, gender differences seem to have little or no effect on movement development. Yet gender determined differences in motor performance do tend to occur after the pre-school years, where most boys are able to out-perform girls in activities where strength is required and most girls tend to excel in tasks requiring precision and accuracy, such as rhythmic activities and balance (Connell 1955). One of the few tests of kinesthetic perception conducted on children revealed no significant differences between the abilities of boys and girls (Witte 1962).

Differences in test findings could be attributed to various factors such as the nature of the tests, the particular subjects participating in the tests, or the environment and atmosphere in which the tests were conducted. In this regard Espenschade and Eckert (1967) suggest that not much distinction is made between boys and girls in early childhood, but that where differences are found it is usually due to subjectivity in testing. It is further suggested that where sex differences are likely to occur, test items "which gave neither sex an experimental advantage nor an advantage based on differences in size and weight" should be chosen (Henderson and Stott 1977:41).

2.2. Ontogenetic factors

Ontogenetic factors are related to the environment with which the child needs to interact. The first environmental experience which could exert an influence upon a child occurs in the womb. After birth the child learns to adapt to the greater environment, or even to make changes in the environment to suit his needs. This adaptation process requires learning, which is brought about by experience. The child, however, is only capable of adequately coping with the demands of the environment once he is physically and emotionally ready and adequately motivated to do so.

2.2.1. **Experience**

Experience refers to interaction with factors in the environment that may modify or alter developmental characteristics through a process of learning. Although innate ability cannot be improved by experience, the possibility is that it can be brought to its full potential with appropriate experience. Lockhart (1980:247) explains:

> Development which is genetically induced and controlled (phyletic) cannot be speeded up but an environment which offers appropriate experiential opportunity can somewhat improve ontogenetic learnings.

Pre-school children develop their abilities and attitudes mostly through play. In addition to increased motor skills, often required for play, the child develops the intellectual ability to relate to the environment in different ways, and to give meaning to that which is perceived through the senses. During play a child learns, albeit incidentally, and this learning serves to stimulate curiosity, and in turn leads to further discoveries. The idea of learning through discovery has been stressed by Socrates, Locke, Rousseau, and Dewey. The environment must however provide opportunities for a variety of movement experiences in order to promote discovery of motor abilities.

Variations in motor development are elicited by differences in opportunities. Laszlo and Bairstow (1985) argue that during all overt actions there is an interplay between memory and the appropriate action. The individual naturally draws on previous experience on which to base action, and several studies have been reported indicating that where children have been deprived of certain opportunities normal development was retarded, and where the necessary opportunities were present development was accelerated (e.g. Stott 1967; Singer 1982).

Burns (1986) argues that a two-way interaction exists between neural development and experience. He explains that neural development is facilitated by experience which, in turn, facilitates higher levels of learning and behaviour. Through experiencing various motor activities the child develops the muscles and stimulates the sensory system, thus facilitating perceptual-motor development.

Since actions are usually based on previous experience, it was discovered that the more related the previous experiences are to a new task the less conscious effort it requires to learn (Cratty 1986). This is in contrast to Piaget's suggestion that children acquired knowledge as a result of "rather solitary interactions with and interpretations of various aspects of the environment" (Cratty 1986:25).

2.2.2. **Readiness**

Readiness is a term often used to describe a child's developmental status. Whereas maturation can take place even in the absence of specific experiences, readiness signifies that the individual has reached that specific developmental status in which it may be assumed that a reasonably economic increment in capacity may be anticipated in response to adequate and appropriate stimulation. Before this stage has been reached an individual may fail to profit from such stimulation.

Oxendine (1968: in Barrow 1983:183) notes that readiness "has now been extended to include interaction of maturation, prerequisite learning and motivation". Similarly Singer (1980) stresses the importance of, not only physiological readiness, but also emotional readiness. A child may be physically ready to learn a task, but lack the preparedness to heed relevant cues or concentrate on demands to do so. Lockhart (1980:248) suggests however, that an individual child is only ready to learn a skill "when there is evidence of voluntary involvement". The child must therefore show an interest in the specific activity or skill before he will be capable of acquiring the skills required for learning it.

This leads to the concept of "critical learning periods" which has been used by several authors to describe that crucial time when an ideal stage has been reached in the maturation of the child's sensory, motor, emotional, and motivational abilities for the learning of specific skills (Scott 1955; Hottinger 1980b; Singer 1980; Burns 1986). Pringle (1986) prefers, however, to use the terms "sensitive periods" or "optimal periods".

Espenschade and Eckert (1967) cite Hurlock (1953) and Rarick (1954) as being among those investigators who stress the critical nature of early childhood in the acquisition of motor skills. Singer (1980:322) suggests, however, that "timeliness, and not earliness, is apparently the most important variable with humans". The child would thus not learn sooner if he were to receive early training for a task he is not yet able to cope with maturationally (Burns 1986).

Cratty (1986) explains that calling up appropriate attributes is carried out with less conscious effort as the child matures. Efficient selection of action occurs as a result of the individual's ability to select appropriate work methods from the storehouse of attributes already gained through experience. Barrow (1983:231) agrees with Cratty's argument when he states:

> Excluding maturation with its unfolding of an inherent readiness and innate reflexes, everything the child knows and can do has to be learned, and this principle applies to motor skills as well as knowledges and attitudes.

The status of readiness a child requires before he is capable of learning a specific skill or behaviour is described as a "preparatory set", where readiness to attend to the relevant sensory information "that is forthcoming in a new learning situation" is indicated (Smith 1968:74). In order to benefit from a situation a prior perceptual set needs to be overcome and a new one established. Where tasks are similar, however, there is a certain amount of transfer from the one to the other and changes to the set are minimal. Motor readiness is nonetheless task specific for there is very little transfer of learning between tasks which have little in common. For example, before a child can be expected to learn balancing activities he must have mastered bipedal locomotion to the extent where it has become automatic, or does not require concentration. In order to learn a skill it is essential that the individual's attention is free to focus on the particular requirements of the skill which is being learned. He should not have to concentrate on underlying sub-skills.

Several researchers have concluded that improvement in balance ability occurs with practice (Cratty and Martin 1969; Cotten and Lowe 1974; Bordas 1971, in Cratty 1986). The learner should thus have developed the kinesthetic sensitivity required to control the skill on which the new skill is to be based.

2.2.3. **Motivation**

Motivation is a variable which should not be overlooked when considering motor development in general, and perceptual-motor learning in particular. Motivation is described by Schurr (1975:80) as "a state of need or desire to learn that prompts a person to do something that will satisfy that need or desire" and by Schmidt (1988:139) as "an internal state that tends to direct the system toward a goal". This appears to be very closely associated with maturational readiness, and it appears that children often seem able to sense their own capabilities. Other physical and emotional factors can, however, also influence motivation.

Burns (1986) suggests that it is also through sensory and motor experiences that the child learns the definition of the self, and thus becomes able to estimate his capabilities. Further, he explains that anxiety and fear often result from an inability to accurately evaluate one's ability, and this leads to a negative self-concept, which, as seen above, indirectly, but markedly, influences motor development.

Intrinsic motivation occurs when an individual does something for the pleasure experienced in doing it. This type of motivation is thus influenced to a great extent by previous experience: the individual could, however, also become demotivated where, in the past, performance of similar actions had led to discomfort.

Performance is usually heightened by increased motivation, as motivation interacts with ability and the level of skillfulness in a task (Smith 1968). Locke and Bryan (1966: in Schmidt 1988) suggest that increased effort is applied to the tasks when subjects are either intrinsically or extrinsically motivated.

There appears to be some controversy about the importance of extrinsic motivation in performance (Schmidt 1988), but both Fleishman (1958) and DuRandt (1981) report having used verbal encouragement successfully in motivating subjects during tests. In this regard Cratty (1986:99) stresses the importance of motivation, especially when working with young children:

> Movement tasks, when combined with verbal-linguistic and cognitive skills in ways that help the infant obtain feelings of success, seem more important than just who administers the program and in what setting the intervention effort occurs.

Extrinsic motivation usually occurs when an individual engages in an activity for the sake of recognition (Singer 1982), which is often sufficiently rewarding to encourage participation to the best of the individual's ability. The threat of punitive measures (the opposite of the reward system) also often acts as a motivating factor, but does not warrant discussion as it is irrelevant in the present context.

In summary, each individual is born with genetically determined characteristics and potentials. Development towards these characteristics and potentials takes place in an orderly sequence, according to developmental laws. Every system within the body goes through a series of developmental and maturational stages. Although the sequence of these stages can be predicted, the exact time at which different stages are reached will differ from one individual to another.

Because development takes place as the child grows older, age is often conveniently used as criterion upon which the onset and duration of the various stages are based.

Basically, the boundaries of growth and development are genetically determined, but interaction and learning to comply with the demands of the environment, will determine the limits of development within these boundaries. In order to benefit from any experience the child should be both physically and emotionally ready. This will ensure interest and motivation which is essential for learning to occur.

3. PERCEPTUAL-MOTOR COMPONENTS

The aim of the study is to determine the possible relationship between kinesthetic sensitivity and balance. Both kinesthesis and balance are two very important components of perceptual-motor control. Each of these components is discussed in some detail, with special reference to those aspects important to the study.

3.1. Kinesthesis

Awareness of the environment and the individual's position within it is obtained essentially from the visual and, to a lesser degree, from the tactile systems, while the auditory system plays a very limited role. There is however another network of sensory systems which tenders information about the position of the body and its parts. This is known as the kinesthetic system.

Barrow (1983:138) explains that,

> Where movement is concerned ... one of the vital functions of the nervous system is to instigate, control, integrate, coordinate and monitor through feedback all muscular activity.

Any voluntary movement is controlled and a sense of movement is perceived: the cerebral cortex is kept informed of positions, and rate and extent of movement of the body and its parts, and this information is then appropriately acted upon (Laszlo and Bairstow 1985).

The term "kinesthesis" was first used by Bastion (1880; in Richardson and Tandy 1973:206) to describe this "feeling of motion". Since then, kinesthesis (also referred to as kinesthetic perception) has been given many global definitions and meanings: it was labelled as "position sense" by Wells (1960); Schneider and Tarshis (1975:243) refer to "the sense of movement", and Cratty (1964) calls it "movement sensation". Singer (1982) refers to "conscious muscular movement" and defines it as the sensation (feel) of movement. Laszlo and Bairstow (1985:108) combine these and define it as "the sense of movement and position". More descriptive definitions have been used: Clarke and Clarke (1984:326) describe kinesthesis as "the perception of movement, the sensation of position, or the control of motor performance"; and Baumgartner and Jackson (1982:228) define it as "the ability to perceive the body's position in space and the relationship of its parts". Kinesthesis is also said to include "perception of body movements through balance skills and sensitivity to rate and direction of movement" (French and Horvat 1985/86:28). Gibson (1966:111) suggests that the term "kinesthesis" literally means "the pickup of movement", i.e. perception of movement.

Receptors in the various sensory systems are responsible for picking up information about the body, its movement and its relationship to the environment. A receptor is explained by Gibson (1966) as being a cell which reacts variously to different forms of energy. As the exteroceptors (the eyes and ears) provide information about what is happening outside the body, so the interoceptors and proprioceptors provide information about the body itself. The term "proprioception" was first used by Sherrington (1906; in Goodwin 1976) to describe the senses subserved by receptors in the muscles, tendons, joints, and the labyrinth; and Baumgartner and Jackson (1982:229) explain that these proprioceptors are highly developed sense organs which constitute a "highly sensitive system of kinesthetic perception".

Sensory modalities (visual, auditory, kinesthetic, vestibular, tactile, and visceral) give essential information, in different ways, of all postural adjustments. Gibson (1966) classifies the subsystems responsible for kinesthetic information as follows:

(1) the cutaneous or touch subsystem, which provides information about weight distribution (Ruffini organs and Pacinian corpuscles);

(2) the kinesthetic or articular subsystem, which gives information about the angular movement of joints (Golgi tendon organs);

(3) the muscular subsystem, which gives information about the contractile status of the muscles (muscle spindles);

(4) the vestibular subsystem, which provides information about linear and angular acceleration of movement;

(5) the haptic subsystem, which provides unique information from the touch and kinesthetic subsystems;

(6) the dynamic touch subsystem, which integrates information from the muscular, kinesthetic, and touch subsystems.

A distinction can be made between the interoceptors which provide visceral information and the proprioceptors which provide positional information. The proprioceptors are mechanoreceptors, reacting specifically to mechanical energy and constantly providing the brain with information about the movements and positions of the various parts of the body. Schneider and Tarshis (1975:249) explain that "proprioceptive cues convey two kinds of information: awareness of body position and balance with respect to gravity; and awareness of limb position". The similarity of these explanations indicates the synonymy of the terms "kinesthesis" and "proprioception".

As various motor skills are performed it is necessary to be able to adjust and modify movements in order to attain satisfactory results. Elliot et al. (1978:140) found that "the kinesthetic perception that one has for the body and its parts during the performance of movement activities affects the quality of performance". Laszlo and Bairstow (1985) obtained similar findings and explain that coordinated movement or the achievement of fluency and accuracy in movement occurs due to the interaction of the body parts which, in turn, leads to control during balancing tasks, sequential timing, and smooth interaction of the various muscle groups involved in the task. They explain that although several receptors supply information concerning movement, they do not often act in isolation. Several of the receptors could be involved during a single action, and Travis (1945) pointed out that the dominance of one over the other was impossible to determine.

There is, however, no general kinesthetic sense, and even to measure the sensitivity of a specific kinesthetic subsystem (e.g. at a joint) is very difficult, because the muscles are inevitably also involved. Singer (1982:121) explains that kinesthesis is also "specific to the test and part of the body involved in the skill". It has been argued that information about movement and position of the body and its parts is also provided by the exteroceptors, for as Smith (1968:40) argues "it is possible that man cannot rely on his kinesthetic feedback to provide detailed information about his movements". It is often found that vision is used by an individual to correct errors of position not perceived kinesthetically. Hence the use of mirrors in dance studios. For this reason Pleasants (1971:36) calls kinesthesis "that uncertain feeling". He argues that there is much uncertainty about how one "feels" in terms of whether or not a movement is correct. His question is: "to what extent are we consciously aware of these adjustments and the feel of movement?", and suggests that the possibility of answering this and similar questions "centers around how motor learning takes place, and the meaning and significance of kinesthesis in relation to performing physical skills".

Many of the definitions of kinesthesis imply that we are "consciously aware of the various aspects of a movement due to kinesthetic feedback, and this awareness in some way guides the movement" (Pleasants 1971:37). Cohen (1981:116) suggests that "the excitation of receptors in the proprioceptive field is primarily the result of some action or change in the spatial position of the organism". The individual is thus provided with internal feedback about movement and position of the body without having to rely solely on vision. Richardson and Tandy (1973:207) however explain that,

> Kinesthesis is not an automatic by-product of movement, for it is dependent upon conscious awareness. This means that the child must be capable of processing movement and organizing sensory information received from kinesthetic receptors, ... and balance mechanisms.

Lawther (1968; in Pleasants 1971:37) is not quite as convinced of this when he hypothesises that "kinesthesis is comprised of a group of more or less integrated cues from our somasthetic receptors and may or may not be recognized or responded to below the awareness level of consciousness".

As will be discussed later (see 3.2), balance receptors appear to function at an unconscious level (Schneider & Tarshis 1975; Marsden et al. 1981). French and Horvat (1985/86:31) classify both balance and kinesthesis under "Body Management Skills", where kinesthesis falls under the heading Body Awareness, and static and dynamic balance under Body Control.

Richardson and Tandy (1973:207) point out that "research evidence indicates that kinesthesis involves the proprioceptors of the body and that practice is required in order to establish the proprioceptive pathways for movement". Kinesthetic acuity or the accurate awareness of specific movements and positions of various parts of the body thus requires that the individual be familiar with these movements and positions.

Schneider and Tarshis (1975:242) illustrate that "proprioceptive stimulation has two sources. First, balance, which is nothing more than awareness of body position in respect of gravity" and is mainly controlled by the vestibular apparatus, and second, "the awareness of limb position ... monitored by receptors located in the joints and ligaments". Limb movement and position is encoded by the kinesthetic receptors which gather information by sensing the relationship between the hinged bones of a limb and translating it into neural impulses.

Muscles and joints are quite different structures: during movement muscles vary in length while joints vary in angle. The joint registers the relative position of articulating bones, both during sustained positions and during movement, while the receptors in the muscles (muscle spindles) register the length of and tension in the specific muscles. The mechanics of these structures are thus different. "The evidence strongly suggests that muscle sensitivity is irrelevant for the perception of space and movement, whereas joint sensitivity is very important for it" (Gibson 1966:109). Rose and Mountcastle (1959; in Gibson 1966:110) explain that:

> The sense of position and movement of the joints depends solely on the appropriate receptors in the joints themselves. There is no need to invoke a mysterious 'muscle' sense to explain kinesthetic sensations, and to do so runs contrary to all the known facts concerning the muscle stretch receptors.

Skogland (1956 and 1973; in Goodwin 1976:109) suggests that "Golgi tendon organs in the joint ligaments could provide the necessary objective joint angle uncontaminated by muscle contraction" when using passive movement. Burgess and Clark (1969; in Goodwin 1976) were however unable to substantiate this explanation. Goodwin explains that one possibility for these findings could be that joints may have receptors which behave differently, i.e. detecting only active movement. Geldard (1972:378) found that discrimination of motion at joints proved to have been remarkably accurate. The shoulder was found by Geldard to be the most sensitive joint. Laidlaw and Hamilton (1937) had found however that the hip joint was slightly more sensitive than the shoulder.

Rose and Mountcastle (1959; in Gibson 1966) discovered that joint receptors discharge at a given rate for a given angle of the joint. Through, and from this, they were able to determine the ideal angles for testing. For abduction of the shoulder joint, a 90° angle was found to be the most accurate in most subjects. However, Goodwin (1976:100) warns against "too simple a view of the sensory mechanisms underlying position sense". One of the underlying aims of this investigation is thus to attempt to learn more about these mechanisms.

Scott (1955:330) postulates that the arm action in balance could be significant and "not just a mechanical asset as sometimes is assumed in analysis". The present research relied on these assumptions to justify the inclusion of the tests for sensitivity at the shoulder and hip joints respectively.

Travis (1945:233) explains that there is a difference between kinesthesis in static and dynamic operations. He describes static operations as "movement of isolated parts of the body", and dynamic operations as those involving movement of several body parts. This would imply that a dynamic operation, such as balance, would thus require higher levels of kinesthetic organization than would the positioning of a single limb.

It would thus appear that, whereas position registration is basically dependent on the sensitivity of the joints involved, the kinesthetic sense involved in balance depends primarily on the sensitivity of muscle receptors. However, Nashner and McCollum (1985: in Schmidt 1988) conclude that the major receptor mechanisms for the control of balance are situated in both the muscles and joints. Singer (1980:202) also claims that "the stretch reflex works in sustaining body posture". This implies that the muscle spindles and the Golgi tendon organs are responsible for controlling balance. The role of the labyrinthine structures of the inner ear is often stressed where balance is concerned, but Bass (1939:50) concludes that "the semicircular canals do not function in ordinary tests of balance as much as is usually thought to be the case". The vestibular apparatus is thought by Cratty (1986) to act merely as an integrator between visual and motor information.

It is important, in the light of the age group involved in this study, to note that the kinesthetic sense is the first sensory system to develop: a process which already commences in utero

(Bressan and Woollacott 1985/86). In fact Richardson and Tandy (1973:206) point out that "...the first two years of life are important for the development of kinesthesis". Laidlaw and Hamilton (1937) agree that kinesthetic sensitivity develops early, but suggest that it remains stable until after fifty, when it deteriorates. This suggests that kinesthetic sensitivity develops fully at a relatively early age and does not benefit further from experience. This appears to be a rather fatalistic view, for motor learning, which is dependent on kinesthetic sensitivity, does not take place only during early childhood.

Ashby (1983) conducted one of the few kinesthetic tests on children (aged six to ten years). His aim was to determine the efficacy of short-term retention of kinesthetic end-location. The conclusion was that young children (6 years old) are less competent in the efficient encoding of kinesthetic cues than older children (aged 8 - 10 years). However, since only a single attribute of kinesthesis was explored by Ashby, and in view of the small sample involved (N = 60), a generalisation, such as that made by him, cannot be accepted without some trepidation.

In the discussion on the development of the sensory system it was noted that certain changes take place. Among these developmental changes in sensory-perceptual processes three major changes are emphasised by Williams and DeOreo (1980):

(1) there is a shift in dominance from reliance on tactile-kinesthetic information (which is relatively crude) to the telereceptors (mainly the eyes) which are more refined, for control and modification of movement;
(2) as the child becomes able to integrate information from several sensory systems, improved intersensory functioning occurs;
(3) each individual sensory system appears to develop a more refined capacity to discriminate between cues.

3.1.1. Sensory integration

Burns (1986) explains that the motor area matures ahead of the sensory area. For control of movement the child needs to move away "from a reliance on single sources of sensory information" towards the ability to "interrelate and match up information from several sensory systems simultaneously" (Williams and DeOreo 1980:145). Shumway-Cook and Woollacott (1985) found that between the ages of four and six years there is an increase in the importance of somatosensory input in the control of balance. This suggests a shift away from reliance on visual dominance to greater utilisation of kinesthetic feedback.

As kinesthetic perception forms the basis for this investigation, the ability of pre-school children to integrate information from the proprioceptors is important. The proprioceptors considered to be the most likely to be involved in the present study are the muscle, joint, and cutaneous receptors. Kinesthetic sensitivity of joint position would invariably rely on the integration of information from both muscle and joint receptors. Since the sub-cutaneous receptors (Ruffini organs) provide information about weight distribution they are also seen as important factors, especially where balance is concerned.

Multiple sensory inputs are thus possible for the adaptation of behavioural responses; improved intersensory discrimination tends to occur simultaneously with improved intersensory communication. All this allows for motor control in that it allows for finer discrimination and better coordinated responses.

Scott (1955) suggests that balance tests should form part of kinesthetic test batteries. Her test battery consisted of twenty-five items, one of which was an arm raising test similar to the one included in the present study (also used by Wiebe 1954; Witte 1962; Young 1945). The conclusion has been reached that there is little relationship between the tests, which points to the specificity of the tests. Scott warns that many of the tests for kinesthetic sensitivity do not lend themselves to objective measurement; are not suitable for testing young children; require expensive equipment; and do not stimulate the interest of the children.

3.2. Balance

The term "Balance" is used as an all-encompassing term to describe the maintenance of stability during different movements and positions. Different types of balance have thus been identified. The two most commonly investigated forms of balance are static balance and dynamic balance, which were first reported by Bass (1939).

DeOreo and Keogh (1980:87) identify four kinds of balance. First, postural balance (postural control) - which they describe as "the body's reflexive response to gravity". This type of balance assists with the maintenance of the upright position in everyday movements. The second type of balance is static balance, which is defined as the ability to maintain particular body positions without moving. The author finds this definition confusing as not all positions which are held are in a balanced state. It is suggested that it could better be expressed as the ability to maintain particular stationary body positions on a limited support base. Static balance is usually measured on balance boards, stabilometers, dynabalometers, and balance sticks. The third form of balance is identified as dynamic balance: "the ability to maintain and control posture while moving through space" (op cit). Fourthly, they describe the balance required for gymnastic skills and movement combinations. Over and above balancing ability this type of balance requires a great deal of strength, coordination and control. A fifth kind of balance is identified by Cratty (1986), namely the ability to balance objects on body parts.

Due to the specificity of balance it becomes important to examine each type separately. Although four types have been identified, only the three directly pertinent to the present investigation are examined in detail i.e. postural control, static balance and dynamic balance.

The terms "postural control" and "balance" often appear to be used synonymously in the literature. An attempt was made to make some distinction between the two here, as postural control appears to be largely controlled by reflexes, while balance appears to be more under conscious control.

3.2.1. **Postural control**

One of the most important voluntary movements in infancy is that of assuming the upright position, i.e. the postures and balances necessary for bipedal locomotion. This is acquired, firstly through the stabilisation of the body during sitting, crawling, standing, and ultimately walking. Bressan and

Woollacott (1985/86) suggest that of all the motor control capacities to develop in children, balance control is among the first to mature. The reason behind this assumption is given by Hurlock (1978:139):

> The cerebellum, or lower brain, which controls balance, develops rapidly during the early years of life and practically reaches the mature size by the time the child is five years old.

Gibson (1966:35) suggests that the "upright posture, and a sense of the postural vertical, are assured by both the gravity receptors in the muscles and the vestibular apparatus". Singer (1980:202) agrees that the "stretch reflex works in sustaining body posture". He suggests that even for normal erect stance interaction of a number of neurophysiological structures is involved. Gibson explains the gravity receptors as statocysts which are located within the vestibular receptors. He maintains that these inner ear sensors give rise to circular and continuous effects on postural correction. DeOreo and Keogh (1980:87) describe balance as "the body's reflexive response to gravity".

Psychologists have classified inputs (afferent impulses) regarding information about body position into two types: exafferent (mainly exteroceptive) and reafferent (mainly proprioceptive) (Gibson 1966). Gibson distinguishes between two proprioceptive systems: the lower proprioceptive system, which he felt was concerned with balance and equilibrium, and acts in reflex cycles; and the higher proprioceptive system which is concerned mainly with purposeful action and can be controlled voluntarily. He classifies these as follows - from the lowest to the highest: muscular; articular; vestibular; cutaneous; auditory; and visual proprioception. (Visual proprioception being the information given by the muscles of the eyes, and not vision itself, although the need to focus on a specific point determines the amount of stretch in the muscles of the eye.) Gibson (1966:36) goes on to explain that "the lower level of kinesthesis is entirely subservient to the higher, visual level ...".

The lower systems are thought to be more automatic or reflexive, while the higher systems are less automatic and could be controlled voluntarily. He also suggests that the tension in the antigravity muscles depends on the stretch receptors (muscle spindles and Golgi tendon organs), and claims that the maintenance of equilibrium "... is a process of continuous compensation ..." (ibid.:35).

This assumption was based on the work done by Sherrington (1900; in Gibson 1966) who demonstrated that the actions necessary for resisting gravity or maintaining posture, were reflexive (corroborated by others e.g. Marsden et al. 1981). Gibson explains that as proprioceptors are activated a reflex cycle arises, which immediately shortens the muscles to compensate for the stretch. He also insists that a similar cycle operates during visual control of balance, but at a higher level (i.e. involving visual, cutaneous as well as kinesthetic cues).

Marsden et al. (1981:529) suggest that the body possesses "many quick subconscious mechanisms for adjusting posture...". The muscles acting in postural control have been found to react very quickly, in fact so quickly that it causes difficulty in pinpointing the receptors involved. They explain that "... their response is often so rapid that they start (firing) before posture (even) begins to be disturbed and can, in the true sense of the word, be said to anticipate: parts of the body are braced in advance ...". This is the reverse of what Sherrington calls a chain-reflex reaction, and it was argued that these reactions are not due to reflex arcs in the muscles, but are driven by reflex inputs from the parts of the body where disturbance is felt, also referred to as a "driven response" (Marsden et al. 1981). The relationship between driven responses of this nature and stretch reflexes in the postural muscles is however still obscure. Marsden et al. (1981) suggest that where reflex responses and driven responses occur simultaneously the driven responses override the stretch reflexes in some obscure way. The driven responses are thought to be driven by afferent inputs and to be ontogenetic (learned) reflexes. Bruner (1973:2) postulates that internal feedback (also called feed-forward) prior to action gives rise to intention, and explains that,

> Even at the simplest level of postural adjustment or effector movement, it is impossible to conceive of directed action without the compensation made possible by such prior signalling of intention.

He therefore suggests that reflex behaviour is converted to intentional action once the child is given the opportunity to observe the results of his actions.

Several authors place the emphasis on the systems involved in postural control and balance differently:

Schneider and Tarshis (1975:249) explain that,

> The chief sources of balance are two receptor organs (the labyrinthine sense organs) located in the non-auditory part of the inner ear. One organ consists of the semicircular canals, which are three fluid filled canals sensitive to rotating movement. The other consists of the vestibular sacs, which are two fluid filled sacs sensitive to linear movement. The transduction process in both organs is based on the same hydraulic principle.

They go on to explain:

> The neural circuits that connect the semicircular canals and the vestibular sacs to the brain take a similar course .... The nerve contains neurons that are relatively large in diameter, thus promoting speed of conduction and establishing the neural basis for the speed needed for postural reflexes in response to abrupt changes in body position.

This could account for the assumption that balance control is reflexive.

Butterworth (1981) and Cratty (1986) name three subsystems responsible for efficient balance: vision, and its stabilising effect; the ability to make precise adjustments in the maintenance of balance; and the mechanisms of the inner ear, which they suggest act as integrators of visual and motor information. Travis (1945) adds to these the visceral senses, and explains, in agreement with DeOreo and Keogh (1980), that the dominance of one subsystem over another is impossible to determine.

Sherrington (1906, 1947; in Clark and Watkins 1984) identifies eight factors which are important for the ability to balance:

1. the general eye-motor factor (eyes open or closed),
2. general kinesthetic response factor (the ability to feel body position),
3. general ampullar sensitivity (semicircular canal functioning),
4. vertical semicircular canal functioning,
5. tension-giving reinforcement,
6. general muscle tone,
7. the surface on which balance takes place (balance stick, stabilometer, etc.),
8. the position of the base of support e.g. the foot (lengthwise or crosswise).

According to this, all balancing requires accurate perception of information from the combined efforts of simple reflexes, kinesthetic sensitivity, visual information, and information from the vestibular apparatus and the reticular formation.

Singer (1982) identifies four sensory modalities involved in the kinesthetic response factor during balance as:

(1) the tactile sense - through this system information about body sway is conducted through the pressure exerted on the skin and underlying tissues of the part of the body bearing the weight (the cutaneous receptors). In this way weight distribution is registered;

(2) the kinesthetic sense which involves the proprioceptors in the muscles, tendons, and joint capsules;

(3) the visual sense, which gives information about the position of the body in relation to an external point of reference in the maintenance of balance;

(4) the vestibular system, which is located in the inner ear, and is concerned with rotatory movement and the position of the head in relation to the rest of the body.

Forssberg and Nashner (1982; in Shumway-Cook and Woollacott 1985:132) found:

> In young children the temporal and spatial structures of automatic postural adjustments is mediated by support surface somato-sensory inputs, just as it is in adults.

According to the hierarchy of postural control systems suggested by Gibson (1966) and Singer (1982) it would appear that the cutaneous receptors which are in contact with the supporting surface also contribute to the responses. This supports the researcher's reason for allowing cutaneous receptor feedback in the present study - by letting subjects perform barefooted.

3.2.2. **Balance control**

Balance control is an aspect of human movement which has received considerable attention from psychologists, physical educationists and physiologists. Some contemporary authors however differ in their classification of balance: while Gallahue (1983) calls it a perceptual-motor skill, Williams (1983) places it in a category which does not include gross motor skills. Sherrington (1906, 1947; in Clark and Watkins 1984:854) considers that "the ability to establish and maintain one's balance has long been recognized as an important element of skillful movement behaviour". Cratty (1986:188) agrees, but states that balance is "not a skill but a rather important movement quality underlying the performance of a large group of skills". Bressan (1986) goes as far as to suggest that children should not be taught ball skills before they have become proficient in balance. This is in line with the conclusion reached by Nichols (1986), that children should first develop body management before they can successfully master perceptual-motor skills.

The importance of balancing ability to humans is also stressed by several other researchers (Singer 1980; Espenschade and Eckert 1967; Laszlo and Bairstow 1985; Elliot et al. 1978). Ulrich and Ulrich (1985) found that balancing ability is an important predictor of overall performance of fundamental gross motor tasks in pre-school children.

Because of the difficulty in establishing exactly which proprioceptors are involved in balance control several authors have come to different conclusions in this respect. While Nashner and Mc Collum (1985; in Schmidt 1988) concluded that the major receptor mechanisms responsible for the control of balance are situated in the muscles and joints, Woollacott et al. (1987) determined that the ankle joint appears to be the dominant source of sensory input controlling standing posture. DeOreo and Keogh (1980:175) dispute this claim and explain that it is believed that neither the muscle spindles nor the Golgi tendon organs have a role in "conscious kinesthetic perceptions". Marsden et al. (1981) agree that different nervous mechanisms from those primarily investigated in prime movers are employed in the control of balance (i.e. neither the muscle spindles nor the Golgi tendon organs). They are believed to assist only in the control of posture and movement without giving rise to conscious sensation. Spindles are thought merely to mediate reflexive postural adjustments (DeOreo and Williams 1980). Muscles therefore appear to take part in postural responses only where conditions are such that they could assist in balance control. This diversity of conclusions indicates the lack of certainty which exists about the precise role of the different prorioceptors in balance control, and the part played by perception.

Gibson (1966:45) came to the conclusion that "the proprioceptive systems overlap with the perceptual systems but do not correspond with them". Meaning that these two systems may coordinate, but function quite independantly. Perception pertains to making sense of the (internal and external) environment, while proprioception pertains to the "feeling" of the position of the body and its parts.

It is asserted that "between the ages of one and three, children's capacity for balance explodes" (Bressan and Woollacott 1985/86:7), but that they still rely heavily on visual cues for control. Shumway-Cook and Woollacott (1985) differ slightly in their report, finding that prior to three years of age the child primarily uses both visual and vestibular inputs to control static balance. Butterworth (1981:63) agrees with this and explains that it is during the early stages of the acquisition of postural control that balance seems to "depend critically on congruence between visual and mechanical-vestibular indices of postural stability".

With experience, control of posture gradually shifts in favour of the mechanical-vestibular system and the young child "becomes progressively able to overrule the visually specified instability" (op cit.). Schneider and Tarshis (1975:243) suggest that "closing the eyes puts the brunt of balance control on the labyrinthine receptors". So when visual cues are absent the individual has to rely on information from the appropriate proprioceptors.

Between the ages of four and six years there is a transition from reliance on vision for balance control to the inclusion of kinesthetic and vestibular cues (Butterworth, 1981). This might explain the findings of Gesell and Ilg (1946; in Laszlo and Bairstow 1985) that by five years of age coordination reaches greater maturity which leads to greater economy of movement and improved balancing ability. It was found that only after the age of seven years the "kinaesthetic system appears to become their primary source for balance relevant information" (Bressan and Woollacott 1985/86:13).

The researcher believes it safe to assume that it is essentially postural control which underlies many perceptual-motor abilities, and that it is also an important element of both static and dynamic balance. Without control of posture, balance per se would thus be impossible.

Balance should therefore not be seen as an isolated skill, for each type of balance requires a different set of controls. It has even been found that every type of sport requires unique kinds of balance (Singer 1980). Shumway-Cook and Woollacott (1985:145) explain that studies have indicated that "the controlling sensory inputs to the postural control system are context specific". Balance is thus task specific, and when measuring balancing ability, e.g. on a Bass stick, the results will only indicate the subject's ability to balance on the Bass stick and nothing else. DeOreo and Keogh (1980), however, submit that because all balancing abilities are interrelated, measurement of a single type of balance is very difficult.

3.2.3. **Static balance**

The maintenance of static balance is a matter of alignment of the body segments in relation to the supporting surface. Gerhardt (1973:130) defines static balance as the "stability produced by the even distribution of weight on each side of the vertical axis". He suggests that "some children seem to spontaneously sense the centre of balance while others struggle or give up" (op cit.). As indicated earlier, the maturational status of the systems involved would influence this, and consequently the ability to perform static balance. The child should have developed kinesthetic sensitivity, or the awareness of proprioceptive cues and their meaning, and should also be able to integrate the cues supplied by the various receptors before he is able to balance with control. Woollacott et al. (1987:167) explain that,

> The accuracy with which a child or an adult is able to balance during quiet stance and voluntary movement depends on efficient detection and integration of information from the somatosensory, visual, and vestibular systems, as well as the consequent activation of appropriately organized muscle responses to correct body sway.

It has been shown that there are "clearly organized leg muscle responses" in young children during balancing on a balance board (Woollacott et al. 1987:174). This would imply that the muscle spindles and the Golgi tendon organs are responsible for controlling this type of balance. Here the muscles are thought to assist in balance control as balancing on an unstable platform requires conscious effort to maintain a position. This contradicts earlier claims that the spindles and tendon organs do not have a role in conscious kinesthetic perception. It was also seen earlier that the ankle joint appears to be important for the control of standing posture (Woollacott et al. 1987). Different findings such as the above appear to result from studies in which only isolated receptors were investigated.

Added to the above, are the conditions under which children perform and which would determine the amount of anxiety and the resultant tension within the muscles. Smithells et al. (1962) explain that muscle tension is shown to interfere with kinesthetic feedback. Tension would thus alter the ability to maintain static balance. It was found by Morris et al. (1982) that to ask a young child to balance on one foot "for as long as possible" would reflect the child's pain threshold rather than his ability to balance (Cratty 1986:153). Holbrook (1953, in Cratty 1986) and Singer (1982) also caution against the use of one-footed balance tests for young children. An explanation for this is that at this age children have not yet developed the kinesthetic response factor; their attention span is limited; and they lack experience in static balance per se (Singer 1982). The ability to perceive and act effectively on kinesthetic cues is part of the kinesthetic response factor.

Cratty (1986) suggests that prior to the age of five children should posture on two feet, varying distances apart, for balance tests. The "Rhomberg position", or heel-to-toe position, was thus found to be a suitable method for testing static balance in young children.

Vision has been found to dominate voluntary responses from birth (Cratty 1981), and static balance is a voluntary response. It is also concluded by Woollacott et al. (1987)

that during static balance, vision was dominant in two- and three-year-olds. The age period four to six years has been found to represent a transition period in postural development "when children learned to integrate and alternate between visual, proprioceptive and vestibular inputs in controlling balance" (Woollacott et al. 1987: 185). Being deprived of sight, however, puts the emphasis on the labyrinthine receptors (Schneider and Tarshis 1975). Gibson (1966: 303) also suggests that when a subject is deprived of exterosensory stimulation he is able to "fall back on the haptic system" (a sensitivity to the environment adjacent to the body, as well as to the position of the body itself). This conclusion was reached after extensive experiments were conducted to determine the effects of impoverished stimulation and inadequate information.

Three interesting observations regarding vision and static balance are reported. Woollacott et al. (1987) discovered that vision is not required for the activation of postural responses, i.e. that there appear to be other mechanisms in the body that give information about the vertical axis in relation to gravitational force. Secondly, Cratty (1986) reports that some subjects actually balance better with their eyes closed. This would possibly depend on the specific task, for, finally, as Shumway-Cook and Woollacott (1985) indicate, the role of vision plays a more important role in novel situations or where the support surface is unstable. It would thus appear that Cratty's observations could have been based on static balance performed only on stable support surfaces.

Several researchers (Ulrich and Ulrich 1985; Cratty 1986) have found that balancing ability improved with age. Cratty (1986) comes to the conclusion that there is often a dramatic improvement in balancing ability from the fifth to the seventh year. Erbaugh (1984) argues that the improvement in general balancing ability is due to maturation rather than to age. Bachman (1961a), however, found that static balancing ability on an unstable platform (balance board, stabilometer, etc.) declines with age during childhood. Renshaw and Wherry (1931; in Samuel 1981:378) conducted a spatial-localization experiment, and found that there was a "decline in proprioceptive efficiency concurrent with greater reliance on vision as the child grows older". This would explain the decline in ability as children grow older. This also accentuates the dominance of the higher systems over the lower systems, and implies that a conscious effort is required to become aware of kinesthetic cues once visual feedback has become dominant.

Several researchers (DeOreo and Wade 1971; Holbrook 1953 and Winterhalter 1974, in Cratty 1986; Cratty and Martin 1969) found girls to be superior to boys in static balance. Ulrich and Ulrich (1985), however, found no significant gender differences. Differences in tests, subjects and/or testing conditions could, once again, be an explanation for conflicting findings such as these.

In conclusion, it must be stressed that "static balance in children is a multidimensional construct" and therefore no single test item can adequately assess static balance ability (Clark and Watkins 1984:856).

3.2.4. **Dynamic balance**

Cratty (1986) gives the second kind of balance skill (the first being postural control) acquired by infants as: control in the loss of balance and restabilisation thereof, e.g. walking, running, skipping, etc. DeOreo and Keogh (1980:87) describe dynamic balance as "the ability to maintain and control posture while ... moving in space". Espenschade and Eckert (1967:163) define it as "the maintenance of posture during the performance of a motor skill which tends to disturb the body's orientation. This form of balance is usually measured traversing balance beams of various widths, or simple line walking (Bayley 1935; in Cratty 1986).

Travis (1945) maintains that the dynamic component of equilibrium, characterised as an orientating perceptual-motor adjustment of the body while in motion, is not at all relevant to the static component, which is characterised by continuous tonic reaction. This unrelatedness is indicated by the low correlations between performance in the two types of balance (Bass 1939; Drowatsky and Zuccato 1967). It has however been observed by the researcher that young children are more willing to perform dynamic balance activities than they are to perform static balance activities while wearing a blindfold. As yet there is no explanation for this phenomenon, but the assumption is made that whereas the cutaneous receptors add to the kinesthetic information during dynamic balance, the child needs to rely on limited receptor feedback during static balance. Another explanation could be that during active movement the young child's attention can be held for a longer period than during the maintenance of static positions - to the child there does not seem to be any purpose in the latter, while in the former the child perceives a definite aim (i.e. reaching the end of the beam).

Some investigators (Keogh 1965; Seils 1951) point out that where similarities are found in the results of static and dynamic balance, these are probably due to development in both abilities following a similar course (Espenschade and Eckert 1967).

In summary: kinesthesis is defined by Baumgartner and Jackson (1982:228) as "the ability to perceive the body's position in space and the relationship of its parts". Information about body movement and the relationships between its parts is relayed to the brain by different receptors - proprioceptors - within the body.

Several types of proprioceptors exist in various parts of the body and transmit different types of information; muscle spindles, located within the muscles, supply information about the amount of stretch within muscles; Pacinian corpuscles, situated within the dermis of some regions of the skin (e.g. the soles of the feet), supply information about pressure distribution and possibly postural orientation; Ruffini organs, located within joint capsules, give details about joint angle; Golgi tendon organs furnish information about the amount of tension within a tendon. Although the organs are specialised in function they seldom act in isolation. Several of the receptors could be involved during a single action, and Travis (1945) points out that the dominance of one over the other was impossible to determine. As testing of general kinesthetic sensitivity is not possible, this investigation isolated joint sensitivity as a form of kinesthetic sensitivity index.

This sensory integration is important for motor control, such as that required for balance. Richardson and Tandy (1973) explain that the child needs conscious realization to be able to process sensory information, and that kinesthesis is not an automatic by-product of movement.

Different types of balance have been identified, but those involved in the present study are postural control, static balance and dynamic balance. Several kinesthetic sub-systems involved in the maintenance and control of balance have been identified by researchers (Cratty 1986; Butterworth 1981; Travis 1945; and others).

4. PERCEPTUAL-MOTOR DEVELOPMENT

Each individual is born with genetically determined characteristics and potentials. Experience will, however, determine to what degree the individual comes close to reaching his full potential. It is through experience that the individual learns to control his actions with regard to the demands of a particular environment. Coping strategies are also influenced by phylogenetic factors such as gender, physical condition, age and the maturation of the systems involved.

Several of the terms used in research reports are often confusing and require some preliminary explanation. These are terms such as motor ability, motor behaviour and motor performance.

4.1. Motor ability

The terms "physical ability" and "motor ability" are used synonymously in the various texts. Motor ability is defined as the potential an individual has for motor performance, and as Morris and Whiting (1971) maintain, could place limits on later skill proficiency. Rosentswieg (1980:295) explains that "motor ability represents present status as determined by a particular measure or test". These two definitions appear to describe different aspects, in the sense that the former seems to indicate motor potential, or the innate ability of the individual, whereas the latter appears to be an operational definition for present movement behaviour.

For the purpose of this study motor ability is taken to mean the potential the child may possess for motor performance, as suggested by Morris and Whiting (1971), rather than the child's present status of ability, as suggested by Rosentswieg (1980). Several of the general motor ability tests (as reported by Espenschade and Eckert 1967; Cratty 1970; and others) appear to test performance, but classify it as ability. In this case ability could not have been seen to mean potential, for it is virtually impossible to establish when full potential has been reached.

General motor ability tests have been widely administered to children (e.g. Espenschade and Eckert 1967; Cratty 1970; Corbin

1980), and from these tests norms have been developed according to which children's abilities were measured in order to determine individual status of general motor ability (i.e. the individual child's ability to perform various motor tasks). The concept of general motor ability is however challenged by Bachman (1961b) who reports that individual abilities have been found to be task specific: children may display advanced ability in one area of movement skill while showing limited ability in another. In agreement with this, Singer (1980:181) suggests that ability or skill depends upon a variety of abilities and how they influence success: "Every skill reflects the need for varying degrees of physical, cognitive, motor, and emotional involvement". These various abilities thus develop as the individual matures physically, cognitively, emotionally, and motorically.

Fleishman (1964; in Singer 1980), has researched motor ability extensively and concludes that particular combinations of abilities contribute to motor skill performance; continued practice brings about changes in the combination of these abilities; motor abilities become more important in task performance than non-motor abilities; and task specific factors emerge with practice. Nine factors are regarded by Fleishman as important for physical proficiency: static strength; dynamic strength; explosive strength; extent flexibility; dynamic flexibility; gross body coordination; multi-limb coordination;

and stamina. It is interesting to note that Fleishman does not appear to regard balancing ability as an important factor for physical proficiency. Cratty (1986), Clark and Watkins (1984), and others, regard balance as an important prerequisite for skilful performance.

Balance is seen as a specific ability. Cratty (1986) explains that the ability to balance matures between the ages 3 to 5 years and this leads to an improvement of general motor ability, and the subsequent expansion of movement skills. This is corroborated by researchers such as Clark and Watkins (1984). Ulrich and Ulrich (1985) found balancing ability to be an important predictor of general performance of gross motor tasks in pre-schoolers. Motor ability does not, however, develop naturally and children have to work at developing physical abilities (Terry et al. 1979).

4.2. Motor behaviour

Motor behaviour, which depends to a large extent on motor ability, determines the proficiency of movement performance and is determined by several factors: the maturational level of the child's sensory system; emotional condition; physical status; and the selected response to specific conditions at a given stage of development. Mature movement behaviour indicates that the child has reached the level of maturity in keeping with the norms for a specific stage of development.

It is important at this stage to point out that immaturity in any of the above-mentioned aspects, if not taken into consideration, could affect test results. Factors such as limited attention span, motor memory and self-concept would influence the way in which the child would be capable of coping with the tasks in question. Behaviour could be observed as being immature and impulsive, or mature and controlled.

4.3. Motor performance

Motor performance, on the other hand, is a "relatively short-term aspect of movement behaviour ... considered to be goal centered, purposeful, observable movement behaviour of relatively short duration" (Cratty 1967:10) and is the way in which an individual performs a specific skill. Erbaugh (1984) explained that a complex network of factors influences motor performance. Kinesthetic or motor memory is acknowledged by Barrow (1983) as being a very important factor, but he also emphasises factors such as stress, fatigue, expectancy, and habituation which could have a disorganising effect on performance. Selye (1956) explains that anxiety could cause distortion of kinesthetic perception.

Substantial research has been conducted to determine motor performance in school-aged children (e.g. Espenschade and Eckert 1980; Singer 1980; Milne et al. 1976). There is, however, a lack of published research on the motor performance of pre-school children. Where research has been conducted it has focused on maximum performance in only one or two skills (DeOreo and Wade 1971). Keogh and DeOreo (1980:95) explain that the "focus upon maximum achievement has restricted our view that acquisition of motor control should be a basic focus in the study of motor development".

4.4. **Motor impairment**

A child's motor behaviour is affected by motor impairment, which is explained as "the inadequacy of an individual's physical responses to the everyday demands of his environment" (Whiting 1973:64). This inadequacy in perceptual-motor control is often referred to as clumsiness, and is usually characteristic of children who have difficulty in acquiring and performing even the simplest motor skills (Stott 1966; Morris and Whiting 1971). Motor impairment could be the result of inadequacies in one or several of the processes involved in the child's ability to process information adequately (see the introduction to this chapter).

Cratty (1986:136) explains this when he states that "marked individual differences exist not only in pre-school children's physical abilities, but in the maturity of the mechanics they appear to use when performing various skills".

5. PERCEPTUAL-MOTOR CONTROL

Perceptual-motor control refers to the ability of the individual to integrate and coordinate the various systems involved in skilled movement. To gain control of movement the individual needs to utilise and integrate feedback from the senses in order to select a suitable response for the task to be performed (Singer 1982). For this one relies partially on the memory one has of similar tasks. It must be remembered that ability for gross motor control develops before that for fine motor control.

A discussion of the development of motor control thus demands an examination of the behavioural, physical and neural aspects of movement development. It is however important at this point to revise the nature-nurture dichotomy, in order to assist with the understanding of the aspects mentioned above.

A review of the literature indicated several factors which affect perceptual-motor control. A separate discussion of each of these follows.

5.1. Perceptual-motor learning

The problem of distinguishing between changes which occur as a result of learning and those due to maturation often confronts investigators in the field of motor development (Espenschade and Eckert 1967). This is especially so when dealing with young children.

As the aim of the present investigation is not directly concerned with overt learning, but rather with incidental learning as it manifests itself in the abilities of the subjects in the sample, it is necessary to explain briefly how learning affects motor control.

As already explained, the child needs to gain control over his neuromuscular processes in order to perform appropriate voluntary actions. Williams (1981:32) concludes that all the time spent by young children in trial-and-error practice is an integral part of the learning process, and therefore also of development of the neurological mechanisms which "underlie the ultimate control and refinement of motor skills".

Perceptual-motor learning occurs only where sensory stimulation is present and is responded to motorically. The nature of the sensory stimulation and the effect thereof will depend on the maturational level of the child. Godfrey and Kephart (1965:25) explain motor learning as "any learning directly or indirectly involving the muscular and neuromuscular systems of the body". Pleasants (1971) cautions that in interpreting the above it should be understood that it is patterns of movement that are learnt, and not specific muscle actions. This implies that the integration of kinesthetic cues contributes to the learning of perceptual-motor skills.

One of the most powerful variables in perceptual-motor learning is feedback (Baumgartner and Jackson 1982). The individual gains knowledge of the outcome of his actions from different sources: firstly by means of internal feedback (kinesthesis); secondly, through knowledge of results; and thirdly, from external sources, e.g. formative or summative evaluation by another. (Formative evaluation pinpoints errors during the learning process, while summative evaluation measures the degree of success of the action as a whole.)

Although Schmidt (1988) argues that perceptual-motor learning is not directly observable, the results of learning can be observed in the relatively permanent changes in performance that occur as a result of practice and experience in a particular situation (Cratty 1967; Singer 1982).

5.2. Motor (kinesthetic) memory

If previous experience plays such an important role in determining the ability to learn and perform certain skills, no matter how elementary, it follows that memory is important. Motor or kinesthetic memory refers to the period of retention of specific movements, and is dependent on the efficiency of the perception of kinesthetic cues (Ashby 1983).

Barrow (1983:242) maintains that even the simplest form of performance requires "some temporary storage of information". It appears that some kinds of information are held for very brief periods only, while others appear to be retained for an indeterminate period. The evidence from a great deal of empirical studies led researchers to differentiate between short-term memory and long-term memory. Schmidt (1988:92) illustrates another memory system which has been identified by researchers: the short-term sensory store, which "is thought to be a memory system that serves to hold massive amounts of information presented to it for a brief period of time" through the senses. He goes on to propose that such a system exists for each of the senses, including the kinesthetic sense. John (1967; in Singer 1980:147)) however challenges this view and insists that "stored information is associated with spatiotemporal patterns of organization in enormous aggregates of neurons". Specific neural cells are thus not seen to be associated with the learning of specific movements. This concurs with what was previously said about pattern learning through the integration of kinesthetic cues. Phillips and Summers (1954:468) support the hypothesis that "kinesthesis is more related to learning in the early stages of acquiring a motor skill than it is in the later stages".

Adams (1971) proposes a closed-loop theory of movement in which two independent memory states govern: one termed the perceptual trace and the other the memory. The former is thought to determine the extent of movement and to evaluate accuracy. The perceptual trace, therefore, compares a movement with previous movements. This compares with the concept of kinesthetic memory which appears to be closely related to short-term memory and pertains to recall of the "feel" of a movement or position previously experienced. The kinesthetic memory store was found by Posner (1967) to be susceptible to temporal decay, (i.e. the ability to recall is short-lived). It is suggested that this often happens because of the volume of information entering the short-term sensory store, not much recoding takes place, resulting in loss of ability to recall as new information enters the system (Soren and Starkes 1985/86).

Connolly and Jones (1970) concluded that visual and kinesthetic information are held in separate short-term memory stores, and that the translation from one modality to the other is dependent upon information from an integrated long-term store. Later, however, they found evidence to show that translation of information takes place prior to its placement in the short-term memory store. Laszlo and Bairstow (1985) argue that during all overt actions there is an interplay between memory and the appropriate action. Barrow (1983:243) explains that "all learning is influenced by transfer". The individual naturally draws on previous experience on which to base the action and, as previously shown, the closer the similarity between two skills the easier learning becomes. Ashby (1983) also points out that motor memory improves with rehearsal.

5.3. Selective attention

Essential to both motor memory and learning is selective attention, which Singer (1980:275) describes as "the readiness of the organism at any moment to receive and process information". Stratton (1978:50) proposes three stages of operation in the development of attention: the over exclusive mode, in which children attend "to one aspect of the stimulus or environment to the exclusion of all others"; over inclusive attention, where any stimulus receives attention; and, selective attention, which requires the ability to select only appropriate cues. Selective attention is developed through maturation, experience and learning. Support for this comes from evidence that older children are better able to select relevant cues than younger children (Hagen and Sabo 1967; Pick, Christie and Frankel 1972; Pick and Frankel 1973 - all in Stratton 1978). Stratton believes that pre-schoolers operate in the over exclusive mode and therefore often have difficulty in concentrating their attention on the appropriate stimulus.

5.4. Physical growth

Physical growth characteristics have frequently been used in studies as possible predictors of motor performance. For example, Govatos (1959:339) attempted to determine the relationships and age differences in growth measures and motor skills, and reports that,

> When the individual aspects of growth and organismic age are correlated with each motor skill, the resulting relationships were found to be positive and significant for both boys and girls.

This corroborates the theory (Herkowitz 1980) that gross physical development accompanies the ability to manipulate those parts that have grown. Cratty (1986) presents reports of studies which indicate that the relationship between physical growth and motor performance seems to be more significant in pre-school children than in older children. It is suggested that the reason for this could be that as muscles develop in size and strength so co-ordination becomes more precise (Ausubel et al 1980).

A period of rapid growth in the first eighteen months appears to be followed by spurts of growth which occur at intervals. Shumway-Cook and Woollacott (1985) suggest that between the ages of four and six years there is a period of disproportionate growth which would possibly have an effect on performance. By this is probably meant that different parts of the body grow at different rates and this could possibly lead to difficulty in kinesthetic perception relating to the parts that have grown. This could cause the control of movement to be affected.

5.5. **Age and perceptual-motor control**

Inclusion of a discussion of age as related to control of movement is considered necessary as developmental stages are often discussed in the literature with reference to specific ages rather than to maturational status.

There are so many facets to motor performance (and thus also motor control) that need to be considered when studying young children that purely objective measuring becomes virtually impossible. Years of experience in working with pre-school children has taught the researcher that performance could vary from day to day, with the result that accurate recording of their ability to control movement is very difficult. An understanding of the theory behind age-related changes in perceptual-motor control is therefore essential.

Afferent control (or sensory-perceptual control) leads to economical and coordinated voluntary movements. This is brought about by kinesthetic perception, which is described as "the sensations and perceptions which occur as the result of bodily movement" (DeOreo and Williams 1980:174).

Williams and DeOreo (1980:142) explain the concept of perceptual-motor development as,

> ... one which deals with age-related changes in the child's capacity for exerting more and more refined afferent control over overt motor behaviour.

This is a controversial statement, for as discussed earlier, it is maturity, and not age, which is responsible for changes in behaviour, and therefore, motor control.

Piaget (1929) described the period from birth to two years as the sensory-motor period of a child's development. He postulated that the development of sensory-motor control is dependent on the formation of what he referred to as "schemata" or the development of a "blueprint" (Kagan 1971; in Salkind and Ambron 1987). Schema formation is seen as the beginning of mental organisation: new experiences and the individual's reaction to them is based on knowledge gained from a previous experience of a similar nature. Piaget also identifies the process of assimilation: the ability of the child to incorporate new experiences into existing schemata. The process of accommodation is described as that which occurs when the child is able to modify existing schemata, or adapt movements already mastered to present environmental situations. A certain level of maturity of the various perceptual-motor systems is required for both assimilation and accommodation, or integration and co-ordination.

Research clearly indicates that the first four or five years of a child's life is the period during which development is most rapid. In fact, Cratty (1986:146) describes the period between the ages of three and five years as the "age of skill explosion" - "skill" referring specifically to controlled movement. These years therefore appear to be the time during which the potential for perceptual-motor control presents itself most readily.

5.6. **Maturation**

Arnold Gesell's theory of maturation reiterates Rousseau's emphasis on the "internal control of development" (Ausubel et al, 1980:18). In this context "development" refers to improvement in functional capacity which can be attributed only to structural growth and physiological change. There is no universally accepted definition for maturation. The term is usually used to describe developmental changes that take place without dependance on experience or ontogenetic factors. Behavioural development is ascribed to the maturation of the central nervous system (Coghill 1929; McGraw 1945; in Wade 1976). It follows, therefore, that the maturation of the systems involved in movement, and the amount of practice an individual has in a specific situation will determine the degree of control exhibited in performance.

5.7. Gender differences

During the pre-school years there appear to be few general differences in ability for perceptual-motor control between the sexes (except on an individual basis). However, differences do tend to occur after the pre-school years. Cratty and Martin (1969) found that boys perform better than girls until the age of approximately seven and a half years. This is pertinent here as the subjects used in the present investigation are all below the age of seven years.

Connell (1955:151) suggests that,

> When body size and strength are not important determinants of success in athletic skills, gender differences in performance are considerably less.

One of the few tests of kinesthetic perception in children also revealed no significant differences between the abilities of boys and girls (Witte 1962).

DeOreo and Wade (1971), and Travis (1945) report sex differences in favour of girls in static balance performance. This verifies Connell's (1955) conclusion (see 2.1.5.) about the ability of girls to excel in activities requiring precision and accuracy. Erbaugh (1984) cites similar findings by DeOreo (1975), and Clifton (1978). Cratty (1986:167) explains that,

> These differences may be caused by subtle contrasts in the rate of neurological maturation exhibited by the two sexes, and by the accompanying attentional differences these may bring about.

Cratty suggests that girls tend to have a relatively longer attention span than boys of similar age, which could account for the differences in perceptual-motor control. Boys, on the other hand, were found to exhibit more physical aggression than girls (Salkind and Ambron 1987).

Differences in findings could, once again, be attributed to various factors such as the nature of the tests, and/or the environment and atmosphere in which tests were conducted. Espenschade and Eckert (1967) suggest that not much distinction is made between boys and girls in early childhood, but that where differences are found it is usually due to subjectivity in testing.

6. SUMMARY OF REVIEWED LITERATURE

A survey of the literature concerning balance and kinesthesis also demanded a review of perceptual-motor development and control, especially as it pertains to young children. Despite innate ability, it is clear that factors such as age, maturity and experience have a definite influence on both development and control. It was argued that although maturational status is a more important factor than age, age equivalents are often employed to assist with the identification of the onset and the span of the various stages of development.

Although perceptual-motor development follows two distinct directions which allow for predictions to be made regarding performance possibilities, there is no linear pattern to this development. Instead, it seems to occur in step-like progressions in which performance appears to be less variable once such a step had been reached. Some arguments suggested that between the ages three and six years children usually reach such a plateau, which is possibly the reason for the period of "skill explosion" occurring at about this time in a child's life. Some authors explain that proportional changes occur during a child's life, and that the period between three and six years is one in which disproportionate changes occur, resulting in the necessity for the adaptation of previously learned skills.

Reports concerning behavioural, physical and neural changes occurring in young children were examined in an effort to explain differences in responses to the various tests to be administered. Among others, motivation and selective attention were seen to influence a child's behaviour which is further influenced to a great extent by previous experience. Learning, and especially incidental learning, was explained as one possible reason for differences in ability which, in turn, affects performance. Reports concerning the influence of physical growth and sex differences were studied. Strong positive relationships between growth and perceptual-motor ability were reported, especially among pre-school children. Differences between the abilities of older girls and boys were described: girls were more adept at tasks requiring rhythm and precision (e.g. balance), while boys excelled where strength was required. However, these differences appeared to be less evident in pre-schoolers.

Research which included the three types of balance pertinent to the present study was examined and it was pointed out that balance was one of the first gross motor skills to develop. It was also reported that the kinesthetic sense, which is important for the control of balance, was the first part of the sensory system to develop. It was seen that infants initially rely heavily on kinesthetic cues, but that there is a shift to visual dominance once the visual sense begins maturing.

Since various kinesthetic receptors furnish information about the position of the body and its parts to the perceptive mechanisms simultaneously, it is the ability of the individual to integrate, and select from the available information which helps to control movement effectively. When vision, which has become one of the main control systems in balance, is eliminated, the individual needs to fall back on the kinesthetic senses for feedback about body position. In young children there is a gradual shift from reliance on visual cues back to the utilisation of kinesthetic cues in conjunction with other cues, such as those received through vision. Some youngsters appear to rely heavily on visual feedback for balance control and it would appear that this is because they have not yet developed the ability to fall back on kinesthetic cues for control. Thus, they find balancing with their eyes closed unfamiliar and difficult. Therefore the maturity of the sensory system depends more on the ability to integrate and coordinate cues from the various receptors than on the maturity of the nerves per se.

Cratty (1986) suggests that studies to determine the systems involved in balance, especially in young children, are essential for an understanding of their behaviour. There is clearly a need for the present study because, (although kinesthesis is seen as an important aspect of balance) no evidence could be located in the literature which indicated that the relationship between the two had as yet been investigated, especially in pre-school children.

CHAPTER THREE

DESIGN OF THE STUDY

> Most of us, as children, experimented with our sensory adjustments in relation to gravity, and discovered other receptor systems in our heads. We stood on the lawn with arms outstretched and whirled like dervishes until we could remain upright no more.
>
> Milne and Milne (1965:204).

1. INTRODUCTION

As stated previously, the purpose of this investigation was to attempt to determine whether there is a positive relationship between kinesthetic sensitivity and balancing ability in young children. Three hypotheses were presented in this regard:

that there is:

1 a positive linear relationship between scores on tests for kinesthetic sensitivity and balancing ability;

2(a) a positive linear relationship between scores on tests for kinesthetic sensitivity and balancing ability when considered separately for the various age groups;

2(b) a positive linear relationship between age and scores on (i) kinesthetic sensitivity tests; (ii) static balance tests and (iii) dynamic balance tests.

3(a) a positive linear relationship between the scores of the girls on kinesthetic sensitivity and balance tests;

3(b) a positive linear relationship between the scores of the boys on kinesthetic sensitivity and balance tests.

This chapter presents a brief synopsis of the reasons behind the study and sets out to give the rationale behind the choice of test items. The bulk of the chapter covers detailed information concerning the subjects, pre-testing selection, test equipment and test items, as well as the test and statistical procedures employed.

The literature review showed that there is clearly no general kinesthetic sense, but that various kinesthetic systems are important for the control of movement and balance. It has been suggested that the kinesthetic senses are among the first senses to develop and that balance is one of the first gross motor abilities to develop in young children.

The fact that both the kinesthetic senses and balancing ability appear to develop early in a child's life could indicate that accurate perception of kinesthetic cues are essential for the development of balance control. French and Horvat (1985/86) suggest that balance is an element of kinesthesis. Despite these claims, reports on investigations into the relationship between the two - especially where young children are concerned -are lacking.

The present study was designed in an attempt to furnish some information, and enhance further understanding of, the development of young children, especially where kinesthetic sensitivity of joints and their balancing ability are concerned. The isolation of the hip and shoulder joints, in this study, was not intended to suggest that this would be an indication of general kinesthetic sensitivity, but merely to examine one of the kinesthetic systems and its possible relationship to balancing ability.

Items previously tested for reliability and validity by other researchers were carefully examined regarding their suitability for use in the present study. Where necessary minor changes were made in order to render them suitable for testing young children. As norms have not yet been established for a study of this nature the choice of test items and the design of the test battery were done without any statistical considerations.

2. SUBJECTS

Subjects were drawn from a group of white pre-school boys and girls participating in a Movement Development Programme in Grahamstown. In addition three volunteers from local pre-primary schools also participated, thus constituting a convenience sample (Cohen and Manion 1985) rather than a random sample. Age groups were as follows: the three-year age group consisted of children aged three but not yet four years; the four-year group consisted of children aged four but not yet five years; etc. Ages ranged from three years and one month to six years and two months. As it was not the aim of this investigation to set norms, any age and/or sex advantages presented by the various items were considered unimportant.

Sixty children initially participated in the test. The study required that the whole battery should be completed by each subject. Nine of these subjects either did not complete all the tests, or scores had to be disregarded for one reason or another. Ultimately the scores of 51 of these children could be used in the investigation.

Written consent was received from all parents after the purpose of the study was explained to them and the assurance given that their children would not be subjected to any form of stress or discomfort. The subjects were all integrated into the programme before they were tested, in order for the researcher to gain their confidence and trust. None of the subjects participated in the tests without their personal consent.

No physical disabilities could be observed, nor were any reported by parents. Subjects had had no prior training in any of the tasks employed in the test items. All subjects were required to be barefoot and were dressed in clothing which would not restrict movement in any way, especially at the shoulder and hip.

3. DEVELOPMENT OF THE TEST BATTERY

Several researchers have hypothesised about the need for, and the importance of, kinesthesis, especially as it pertains to skill learning. In an attempt to ascertain whether or not this hypothesis holds, a number of independent researchers have developed kinesthetic tests. Although previous test batteries were designed mainly for adults and older children, some of the items contained in them allowed for adaptations which made them suitable for use with pre-school children.

The tests for the present study were developed after studying the work of Cratty (1986); Cotton and Lowe (1974); Marteniuk et al. (1972); Witte (1962); Scott (1955); Phillips and Summers (1954); Roloff (1953); Young (1945); Bass (1939); and others. Test items which have been found to be both valid and reliable were chosen, where at all possible, for use in the present study. In several cases however adaptations and modifications needed to be made to suit the age range of the present sample. All test items were developed in accordance with their practicality as testing tools, their feasibility of construction and their adaptability to the pre-school level. Where necessary, scoring methods were also changed, to conform with others used in the test battery.

The fact that no standardised tests exist against which results could be tested is seen as a weakness in the present testing design. Although a pilot study was conducted in an attempt to determine the acceptability of changes and adaptations needed to suit the present sample, a need exists for standardisation of a test battery suitable for investigations of a similar nature. Standardisation and the setting of norms for such a test battery was not the aim of this study.

3.1. **Sampling**

Subjects were obtained mainly from an organised Movement Development Programme plus a few volunteers from local pre-primary schools. The use of such a convenience sample (Cohen and Manion 1985) has been identified as a limitation of the study, as it is not representative of a total population. As it was not the aim of the investigation to make generalisations or to set norms, any age and/or sex advantages presented by the various items were considered unimportant.

3.2. **Test battery**

An item analysis was carried out on those items employed in the pilot study. Minor changes were made where necessary and a test battery, consisting of six items, was developed. Kinesthetic sensitivity was tested at the shoulder (SHOULDER) and hip (HIP); static balance was tested on a Balance Board (BALBOARD) and on a Balance Stick (STICKBAL); and dynamic balance was tested on a Balance Beam (BEAMWALK) and on Stepping Stones (STSTONES). (For the purpose of statistical computation these tests were coded as indicated in brackets.)

3.2.1. **Kinesthetic Sensitivity Tests (SHOULDER and HIP)**

The Arm Raising Test, as described in several reports was considered a valid and reliable test for kinesthetic sensitivity at the shoulder joint (Scott 1955; Witte 1962; Phillips and Summers 1954; Marteniuk et al. 1972; Young 1945).

Although past studies have been conducted mostly on adults and older children the researcher found this particular test item and the administration of it to be easily adapted for pre-school children. Witte (1962) conducted one of the few kinesthetic tests on children (aged 7 to 9 years) in which she attempted to determine the relationship between kinesthetic perception and bowling ability. She reported a reliability of .908 for this specific test and recommended its use in tests for kinesthetic sensitivity. This specific test was chosen following the argument of Phillips and Summers (1954) that side arm movements (abduction) are common to everyday activities and especially in the control of balance.

Variations of the Hip Sensitivity Test (hip abduction) were used by most of the above researchers. The difference between the described tests and that in the present study was that all the previous tests appear to have been done while the subjects were lying on their sides and abducting the uppermost leg, while in the present test the subjects did not lift the leg against gravity, but rather abducted the hip while lying on the back. The reason for this change was to attempt to avoid tasks which would tire the subjects and possibly act as a demotivating factor and have a negative effect on the performance. In previous tests an angle of abduction of 20°, from starting position, was used. During the pilot study it was found that this angle appeared to be too small for accurate perception by the subjects. The most accurate reproductions were found to be at the 40° angle.

Measuring for both the above tests was done by observing the deviation from the criterion position to the nearest degree.

3.2.2. **Static Balance Tests (BOARDBAL and STICKBAL)**

A modified Bass Stick Test, adapted from tests reported by Bass (1939); Wiebe (1954); Roloff (1953); and Young (1945), was used as one test to measure static balancing ability. This test was recommended by Young as a suitable instrument to be used in research involving static balance and kinesthesis. An adaptation was made: subjects were required to place both feet lengthwise on the stick, rather than one-legged balance as used in most of the above tests. This was decided on after considering the warnings of Cratty (1986) and DeOreo and Keogh (1980), that young children should rather be tested for static balance with both feet on the support surface. Cotten and Lowe (1974) conclude that the difficulty of the one-legged balance test used in their study could have caused the floor effect which occurred among three- and four-year-olds. This floor effect appears to describe the inability of the three- and four-year-old subjects to score on the test.

In previous studies scores were measured by the number of seconds the subjects could maintain a balanced position on the balance stick. In the present study the number of errors, within a fifteen second period, were counted. This was done in order to maintain uniformity (of error scores) throughout the battery (see Appendix C).

The Balance Board, in the present battery, resembles the Teeter Board used by Cotten and Lowe (1974) and DeOreo (1971; in DeOreo and Keogh 1980), except that the board was slightly bigger than that used in this study. Scores for each trial were calculated by counting the number of times the board touched the floor in a fifteen second period.

The above tests have been used both as balance measures and in kinesthetic tests (Scott 1955; Young 1945; and others).

3.2.3. Dynamic Balance Tests (BEAMWALK and STSTONES)

The Beam Walk Test used in the present study was similar to that described by DeOreo and Keogh (1980), except that only one beam was used, and the beam was not divided into quartiles. This was considered unnecessary for the present investigation, as performances on different widths of beams were not being compared.

The Bass Stepping Stone Test used by Drowatsky and Zuccato (1967), consisting of blocks marked on the floor in a zigzag formation, was found unsuitable for the present study. This would, of necessity, have had to involve vision. Were vision excluded, the test would have involved motor memory rather than balancing ability and kinesthetic sensitivity. Kelso, Goodman, Stamm and Hayes (1979; in Ashby 1983) conclude that young children maintain motor information for brief periods only (seven seconds). The present Stepping Stone Test also differed from the original in that it consisted of stone tiles, arranged in a straight line, and could be felt by the subjects' feet. Therefore, this test required the utilisation of the cutaneous receptors (Pacinian corpuscles) under the feet, a certain extent of recall concerning the distance the stones were set apart and dynamic balancing. The number of times either of the subjects' feet touched the floor was counted as an error (see Appendix C).

4. TESTING EQUIPMENT

Two different types of equipment were used for each of the above sections:

KINESTHETIC SENSITIVITY	-	SHOULDER
	-	HIP
STATIC BALANCE	-	BALANCE BOARD
	-	STICK BALANCE
DYNAMIC BALANCE	-	BEAMWALK
	-	STEPPING STONES

4.1. Kinesthetic sensitivity to joint movement and position

4.1.1. Shoulder Sensitivity Test: a measuring board 80 x 160 cm, produced from 0,5 cm masonite and reinforced at the back with 0,5 by 5 cm wooden strips, to prevent warping. An arc with a radius of 80 cm was constructed on the face of the board. The 0° point was marked at the bottom and the 180° mark at the top of the semi-circle, closest to the standing position. Radii were constructed at each ten degree mark, and along the perimeter of the arc each degree was clearly marked. Two guards, consisting of boards measuring 30 by 20 cm were attached to the board, along and 8 cm from the base line of the arc, in order to standardise the position of the subjects in relation to the board and to eliminate vision during testing. A rigid pointer (80 cm long) was attached to the centre of the base line of the arc by means of a frictionless pivot, and an adjustable arm band allowed the subjects' arms to be secured to the pointer. The free end of the pointer was aligned with the line of the arc. This board was suspended from a wall by a system of pulleys, hooks, and window cord, anchored by means of a cleat hook, thus being adjustable to the varying heights of the subjects (Figure 2). (Adapted from Phillips and Summers (1954), Scott (1955) and Witte (1962).)

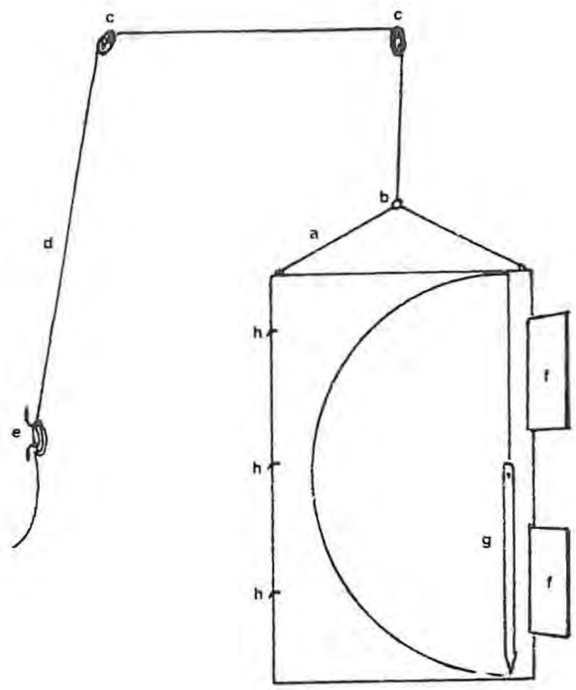

Figure 2. Board for measuring kinesthetic sensitivity at the shoulder

a. harness
b. ring joint
c. pulley
d. window cord
e. cleat hook
f. blinker guards
g. pointer
h. stabilising hooks

4.1.2. **Hip Sensitivity Test:** a measuring board similar to the one described above, but without the guards, was constructed on firm board. A pointer consisting of a sharpened dowel, was attached to the subject's leg by means of two adjustable bands (one at the ankle and one at the topmost end of the pointer). This allowed for accurate readings, as the blackened tip of the pointer was always placed so that the sharpened end pointed exactly on the line of the arc. The dowel was padded to within 10 cm of the pointed end, in order to avoid any discomfort to subject when it was secured to the leg.

4.2. Static balance

4.2.1. **Balance Board Test:** a balance board, stopwatch, and score sheet. The balance board was constructed by affixing a 5 x 6 x 31 cm length of wood (pivot bar) across the centre of a fibre board platform measuring 62 x 31 cm. A line 0,5 cm wide was drawn through the centre (pivot point) on the upper surface of the board.

4.2.2. **Balance Stick Test:** a "balance stick", stopwatch, and score sheet. The balance stick consisted of the above balance board placed upside down. This resulted in the pivot bar forming a balancing surface of 5 x 31 cm, 6 cm high.

4.3. Dynamic balance

4.3.1. **Beamwalk Test:** a low balance beam (surface 5 m x 10 cm), mask, stopwatch, and score sheet. Landing mats were placed below the low beam, which resulted in the height from the walking surface to the mats being only 16 cm.

4.3.2. **Stepping stones test:** six stone paving tiles measuring 16 x 13 x 2 cm each were placed in a straight line, 14 cm apart. The mask, and score sheet formed part of the equipment.

5. RECORD SHEET

A record sheet was used for each individual subject. The following demographic information was included: subject's name, age, sex, and date of testing. Space was allowed for recording five responses in each test. At the bottom of the score sheet, space was left for comments on individual performance. Each response of the subject was immediately noted in the appropriate column provided on the score sheet (see APPENDIX A).

6. TESTING PROCEDURE

6.1. Pilot study

A pilot study was conducted in order to standardise testing procedures, to determine the reliability of equipment, to establish a scoring system, and to determine the objectivity of the scoring for the present study. Eight subjects, one boy and one girl from each of the age groups, were selected for participation in the pilot study. These children were not involved in the main study.

During the pilot study, each subject was given four trials on each of six test items: shoulder abduction, hip abduction, balance board, balance stick, beam and stepping stones. Both right and left arms and legs were tested for joint sensitivity. Most of the subjects appeared not to have established a preference for left or right handedness and where they had, right handedness appeared to be predominant. It was therefore decided to test right sides only, as these scores tended to be more consistent throughout the pilot study.

Where necessary, minor changes were made to methods, equipment and scoring procedures and the process repeated. Scores were recorded once tests and procedures were established. Two scorers were initially used, but it was ascertained that more than one scorer was superfluous, as scoring was totally objective and all testing equipment allowed for accurate readings. Both scorers recorded identical measures of performance for all eight subjects.

6.2. Main study

All tests were administered by the researcher on a one-to-one basis, in a controlled environment. Each subject was tested on the whole battery over a period of approximately 20 minutes. Practice trials were allowed for each test, so that subjects could familiarise themselves with the equipment and the procedures. The tester praised each effort, in an attempt to motivate subjects to maintain an interest in the tasks.

7. TASKS

Each subject was expected to complete five trials on each of the following six tasks:

7.1. Shoulder Sensitivity Test (SHOULDER)

Subjects were required to stand next to the measuring board so that the board might be adjusted to each individual shoulder height. The right arm was placed through the space allowed by the guards on the board and the arm was secured to the pointer. A subject stood with his back and head against the wall in order to eliminate visual location of the arm position. The arm was abducted by the tester to a position 90° from the starting position of 0°. The subjects were asked to hold the arm in that position, then to lower it to the starting position. The arm then had to be abducted by the subject to the 90° mark and lowered to the starting position. This allowed for determination of the ability of each subject to discern the amount of angular displacement at the shoulder joint. The error, to the nearest degree, was recorded on the score sheet immediately after each attempt. Five trials were allowed per subject.

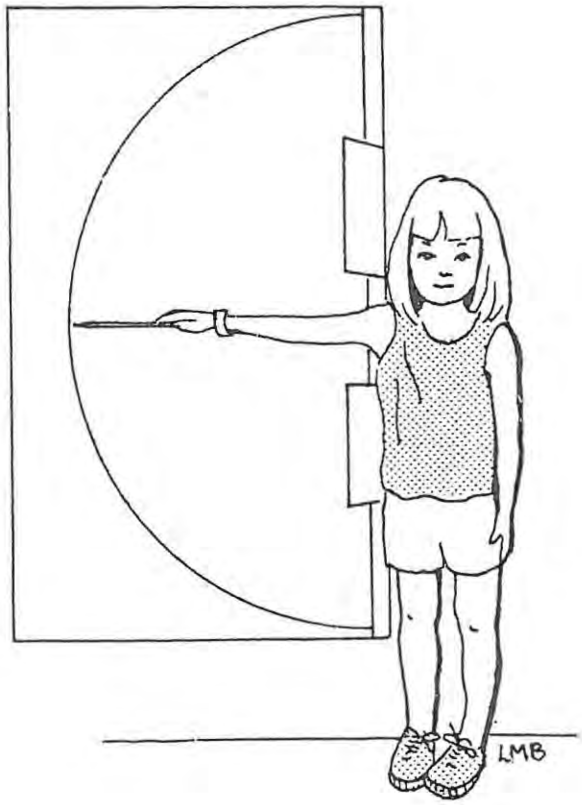

Figure 3. Performance on the Shoulder Sensitivity Test.

As explained above, the right arm only was tested. Laidlaw and Hamilton (1937) found that there was no significant difference in scores between the preferred arm and the non-preferred arm in similar tests (see Figure 3).

7.2. **Hip Sensitivity Test (HIP)**

Subjects were required to lie in a supine position on a mat and the measuring board was placed on the right side with the centre point of the arc directly beneath the hip joint. The pointer was secured to the leg. The tip of the pointer was placed on the exact 0° mark then the leg was moved by the tester to the 40° mark. Subjects returned the leg to the starting position and abducted it to the target mark again while being guided until the criterion position was reached. This was repeated twice. Five trials followed immediately and scores were recorded as in the previous test. Again only the right leg was tested.

7.3. **Balance Board Test (BOARDBAL)**

While the tester supported the board, subjects were asked to place their feet as close as possible and on either side of the centre line. The mask was placed over the subject's eyes and once a balanced posture was achieved the stopwatch was started. The number of times the ends of the board touched the floor during a 15 second period were counted and noted on the score sheet for each trial. Each touch was counted as an error. After each attempt the subject was allowed to dismount, then remount for the next attempt. Five trials were given to each subject (see Figure 4).

Figure 4 Performance on the Balance Board Test.

7.4. Balance Stick Test (STICKBAL)

Subjects were asked to place one foot forward on the surface of the bar, and the other foot behind it, in a heel-to-toe position. Once the feet were both on the surface the stopwatch was started and the number of times either of the subject's feet left the balancing surface, during a 15 second period, was noted. The subject dismounted after each trial. A total of five trials were given per subject.

7.5. **Beamwalk Test (BEAMWALK)**

Figure 5 A typical performance on the Beamwalk Test (sideways shuffle).

Subjects were asked to stand on the end of the beam, then the "blindfold" mask was fastened on. As the subject started to walk the stopwatch was started and was stopped as the end of the beam was reached. The tester walked next to the subjects to assure them that they would be prevented from falling. The number of times balance loss occurred and the time taken was noted for each attempt. Balance loss was judged to have occurred when a subject either stepped off the beam or placed a foot in a position which would have led to falling off the beam. (See Figure 5.)

7.6. Stepping Stones Test (STSTONES)

Subjects were given three opportunities for walking from one end of the stepping stones to the other using vision after which the mask was placed in position and the walk had to be repeated. Each time a foot touched the floor it was counted as an error and at the end of the trial this error score was noted on the score sheet. Five trials were given.

8. SCORING PROCEDURES

8.1. Shoulder Sensitivity Test

The number of degrees between the final position of the subject's arm and the 90° criterion position was noted, to the nearest degree, for each trial. Each degree of deviation was taken as one error. The total number of errors was calculated for the five trials.

8.2. Hip Sensitivity Test

The number of degrees between the final position of the subject's leg and the 40° criterion position was noted, to the nearest degree, for each trial. Each degree of deviation was taken as one error. The total number of errors was calculated for the five trials.

8.3. **Balance Board Test**

Each time the board touched the floor within a fifteen second period, was counted as one error. The number of errors for each trial was noted. The total number of errors was calculated for the five trials.

8.4. **Balance Stick Test**

Each time the subject lost control of balance in a fifteen second period it was noted as an error. The total number of errors was calculated from the five trials.

8.5. **Beamwalk Test**

Each time a subject lost his balance while traversing the length of the beam, was counted as an error. The time each subject took to complete the task was noted. Due to the varying methods subjects adopted for this, a specific factor was allocated to each method according to an estimated degree of difficulty:

Insisting on maintaining contact with the tester (f 1),
Using a sideways shuffle (f 2),
Shuffling forward with one foot leading (f 3),
Walking normally (f 4).

The following formula was used to arrive at final scores:

$$\frac{\text{Time} + \text{no. of errors}}{\text{factor}}$$

e.g. for a subject using a forward movement with one foot leading (shuffle):

$$\frac{36 \text{ seconds} + 6 \text{ errors}}{\text{factor } 3}$$

$$= \frac{42}{3}$$

Final number of errors $= 14$

The obtained score was multiplied by five to give the total score for the test.

During the pilot study it was clear that those subjects who insisted on the tester holding onto them, or who used the sideways or forward shuffle had a distinct advantage over those walking normally. Four of the older subjects were asked to perform the task using the four methods consecutively. Results showed that on average twice as many errors were made using the sideways shuffle as when the tester held onto the subject; three times as many errors occurred when the forward shuffle was used and errors appeared four times more frequently in the normal walk.

8.6. Stepping Stones Test

The number of times a subject lost his balance or missed the stones was noted for each trial. The total number of errors was calculated for the five trials. A similar factor allocation such as the above was not required as subjects all employed the same method for traversing the stepping stones.

An attempt was made to eliminate errors in test scores as far as possible by:

1. ensuring that all test items were carefully selected to represent a sample of those that could possibly be used to measure the variables being tested in this study;
2. testing each subject on the whole battery in a single session, thus avoiding the possible influence of the time factor;
3. ensuring that all subjects were tested in the same environment, by the same tester using the same test instructions;
4. ensuring that all tests were administered using identical scoring methods and times.

Possible errors could, however, have been caused by subjects being initially nervous of the exercise or not being sufficiently motivated. The possibility of sensitisation to the test items over the five trials can also not be ruled out (Walsh and Betz, 1985).

The method of scoring in the Beamwalk test was carefully formulated by the researcher, but may have had some skewing effect on these scores.

All scores were calculated by noting the number of errors and therefore the smaller the subject's total score on each item, the better his performance.

9. STATISTICAL PROCEDURES

In order to stabilise the variation of the scores raw scores were converted to T-scores (Cohen & Holliday 1979). Using the T-score as standard score was decided upon because both the Hull scale and the Z-score method would have yielded negative scores, which would not have been suitable for analysis in the present study.

Hypothesis 1 stated that there is a positive linear relationship between kinesthetic sensitivity and balancing ability in pre-schoolers. Pearson Product-Moment correlation coefficients were computed to determine relationships between test scores:

(a) SHOULDER and STICKBAL;
(b) SHOULDER and BOARDBAL;
(c) SHOULDER and BEAMWALK;
(d) SHOULDER and STSTONES;

(e) HIP and STICKBAL;

(f) HIP and BALBOARD;

(g) HIP and BEAMWALK;

(h) HIP and STSTONES:

Hypothesis 2 stated that there is a positive linear relationship between (a) scores on tests for kinesthetic sensitivity and balancing ability when considered for the various age groups and (b) age and scores on (i) kinesthetic sensitivity tests, (ii) static balance tests and (iii) dynamic balance tests. Pearson Product-Moment correlation was used to compute the relationship between age (in months) and the scores on the various tests. Correlations were also computed to determine the relationships between scores in the different age groups.

Hypothesis 3 stated that there is a positive linear relationship between (a) the scores of girls on kinesthetic sensitivity and balance tests and (b) the scores of boys on kinesthetic sensitivity and balance tests. Tests were the same as those listed above.

Pearson Product-Moment correlation was computed to test the two hypotheses. A t-test was carried out to determine whether there were any significant differences between the mean scores of the girls and the boys on the various test items.

10. SUMMARY

The developmental characteristics of children aged between three and six years necessitated the careful planning and construction of tests and testing procedures. Although this investigation dealt mainly with perceptual-motor development, the cognitive, emotional and social aspects of the sample's developmental status had to be considered when tests were designed and procedures determined.

Subjects were recruited from a local Movement Development programme and a local pre-primary school. It was found necessary to obtain permission not only from the parents, but also from the subjects themselves to participate in the study.

No reports of similar investigations, which could serve as guidelines, could be located. Test items, equipment and scoring methods were selected for suitability in testing pre-school children, and were based, where possible, on tests carried out by previous researchers. Test equipment was constructed for maximum scoring accuracy and simplicity of use. After the pilot study, the original testing equipment was slightly altered and scoring techniques adapted, where necessary. These changes were found to be acceptable in that reliability of equipment and scoring procedures was improved.

The battery consisted of six tests: two for measuring kinesthetic sensitivity; two for measuring ability in static balance; and two for measuring ability in dynamic balance. Individual record sheets were kept for subjects' scores.

Subjects were familiarised with the equipment and tasks prior to testing. A happy, playful atmosphere was maintained during testing sessions in order to motivate the subjects to do their best on all the tests. Subjects were also praised, encouraged and reassured throughout the testing session in an attempt to maintain attention and motivation levels.

Five trials were given on each test. Where necessary, subjects were allowed to go through the motions of a test without a blindfold, prior to being tested. Raw scores for each item consisted of the total number of errors a subject scored on the five trials.

A detailed description of statistics and statistical procedures employed follows in Chapter Four.

CHAPTER FOUR

RESULTS OF THE STUDY

Since the days of Comenius we have been urged by the great educators to watch children, to notice what they do and how they do it and to base education on our observations so that time, energy and effort are not wasted.

Ash and Rapaport (1970:12)

1. INTRODUCTION

The aim of the study was to determine (1) whether or not linear relationships existed between kinesthetic sensitivity and balancing ability in pre-school children; (2) the influence of age on performance, and (3) the influence of gender on performance.

The reliability and validity of the proposed tests were computed from scores obtained in a pilot study. This was, however, not an attempt to standardise tests or testing procedures, nor to set norms for general use.

For the purpose of the main study fifty-one pre-school children were each given five trials on each of six tests: two to measure shoulder and hip sensitivity; two to measure static balance performance; and two to measure dynamic balance performance. The total number of errors on each test was computed for each subject. The minimum number of errors was zero (0), but no limit was placed on the maximum number of errors (see score sheet APPENDIX A). So the lower the total score on each test, the better the performance of the subject. Raw scores were converted to T-scores in order to stabilise the variation of the scores (APPENDIX C).

A Pearson Product-Moment Correlation was computed to determine the relationships between pairs of scores.

2. DISTRIBUTION STATISTICS

2.1. Age distribution

The average age of the subjects was 53.64 months (4.47 years). There was not an equal distribution between the different age groups within the sample. Table I represents the distribution of subjects in each of the age groups.

TABLE I Numbers in each age group represented as a percentage of the total sample.

n	age intervals	age group	% of sample
10	36 - 47 months	3	19.61
16	48 - 59 months	4	31.37
16	60 - 71 months	5	31.37
9	72 - 83 months	6	17.65
51			

2.1.1. Mean scores

Mean scores were computed for each age group on the six tests in the battery so that comparisons could be drawn between their performances.

Table II represents the mean scores (T-scores) for the various age groups on each of the six test items. (See means plots in APPENDIX D 1 to 6.)

TABLE II Inter-age mean scores on the six tests.

Age	SHOULDER	HIP	STICKBAL	BOARDBAL	BEAMWALK	STSTONES
3yrs	57.00	52.69	54.47	53.55	55.47	60.22
4yrs	48.82	50.34	49.06	50.88	48.45	49.85
5yrs	47.68	48.01	51.62	49.96	50.96	45.72
6yrs	46.14	47.60	43.33	44.79	44.98	46.52

Remembering that lower scores indicate better performance, it can be seen that performance appears to improve with age in all but two of the tests. On the Beamwalk Test the five-year-olds made more errors than the four-year-olds. The six-year-olds average more errors than the five-year-olds on the Stepping Stones Test.

In order to determine whether significant differences existed between the means of the different age groups in each test one-way Analysis of Variance (ANOVA) was computed.

TABLE III ANOVA between scores for the different age groups.

	Scores	F ratio	p-value
1.	SHOULDER	2.521	.0692
2.	HIP	0.508	.6784
3.	STICKBAL	2.391	.0805
4.	BOARDBAL	1.312	.2816
5.	BEAMWALK	2.051	.1195
6.	STSTONES	6.384	.0010

The resultant p-values (Table III) for age vs. test scores (1 to 5) are all >0.05, which signifies no significant differences in the mean scores between the different age groups. The p-value of 0.0010, for ANOVA for mean scores on the Stepping Stones Test and age, is <0.05 and indicates that there was a significant difference in the mean scores between the different age groups on this specific test only. (See means plots Appendix D.)

2.2. Distribution of the sexes

Table IV represents the percentages of boys and girls in the total sample.

TABLE IV Ratio of sexes presented as percentages.

n	gender	% of sample
29	boys	56.86
22	girls	43.14
51		

Although a greater number of boys participated in the study the difference was not significant (z statistic 0.9802, p-value 0.3365). There was however a significant imbalance between the ratio of boys to girls when the age groups were separated (see Table V.)

Differences in the ratio of boys to girls in the various age groups did not appear to influence results to a great extent and would probably only have had a negative impact on the results if it were found that there was a significant difference between the performance of the different sexes.

TABLE V Ratio boys to girls (in each age group) presented as percentages.

Age group	Boys	Girls
36 - 47 months	70.00%	30.00%
48 - 59 months	31.25%	68.75%
60 - 71 months	62.50%	37.50%
72 - 83 months	77.78%	22.22%

2.2.1. Differences in scores between boys and girls

Using the T-scores, the means for boys and girls were computed separately for each item in the battery (Table VI). This was done in an attempt to determine the overall differences in performances between the sexes.

It should be taken into account that as scores were made up of the number of errors made by subjects on each test, lower scores indicate better performance.

With the mean T-score for the total sample at approximately 50 Table VI shows that the girls in the present sample generally scored slightly better than the boys on most tests. Exceptions occurred on the Board Balance and Stepping Stones Tests, where the boys' average scores were slightly better than those of the girls (Appendix E, Figures 1 to 6).

TABLE VI Comparison of mean scores between boys and girls.

	Boys & girls	Boys	Girls
SHOULDER	49.60	50.68	48.16
HIP	49.59	49.90	49.17
STICKBAL	49.91	50.80	48.75
BOARDBAL	50.04	49.60	50.62
BEAMWALK	50.00	51.96	47.42
STSTONES	50.00	49.17	51.12

Generally separate mean scores for boys and girls differed very slightly from the total mean. A t-test was computed for each independent sample to establish whether mean scores differed significantly between boys and girls. It was assumed that no significant differences would exist between the average performance of the girls and boys on the different tests.

As the obtained t values shown in Table VII are smaller than the tabled values (at $p < 0.05$ and $p < 0.01$) it can be accepted that there are no significant differences between the average performance (on kinesthetic sensitivity, static balance and dynamic balance tests) of girls and boys in the present sample.

TABLE VII Computed t-statistics for test scores of boys and girls.

Test	Difference between means	t-statistic *
Kinesthesis		
SHOULDER	2.52	0.87
HIP	0.73	0.24
Static balance		
STICKBAL	2.06	0.73
BOARDBAL	1.02	0.36
Dynamic balance		
BEAMWALK	2.28	1.63
STSTONES	1.95	0.69

* Tabled t-values for df 49 at $p < 0.05 = 1.684$ and at $p < 0.01 = 2.4065$

3. RELIABILITY AND VALIDITY TESTING

A pilot study was essentially carried out to establish the validity and reliability of test data, but primarily to test the suitability of test equipment and to eliminate procedural problems which may have arisen during data collection.

Split-half correlation (r), using odd and even scores (Appendix B), was computed for the final scores of the pilot study by means of Pearson Product-Moment Correlation. This was an attempt to test reliability of the proposed items.

TABLE VIII Results of split-half reliability test on pilot study results.

TEST	split-half r
SHOULDER	.9219
HIP	.9302
STICKBAL	.9145
BOARDBAL	.8661
BEAMWALK	.9468
STSTONES	.9913

The equipment, tests, scoring and testing procedures, developed for the pilot study, were thus found to be reliable and acceptable for the purpose of testing the variables used in the study.

To test the reliability of items within the final battery the Product-Moment correlation coefficient between the total score for the odd test trials (3 and 5) and the total score for the even test trials (2 and 4) was computed (see Appendix B). This method is recommended by Baumgartner (1969) as an accepted means for determining consistency or repeatability of the tests.

The coefficient of determination or reliability coefficient was calculated by determining r^2 and expressing it as a percentage (Kerlinger 1973). This indicates the percentage of the total variance the two sets of scores had in common (see Table VIII).

The relatively high correlations between the pairs of scores ($p < .01$) attained by the subjects indicated that there were no significant differences between the performance on odd and even trials. The coefficients of determination calculated from the coefficients ($r^2 \times 100$) suggested that the pairs of variables shared between 82.25% and 99.34 % of the total variance.

TABLE IX Percentage variance common to the two sets of scores.

TEST	observed r	r^2	percentage variance
SHOULDER	.9069	.8225	82.25%
HIP	.9599	.9214	92.14%
STICKBAL	.9927	.9855	98.55%
BOARDBAL	.9922	.9845	98.45%
BEAMWALK	.9967	.9934	99.34%
STSTONES	.9880	.9761	97.61%

Walsh and Betz (1985) claim that the validity coefficient could be determined by calculating the square root of the reliability coefficient (r). Young (1945) used the method of stepping up the resulting correlation coefficients from odd-even scores by means of the Spearman-Brown formula. Both the above calculations were applied to the obtained coefficients and the resulting validity coefficients can be seen to differ very slightly (see Table X).

According to the values in Table X the tests all appeared to have given valid measures of the various abilities they set out to test.

TABLE X Validity coefficients obtained from r and stepped up by means of the Spearman-Brown formula.

	reliability coefficient (r)	validity coefficient (r)	Spearman-Brown $\frac{2r}{1+r}$
SHOULDER	.9219	.9602	.9594
HIP	.9302	.9645	.9638
STICKBAL	.9145	.9563	.9553
BOARDBAL	.8661	.9306	.9282
BEAMWALK	.9468	.9730	.9727
STSTONES	.9913	.9956	.9956

4. RESULTS REGARDING THE FIRST HYPOTHESIS

The first hypothesis stated:

> there is a positive linear relationship between kinesthetic sensitivity and balancing ability.

In the context of this study kinesthetic sensitivity refers specifically to sensitivity of the shoulder and hip joints.

Balancing ability refers to performance on two static balance tasks and two dynamic balance tasks.

It was the purpose of this study to determine whether a relationship existed between kinesthetic sensitivity at the hip and shoulder joints and balancing ability (and the nature of this relationship) in the sample of pre-school children. For this purpose Pearson Product-Moment Correlation coefficients (r) were computed between the following pairs of test scores:

SHOULDER SENSITIVITY AND STICK BALANCE \
STATIC BALANCE
SHOULDER SENSITIVITY AND BOARD BALANCE /

SHOULDER SENSITIVITY AND BEAMWALK \
DYNAMIC BALANCE
SHOULDER SENSITIVITY AND STEPPING STONES/

HIP SENSITIVITY AND STICK BALANCE \
STATIC BALANCE
HIP SENSITIVITY AND BOARD BALANCE /

HIP SENSITIVITY AND BEAMWALK \
DYNAMIC BALANCE
HIP SENSITIVITY AND STEPPING STONES/

TABLE XI Correlation matrix for all scores.

	STICKBAL	BOARDBAL	BEAMWALK	STSTONES
SHOULDER	.0265	.0663	.1980	.2848
HIP	-.1452	.1903	.1440	.0992

Among the eight correlations between kinesthetic sensitivity and balancing performance (Table XI) the only statistically significant correlation, at the .05 level, is that between the scores on the Shoulder Sensitivity Test and the Stepping Stones Test (.2848). Although the value is statistically significant it is so low that it possesses little or no predictive value. In this case only 8% (r^2 x 100) of the variation in the one test could be attributed to the tendency to vary linearly with the other.

The other correlations are almost negligible and show hardly any relationship. Although very low, all except one value is positive. The only negative relationship appears between the Stick Balance Test and Hip Sensitivity Test scores.

There is a low positive linear relationship between scores on kinesthetic sensitivity and balancing ability on all except those of the Hip Sensitivity Test and the Stick Balance Test, which is negative. None of the relationships are statistically significant therefore the first hypothesis needs to be rejected.

5. **RESULTS REGARDING THE SECOND HYPOTHESIS**

Hypothesis two is divided into two sections and states that:

(a) there is a positive linear relationship between scores on kinesthetic sensitivity tests and balance tests when considered separately for the various age groups,

(b) there is a positive linear relationship between age and scores on (i) kinesthetic sensitivity tests, (ii) static balance tests and (iii) dynamic balance tests.

5.1. Correlation analysis

(a) An attempt was made to determine how the performance of the different age groups may have influenced the correlation coefficients obtained in Table XI. For this purpose the scores of subjects within the different age groups were used to determine correlation coefficients for sub samples. Table XII illustrates these findings.

The only statistically significant correlation (.7377) , at the .01 level, appears in the three-year-olds' scores (n=10). This high positive correlation exists between the scores on the Hip Sensitivity Test and the Board Balance Test. In this case the coefficient of determination ($.7377^2$) shows that 54% of the variation shown by one set of scores could be attributed to the tendency to vary linearly with the other.

TABLE XII **Between score correlations for the different age groups.**

	STICKBAL	BOARDBAL	BEAMWALK	STSTONES
SHOULDER				
3 years	-.3817	-.4878	.0498	-.1828
4 years	.2478	.1873	-.1157	-.0381
5 years	-.3903	-.1262	.2078	.2942
6 years	.5789	.3463	.2923	.2499
HIP				
3 years	.1562	.7377	-.1143	-.3359
4 years	-.3668	-.4342	.1450	-.1247
5 years	-.4168	.4148	.1341	.2117
6 years	.4005	.2484	.2260	.1789

The number of negative and positive correlations was determined for each age group. Table XIII illustrates how the ratio of positive to negative correlations was found to change with age.

TABLE XIII Comparisons between negative to positive correlations within the age groups.

Age group	negative	positive
3 years	5	3
4 years	5	3
5 years	3	5
6 years	0	8

Table XIII suggests a gradual shift from predominantly negative to predominantly positive relationships occurring among the subjects from the ages three years to six years. This could be an indication of a shift in the importance of joint sensitivity in the control of balance.

(b) Pearson Product-Moment correlations were computed between age and scores on the various tests. This was an attempt to determine whether a relationship exists between the age of the subjects and their performance on the various tasks.

TABLE XIV Correlations between age and performance.

	SHOULDER	HIP	STICKBAL	BOARDBAL	BEAMWALK	STSTONES
AGE	-.3151	-.1618	-.2829	-.2665	-.3096	-.4527

The values illustrated in Table XIV indicate negative correlations between age and scores in all tests. This inverse relationship implies that as age increases errors tend to decrease.

While the correlation coefficients between age and scores on the Hip Sensitivity and Board Balance Tests are not significant, three of the correlations are significant at the .05 level (i.e. between age and the Shoulder Sensitivity, the Stick Balance and the Beamwalk Tests). This indicates that definite, but only slight negative relationships appear to exist between them. The correlation between age and the Stepping Stones Test is significant at the .01 level of confidence. This indicates a moderate negative relationship between these two variables. The Coefficient of determination ($.4527^2 \times 100$) indicates that, in this case, only 20% of the variation in one set of scores could be attributed to variation in the other.

It can therefore be accepted:

(b i) that there is a negative linear relationship between age and the scores on the Shoulder Sensitivity Test (at the .05 level). A weak negative linear relationship existed between age and scores on the Hip Sensitivity Test.

The coefficients of determination ($r^2 \times 100$) indicate that 10% of the variance in the scores on the Shoulder Sensitivity Test could be attributed to age variance. Only 3% of the variance in the scores on the Hip Sensitivity Test could be due to variance in age.

(b ii) that there are weak negative linear relationships between age and scores on the static balance tests. It can therefore not be stated that there is a positive linear relationship between age and static balancing performance per se.

Coefficients of determination for shared variance indicated that 8 and 7% of variance, respectively, in scores on the Stick Balance and Board Balance Tests could be attributed to variance in age. This hypothesis therefore needs to be rejected.

(b iii) that there is a moderate negative linear relationship between age and performance on the dynamic balance tests.

This can be accepted with reasonable confidence as coefficients of determination indicated that 9.6% of the variance in scores on the Beamwalk Test and 20% of the variance on scores on the Stepping Stones Test could be attributed to age variation.

Both parts (a) and (b) of the second hypothesis thus need to be rejected.

6. RESULTS REGARDING THE THIRD HYPOTHESIS

Hypothesis three was divided into two sections and stated that:

(a) there is a positive linear relationship between the scores of the girls on kinesthetic sensitivity and balancing tests;

(b) there is a positive linear relationship between the scores of the boys on kinesthetic sensitivity and balancing tests.

6.1. Correlation analysis between gender and performance

Taking the results of the first hypothesis into consideration (where a positive linear relationship does not exist between scores of the whole sample) it could be assumed that no significant positive relationship would exist between scores on kinesthetic sensitivity and balance tests when those of boys and girls are separated.

6.1.1. Correlation analysis of girls' scores.

Hypothesis 3(a) stated that there is a positive linear relationship between the scores of girls on balancing and kinesthetic sensitivity tasks.

Testing hypothesis 3(a) by correlation analysis of the girls' scores yielded the following (see Table XV):

TABLE XV Correlation matrix for girls' scores.

	STICKBAL	BOARDBAL	BEAMWALK	STSTONES
SHOULDER	.1818	.0363	-.0810	.0165
HIP	-.0851	.0353	.0289	.0361

The obtained correlations in Table XV, between kinesthetic sensitivity measures and balancing measures indicate mostly positive, but negligible, relationships between six of the eight correlations.

Very small, negative correlations are indicated between the scores on the Hip Sensitivity and The Stick Balance Tests, as well as between scores on the Shoulder Sensitivity and Beamwalk Tests.

Hypothesis 3(a) needs to be rejected because of the negative correlations. There does appear to be a positive linear relationship between most of the scores of girls on balancing and kinesthetic sensitivity tasks, although these are not statistically significant.

6.1.2. Correlation analysis of boys' scores.

Hypothesis 3(b) stated that there is a positive linear relationship between the scores of boys on kinesthetic sensitivity and balance tests.

Pearson Product-Moment correlation between the scores attained by boys on all the tests in the battery yielded the following coefficients:

TABLE XVI Correlation matrix for boys' scores.

	STICKBAL	BOARDBAL	BEAMWALK	STSTONES
SHOULDER	-.1069	.1129	.2865	.5132
HIP	-.1989	.3625	.1941	.1611

Except for the relationships between both scores on the kinesthetic sensitivity tests and the Stick Balance Test, which are negative, Table XVI shows generally low, positive relationships.

The correlation between scores on the Hip Sensitivity Test and the Board Balance Test (.3625) was found to be significant at the .05 level. This indicates that a definite, but slight, positive linear relationship exists between scores on these two tests. The only significant correlation, at the .01 level, was found to exist between scores on the Shoulder Sensitivity Test and the Stepping Stones Test (.5132). This indicates a moderate positive linear relationship between scores on the two variables. It can not however be claimed that shoulder sensitivity contributes to control while walking on stepping stones.

Hypothesis 3(b) needs to be rejected because of the negative correlations between scores on the kinesthetic sensitivity and

Stick Balance Test. However, between scores on the Shoulder Sensitivity Test and the Stepping Stones Test a significant linear relationship appears to exist at the .01 level, while scores on the Hip Sensitivity Test and the Board Balance Test indicate a significant linear relationship at the .05 level.

Correlation analysis revealed generally smaller correlations between the kinesthetic sensitivity and balance scores of the girls than between those of the boys. This could have been one reason for the relationships being so low on the total sample. There tended to be greater variability in the scores for the girls. Although statistically significant, the differences in correlations have no conclusive practical implications.

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In summary, the purpose of the investigation was to determine:

(1) whether positive linear relationships existed between kinesthetic sensitivity and balancing ability;

(2) the influence of age on performance;

(3) the influence of sex on performance.

Tests to be used in the study were tested for reliability and validity in a pilot study. A split-half reliability test yielded coefficients between .8661 and .9913 on odd and even scores obtained in the pilot study. A similar reliability test was carried out on odd and even scores obtained in trials of each of the six tests. Coefficients of between .9069 and .9969 were produced and implied that the tests were all reliable measures of the variables tested. The coefficients of determination (r^2) indicated between 82.25% and 99.34% common variance between test scores.

Validity coefficients ranged between .9602 and .9956 for the various tests. This implied that all tests used in the battery gave valid measures of the performance of the subjects on the tests.

The first hypothesis, which stated that a positive linear relationship existed between kinesthetic sensitivity and balancing ability, had to be rejected. Only one of the eight coefficients was statistically significant at the .05 level. Although the relationship was statistically significant only a very slight positive relationship appeared to exist between all, except one of the variables which showed a weak negative correlation.

Low positive correlations were revealed between 7 of the 8 results in the correlation matrix (see Table XI). The most significant of these being the correlation coefficient (.2848) between scores on the Shoulder Sensitivity Test and the Stepping Stones Test. The only negative correlation (-.1452) among the eight was found between scores on the Hip Sensitivity Test and the Stick Balance Test. It was found that a gradual shift from negative to positive correlations occurred from the ages three years to six years.

The second hypothesis stated that a positive linear relationship exists:

(a) between kinesthetic sensitivity and balance when considered separately for the various age groups;

(b) between age and scores on (i) kinesthetic sensitivity tests (ii) static balance tests and (iii) dynamic balance tests.

(a) It was accepted that there was not a positive linear relationship between kinesthetic sensitivity and balance when the scores of the different age groups were considered separately.

(b i) It was accepted that a weak negative linear relationship existed between age and scores on the Shoulder Sensitivity Test (at the .05 level). A negative linear relationship appeared to exist between age and scores on the Hip Sensitivity Test.

(b ii) A moderate negative linear relationship was found to exist between age and scores on the Stick Balance Test (at the .05 level). The correlation between age and the Board Balance

Test yielded a negative, but insignificant relationship.

(b iii) Significant negative linear relationships were found to exist between age and both the dynamic balance test scores. Correlation coefficient between age and scores on the Beamwalk Test was -.3096 (significant at the.05 level), and between age and scores on the Stepping Stones Test -.4527 (significant at the .01 level). As age increases so errors in dynamic balance performance decreases, which implies that dynamic balance improves with age.

Hypothesis three was divided into two parts.

(a) A positive linear relationship exists between the scores of girls on the kinesthetic sensitivity and balancing tests.

Correlation analysis indicated mostly very low positive relationships between test scores attained by the girls in the sample. Two almost negligible negative correlations were yielded between scores on the Shoulder Sensitivity Test and the Beamwalk Test, and also between scores on the Hip Sensitivity Test and the Stick Balance Test. Hypothesis three (a) was therefore rejected.

(b) A positive linear relationship exists between the scores of boys on the kinesthetic sensitivity and balance tests.

The correlation coefficient between scores on the Shoulder Sensitivity Test and the Stepping Stones Test was significant at the .01 level and that between scores on the Hip Sensitivity Test and the Board Balance Test, at the .05 level. Low negative values were yielded for relationships between scores on both the Shoulder Sensitivity Test and the Hip Sensitivity Test and scores on the Stick Balance Test. Hypothesis 3 (b) was rejected as there was not a positive linear relationship between age and scores on any of the tests.

It was also determined that there were no significant differences between the mean scores of boys and girls in the different test items.

CHAPTER 5

DISCUSSION, CONCLUSIONS AND RECOMMENDATIONS

A child is not merely a more complicated and delicate thing than the most complicated and delicate machine; he is a thing of a different order, and requires thinking of a different order to understand him.

Harwood (1979:38)

1. INTRODUCTION

Questions to which answers were sought through this investigation were the following: (a) does a relationship exist between kinesthetic sensitivity and the ability to perform simple balancing tasks in pre-school children? (b) what is the magnitude of such a relationship? (3) How does age and sex affect performance and what are the influences of these variables on relationships?

Clarke and Clarke (1984:326) explain that:

> Young children are typically uncoordinated in their responses and have poor balance ..., as they grow during childhood, they become better at proprioceptive adjustments.

Bressan and Woollacott (1985/86) and Hurlock (1978) claim that balance control is one of the first motor control capacities to mature in children. On the other hand Richardson and Tandy (1973) found that kinesthesis is one of the first sensory systems to mature. It is accepted that there is no general kinesthetic sense, but the claim made by Schneider and Tarshis (1975) that proprioceptive cues convey information about limb position and balance, suggests that there could be a parallel development among the different kinesthetic systems. In the light of these claims it was hypothesised that there could be some linear relationship between the development of kinesthetic sensitivity and balancing ability, especially in pre-school children.

The investigation set out to determine whether relationships existed between the development of kinesthetic sensitivity and balancing ability in pre-schoolers. The influence of sex and age (or more specifically, the maturation of the systems involved in the two) on these relationships, necessarily formed part of the study.

2. SUMMARY OF PROCEDURES

A convenience sample of fifty-one pre-school boys and girls participated in a test battery consisting of two measures each of kinesthetic (joint) sensitivity, static balance and dynamic balance performance (six test items). Each subject was given five trials on each of these test items and the total number of errors on each made up the raw scores. As the total number of errors on each test item represented scores, lower scores indicated better performance.

The average age of the subjects was four and a half years. Of the fifty-one subjects twenty-nine (56.86%) were boys and twenty-two (43.14%) were girls. Within the different age frequencies the ratio of boys to girls differed significantly, with boys in the majority in all but the four-year-old group.

3. RELIABILITY AND VALIDITY

Split-half correlations computed from odd and even scores in the main study compared favourably with those obtained in earlier studies even though the ages of the subjects varied considerably:

	Current	Others
Shoulder sensitivity	.92	.91 (Scott 1955)
		.908 (Witte 1962)
Hip sensitivity	.93	.93 (Scott 1955)
Stick balance	.91	.78 (Young 1945)

Scoring and testing procedures used in the rest of the tests in the battery differed so much from similar reported tests that comparisons could not be drawn between them.

Tests and testing procedures were found to be reasonably reliable on both the pilot study results and the results of the main study. It was, therefore, accepted that the equipment, testing and scoring procedures used in this study were acceptably repeatable.

Validity values of between 93.06% and 99.56% were calculated between odd and even scores obtained in the main study. This appears to indicate that the tests did indeed measure what they set out to measure.

4. DISCUSSION OF RESULTS REGARDING THE RELATIONSHIPS BETWEEN KINESTHETIC SENSITIVITY AND BALANCING ABILITY

The first hypothesis stated that a positive linear relationship exists between kinesthetic sensitivity and balancing ability. This implies that there may be a positive linear relationship between the maturation of the systems involved in kinesthetic sensitivity and those responsible for balance control.

4.1 Kinesthetic sensitivity

From the results it was obvious that kinesthetic sensitivity is reasonably well developed in pre-schoolers. This argument is strengthened by the relative accuracy with which the subjects were able to duplicate movements and positions of both arms and legs (see Appendix F). The greatest average deviation from the criterion was only 11.8 degrees (shoulder) and 12.6 degrees (hip), and both these were obtained from members of the youngest group. If these findings were to be analysed according to Burns' suggestion (1986) that the motor area develops ahead of the sensory area, it would appear that the stage has been reached where both the motor and sensory areas have reached reasonable maturity in the majority of the subjects in the sample. It would also confirm the suggestion made by Laszlo and Bairstow (1985:121) that the maturation of the motor and sensory systems parallel each other "at least from the age of five years".

The proximal situation of the hip and shoulder joints leads one to assume that sensitivity to position could have reached some level of maturity in many of the subjects by the age of three years. This supports the suggestion by Richardson and Tandy (1973) that development of kinesthesis occurs during the first two years of life. It however negates the findings of Ashby (1983) that young children (six years old) are less capable of efficient encoding of kinesthetic cues than older children. In the above cases the differences in findings could also be attributed to the different tests or the different measuring techniques.

On the kinesthetic sensitivity tests, mean scores for trials (calculated from raw scores) for the total sample were 5.35 (shoulder) and 4.96 (hip). Reasons for greater accuracy at the hip cannot be explained with any certainty. Laidlaw and Hamilton (1937) found the hip to be more sensitive than the shoulder, but this study was conducted on sensitivity to passive movement of joints. In active movement Geldard (1972) found the shoulder to be the most sensitive joint. Several reasons could be suggested for these differences in results, but the most likely explanations could be that tests differed, the testing environments and methods were different, and the sample in each study was unique.

The difference between the two kinesthetic sensitivity tests, which could have influenced scores and relationships, was the influence of gravitational force on performance of the shoulder sensitivity task, which was not a factor during performance on the Hip Sensitivity Test. This additional force on the test for shoulder sensitivity could have resulted in greater participation of shoulder muscle proprioceptors which may have contaminated the information received from the joint receptors. The inability of subjects to integrate sensory information could also have influenced accuracy. Also in this regard, Swartz (1978) found that children with a poor attention span displayed poor kinesthesia.

Although both kinesthetic sensitivity tests were supposed to measure the same ability it needs to be recognised that this ability was tested at two different joints and in two different attitudes - one in the upright position and the other in the supine position. Therefore, the assumption cannot be made that sensations picked up by the one joint could be equated with that of the other. Baumgartner and Jackson (1982) ascribe low correlations between kinesthetic tests to either task-specificity or poor test reliability. In this study the low correlations could then be due to task specificity.

4.2 Static balance

There appears to be some controversy in the literature about the difference between postural control and balance control. It may be logical to assume that postural control needs to be acquired before controlled performance of balancing tasks is possible. It has been stated that balance is a reflex action, but in the author's view it could be postural control which is reflexive while, balance control appears to be the product of overt action.

The two static balance tests differed so much from each other in control requirements, that it is feasible to accept that the abilities required for each of them would have been task specific. It was however accepted that the tests did indeed measure static balance, but different forms of static balance. It can, in fact, be accepted that two forms of static balance were tested in the battery. Clark and Watkins (1984) warned that, where children were concerned, balance (and specifically static balance) was a multidimensional construct. By this they implied that no single test item could adequately assess all dimensions of static balancing ability.

4.3 Dynamic balance

In the present study the Board Balance Test and the Stick Balance Test clearly differed in that intrinsic to the former was a dynamic element, which was absent in the latter. More control appeared to be necessary to keep the board steady than to balance on a stationary balance stick. Although the mean scores for the total sample on the two tests differed only slightly, the Pearson Product-Moment Correlation Coefficient for the two was only .2409. This was slightly lower than the .2454 correlation obtained between the Stick Balance and the Stepping Stones Tests which measured performance on static and dynamic balance respectively.

As was the case with the static balance test items, both dynamic balance tasks also differed from each other as regards requirements for successful performance. In addition to accepting the conclusion that static balancing ability could not be tested by means of a single test, the researcher has come to the same conclusion regarding dynamic balance. Different controls appear to be required for each balancing task, depending on the degree to which testing equipment and tasks differ from one test to the other. It could therefore also be accepted that two different forms of dynamic balance were tested in the battery.

The skills required for the Beamwalk Test and the Stepping Stones Test differed considerably. While the former only required maintaining balance while traversing the beam, the latter required, in addition, the accurate perception of the distance between the stones. It was found that the Stepping

Stones Test not only tested balancing ability, but also two different types of kinesthetic sensitivity - tactual sensitivity of the soles of the feet and recognition of the pattern of distance between the stones. According to the final scores this did not, however, appear to affect scores notably. The results showed a much lower correlation between hip sensitivity and performance on the Stepping Stones Test than was expected. The correlation coefficient of .2651 between the two dynamic balance tests, indicates that the two tests shared only 7% of the total variance.

4.4. **Relationships between kinesthetic sensitivity and balance.**

Pearson Product-Moment Correlation analysis between scores on kinesthetic sensitivity and balancing ability tests yielded mostly very low, but positive relationships. It is thus not possible to assume any causal relationships between kinesthetic sensitivity and balancing ability.

4.4.1. **Shoulder sensitivity and balance.**

The only statistically significant correlation was found to exist between scores on the Shoulder Sensitivity and the Stepping Stones Test (.2848). The percentage common variance between the two sets of scores was however too low (8%) to be of any practical significance. In this regard Scott (1955:330) explained that "it may be that the arm action in balance is a very significant one, not just a mechanical asset as sometimes is assumed in analysis of skills". Goodwin (1976:90) came to a similar conclusion: "higher sensitivity at ... proximal joints is appropriate if, for example, it is used for conscious correction of postural sway". Although the significance of this correlation may have occurred due to the unique composition of the present sample, the possibility does exist that arm action could play an important part in the maintenance of balance and in reinforcing kinesthetic memory during locomotion, especially where precision of step length is required.

Richardson and Tandy (1973) explained that movements of isolated body parts require much lower levels of kinesthetic organisation than locomotor movements would, especially where they require balance control. If this is true then the two tasks required quite different levels of kinesthetic organisation. It is also possible that subjects relied heavily on compensatory motion of the arm in the maintenance of balance on the Stepping Stones Test.

Another possible explanation for the significant correlation could be the obvious delight the subjects derived from performing these two tasks. They appeared to find the Shoulder Sensitivity Test exciting and the Stepping Stones Test challenging. This once again accentuates the importance of motivation for success in performance. The fact that the correlation could have been a chance seems more likely.

The correlation coefficient obtained between scores on the Shoulder Sensitivity Test and the Stick Balance Test (.0265) compares favourably with the unusual correlation reported by Scott (1955) between similar balance stick and arm raising tests -.00 (sic).

4.4.2. **Hip sensitivity and balance.**

The low correlation coefficient between scores on the Hip Sensitivity Test and the Stepping Stones Test was not expected and could indicate that either hip sensitivity is not as important during an activity of this kind, or that the majority of these young children were not dependent on kinesthetic information from the hip.

Although the correlation between scores on the Hip Sensitivity Test and the Stick Balance Test was almost negligible (-.1452), no logical reason could be found for the negative correlation between these scores. This low negative correlation indicated that there was no notable relationship between these variables.

Scott (1955) found the correlation coefficient between similar leg raising and balance stick tests to be -.01. These similarities are especially interesting as Scott's subjects were adults. This could imply that, even where maturity has been reached, a linear relationship does not necessarily exist between abilities of different kinds.

None of the correlation coefficients calculated between any of the variables in this study were significant enough to have any predictive or practical value. These findings affirm those of researchers such as Young (1945), Scott (1955), Erbaugh (1984) and others, and substantiate the theory of task specificity (Clark and Watkins 1984, Drowatsky and Zuccato 1967).

It was found that there is not a significant positive linear relationship between the level of kinesthetic sensitivity and either static balance or dynamic balancing ability.

5. DISCUSSION OF RESULTS REGARDING THE RELATIONSHIP BETWEEN AGE AND PERFORMANCE ON KINESTHETIC SENSITIVITY AND BALANCE TESTS.

This hypothesis stated that there is a significant linear relationship between (a) age and kinesthetic sensitivity, and (b) age and the ability to perform static and dynamic balancing tasks.

5.1. **Age-related differences in performance.**

Hottinger (1980a) and Cratty (1986) were among researchers who suggested that the first five years was the period in which the most growth and development takes place. Cratty (1986) suggested that the relationship between changes in physical growth and motor performance appeared to be higher in pre-schoolers than in older children. The proportional changes which occur with age and growth also have a definite influence on activities such as balance (Herkowitz 1980). This could be one reason why the younger subjects in the sample generally performed less accurately on the balance tasks than the older children. The rate at which these changes occur are, to a great extent, influenced by heredity (Pikunas 1969) which in turn has a unique influence on motor ability.

Results showed that although individual differences occurred in performance (see Appendix G), there was a definite improvement with age in the ability of the young subjects to execute various balancing tasks. Shumway-Cook and Woollacott (1985:146) provided evidence which indicates that this improvement does not occur in a linear fashion, but appears to occur in stages. They ascribe this to the shift in the maturation of the "predominant controlling sensory inputs to posture", i.e. from visual dominance to an integration of visual and kinesthetic control.

Although the literature supports the theory that the motor system develops ahead of the sensory system, and that by the age of five development in these two areas is parallel, there is no evidence as to when sensory integration takes place, or what the influence of the transition period is on control. This could perhaps explain the variability in mean scores obtained in the various tests by the various age groups.

Correlation analysis indicated negative correlations between all scores and age. This implies that as age increased, errors in performance decreased. Four of the six correlations were statistically significant, but did not indicate strong enough relationships to imply any causal or predictive relevance. It could therefore be accepted that ability generally increases with age, but depends more on the maturational status of the child.

An interesting result emerged in the correlation coefficients obtained for the three-year-olds (Appendix E). A very significant relationship (.7377) was shown to exist between scores on the Hip Sensitivity Test and the Board Balance Test. This could be an indication of greater reliance on hip sensitivity at this age, which then appears to diminish in the following three years, or, the maturation of the predominant controlling systems in balance performance.

A negative correlation was yielded between scores on the same tests in the four-year-old group. This indicates that, either a sudden deminished reliance on hip sensitivity takes place at the age of four, which then increases again at the age of five and becomes weaker again at six, or the scores were unique to the present sample.

The mean scores for the different age groups indicated that there is improved kinesthetic sensitivity and balancing ability as children mature and appear to gain more experience through everyday activities. Play has been found to lead to the development of abilities and attitudes, albeit incidentally. Bruner (1973:7) indicated that "play has the effect of maturing some modular routines for later incorporation in more encompassing programs of action". The environment must however provide opportunities for such experiences and thus promote the development of motor abilities.

Results from ANOVA between the mean scores for the different age groups indicated that no significant differences existed except on the Stepping Stones Test. A significant difference was, however, found to exist between the mean scores of the entire group on scores on this test. Multiple range analysis indicated that this difference was a result of the relatively high mean error score of the three-year-olds (60.22). This relatively poor mean score could be attributed to any of three factors: the unfamiliarity of the task; uncertainty induced by the fact that subjects were blindfolded or the possible inability to remember (kinesthetically) the distances between the stepping stones. Another interesting observation - also related to kinesthetic sensitivity - was that the younger children tended to be unable to maintain direction during performance of this task. They were generally inclined to place the leading foot diagonally across the supporting foot in stepping from stone to stone.

Laszlo and Bairstow (1985) submitted that there is an important interplay between memory and appropriate action. The memory - kinesthetic, short-term or long-term - comes into operation once interactions with, and interpretations of, actions in relation to the environment have taken place. This nevertheless requires selective attention, which, according to Stratton (1978), is not yet possible for young children. The nature of sensory stimulation will then also depend greatly on the maturational level of the child's emotional, sensory and muscular systems.

On an individual basis several of the three-year-old subjects made less errors on the different test items than some of the older subjects (see Appendix C). This, once again, points to the differences in maturational status between individuals within a specific age range.

6. DISCUSSION OF RESULTS REGARDING GENDER AND SCORES ON KINESTHETIC SENSITIVITY AND BALANCE TESTS.

The third hypothesis stated that (a) there is a positive linear relationship between the scores of girls on kinesthetic sensitivity and balance tests, and (b) there is a positive linear relationship between the scores of boys on kinesthetic sensitivity and balance tests.

6.1. Differences in performance between girls and boys.

Althoug not stated as a hypothesis it was deemed necessary to compare results with the literature. Only minimal differences were obtained between the scores obtained by boys and girls. On average the boys performed better than the girls on two of the six tests, namely the Board Balance Test and the Stepping Stones Test. These differences could have been due to the different experiences boys encounter during everyday play activities. The girls performed better than the boys on the Shoulder Sensitivity Test and marginally better on the Hip Sensitivity Test. This affirms Connell's (1955) conclusion that girls tend to perform better than boys in activities requiring precision and accuracy. This could be ascribed to the relatively longer attention span of girls proposed by Salkind and Ambron (1987). However, Cratty and Martin (1969) argued that boys performed better than girls until the age of about 7,6 years.

Statistically the differences in scores between the sexes were not significant, which is in agreement with the findings of Witte (1962) and Espenschade and Eckert (1967). Where differences occurred these could, once again, be attributed to the specific subjects used in the study and/or the nature of the tests.

6.2. **Relationships between scores for each gender.**

An interesting phenomenon emerged from the correlation tables for the two sexes: only one of the correlation coefficients between boys' scores was lower than the corresponding coefficient from the girls' scores. There appeared, thus, to be a slightly stronger relationship between abilities of boys than between those of girls. Two correlations were statistically significant for the boys, but none for the girls. A logical explanation for this is not apparent except, perhaps, that girls generally tend to mature faster than boys and the associated changes could have had some influence on performance.

In the light of the evidence it was accepted that there was a low, but statistically significant relationship ($p < .01$) between scores on the Shoulder Sensitivity Test and the Stepping Stones Test among the boys in the sample. Otherwise there did not appear to be any linear relationships between scores on the kinesthetic sensitivity and balance tests.

7. CONCLUSIONS

From the evidence gained from correlation analysis several conclusions can be drawn:

Those children who were able to perform well on the balance items were not necessarily those who performed well on tasks requiring kinesthetic sensitivity. This would indicate that either there is not a significant relationship between kinesthetic sensitivity at the joints and balancing ability in pre-school children or the differences between the items used in the test battery were too great to yield any similarities in ability level. Smith (1968) proposed that perceptual sets are formed for each task performed. The possibility exists that, because different items were tested in quick succession and transfer from the one to the other was minimal, these young children were unable to alter from the set prepared for the previous task rapidly enough to accommodate that needed for the next. This could be an explanation for the task specificity explained by Shumway-Cook and Woollacott (1985) and other researchers. Assumptions are made about the different systems involved in the various tasks, but contamination of the sensitivity of one system by that of others is not reflected in the data analysis.

In view of the low correlations generally found to exist between kinesthetic sensitivity and balance, it is not clear why researchers (e.g. Scott 1955) include balance items in kinesthetic test batteries. In cases such as this the measurement of kinesthesis is measured by relying on correlation analysis to arrive, indirectly, at a measure of kinesthesis. Laszlo and Bairstow (1985) also express their dissatisfaction with this practice.

Errors in response selection could also have led to differences in performance. It is evident that this is not age related, but depends mainly on the maturity of the various systems involved.

Hogan and Hogan (1975) suggested that children differ in terms of the appropriateness of their efforts when dealing with new tasks. To some of the subjects the tasks appeared to be exciting and challenging, while to others they posed some element of risk. This resulted in some of the subjects being more motivated than others, which would no doubt have had an effect on their performance.

Age differences in performance are explained by Shumway-Cook and Woollacott (1985) who suggested that the period between four and six years of age could represent a period of disproportionate growth, which would have an effect on movement performance and its control. During this period the control systems are not only becoming integrated, but also need to accommodate changing body proportions.

It would appear that age, per se, was not an important factor in determining ability on the tasks presented in this study. Although the results indicated that performance improves with age, on average, this was not so in the case of individual subjects. It appeared that maturity of all the systems involved, and the ability to integrate information, which differed from subject to subject, had a much greater influence than age. This agrees with the arguments of several researchers (Coghill 1929 and McGraw 1945: in Wade 1976; Cratty 1986; and others).

Differences in scores by individual subjects could be explained by Kerr's observation (1978) that individuals rarely, if ever, perform exactly the same movement twice. Performance is, therefore, likely not to give a true reflection of an individual's ability.

Where gender related differences are concerned girls scored better on the different test items, on average, than boys. This could be ascribed to the relatively longer attention span of girls proposed by Salkind and Ambron (1987). However, Cratty and Martin (1969) argued that boys performed better than girls until the age of about 7,6 years. In the present study it was, however, shown statistically that there were no significant differences between the mean scores of girls and boys. Correlation coefficients computed between the different test scores for boys, were marginally greater than those yielded for girls. Although the differences were not great, this could indicate some differences in the rate at which systems parallel each other in development.

A weakness of the study is the fact that the sample was very small and was not randomly selected. Parents enrolled children in the movement development programme, either because they thought the child needed to develop coordination or they felt the child showed potential for motor skills. This could signify that only the ends of the continuum were represented in the sample. Another factor which could have influenced the results was the unequal distribution between the different age groups.

8. RECOMMENDATIONS FOR FURTHER RESEARCH

There is a need for standardised tests for the measurement of kinesthetic sensitivity. These would need to include, mong others, tests for variables such as joint sensitivity, muscle sensitivity and tendon sensitivity, so that the role of each of these during the performance of balancing tasks can be established.

Marsden et al. (1981) concentrated their study on muscular responses to balancing activities. A study well worth pursuing would be to determine the role of specific joint receptors in postural responses. These joints would possibly include all the weight bearing joints of the lower limbs, the vertebral column (especially the cervical and lumbar sections) and the joints of the upper limbs which often appear active during balance (shoulder and elbow).

It is recommended that the test battery used in this investigation be used in a cross-cultural study. Broadhead and Church (1985) found white children to be generally better at balance than black children. As far as can be established kinesthetic sensitivity tests have not as yet been administered to black children.

The test combination used in the present study needs to be tested on a larger and more representative sample for any conclusive acceptance of results. Administering a similar test battery to older children, or even adults, could shed some light on whether a stage is reached in development when joint sensitivity parallels balancing ability.

SUMMARY OF RESULTS

* No significant linear relationship existed between the scores on kinesthetic sensitivity and balancing tests. The one statistically significant correlation - between scores on the

Shoulder Sensitivity and Stepping Stones Tests - was not high enough to have any predictive value.

* Although performance generally appeared to improve with age, and the relationships were mostly statistically significant, there was not a strong enough relationship between age and scores on the various tasks in the test battery to permit the conclusion that age played a significant role in the development of ability.

* Analysis of Variance (ANOVA) between mean scores for the various test items and age indicated no significant differences, except for those on the Stepping Stones Test, where the significant difference appeared to be the result of the high mean error scored by the three-year-olds.

* No significant linear relationships were found to exist between the girls' scores on the kinesthetic sensitivity and balance tests. Among the boys' scores relatively larger correlations were evident, but this does not imply any practical significance in the relationship.

* A t-test showed that no significant differences existed between the mean scores of the boys and girls.

*There appeared to be a general improvement with age in performance on both balancing and kinesthetic sensitivity tasks.

APPENDICES

APPENDIX A

SCORE SHEET

NAME .... DATE ....

SEX .... DATE OF BIRTH ....

TEST	TRIALS 1	2	3	4	5
1. SHOULDER TOTAL ________					
2. HIP TOTAL ________					
3. STICKBAL TOTAL ________					
4. BOARDBAL TOTAL ________					
5. BEAMWALK TOTAL ________					
6. STSTONES TOTAL ________					

COMMENTS

1. 4.

2. 5.

3. 6.

APPENDIX B

Scores obtained in pilot study

AGE	n	TEST	TRIALS	
		SHOULDER	odd	even
3	2		23	22
			15	15
4	2		21	20
			13	15
5	2		15	14
			17	19
6	2		10	12
			15	13
		Mean score	16.13	16.25

AGE	n	TEST	TRIALS	
		HIP	odd	even
3	2		14	12
			10	10
4	2		8	9
			11	10
5	2		7	7
			6	8
6	2		5	5
			10	9
		Mean score	8.87	8.75

AGE	n	TEST	TRIALS	
		STICKBAL	odd	even
3	2		12	10
			9	10
4	2		9	8
			9	9
5	2		14	12
			10	10
6	2		7	7
			5	7
		Mean score	9.38	9.13

Scores obtained in pilot study (continued)

AGE	n	TEST	TRIALS	
		BOARDBAL	odd	even
3	2		12	12
			10	9
4	2		6	5
			5	7
5	2		9	7
			6	8
6	2		5	5
			4	3
		Mean score	7.13	7.00

AGE	n	TEST	TRIALS	
		BEAMWALK	odd	even
3	2		20	19
			24	22
4	2		23	23
			23	21
5	2		19	20
			25	20
6	2		18	18
			7	9
		Mean score	19.88	19.00

AGE	n	TEST	TRIALS	
		STSTONES	odd	even
3	2		18	15
			23	20
4	2		15	15
			19	17
5	2		9	8
			9	9
6	2		4	3
			1	0
		Mean score	12.25	10.88

APPENDIX C

Individual T-scores (obtained from total scores) on each test.

TEST	sex*	age	SHOULDER	HIP	STICKBAL	BOARDBAL	BEAMWALK	STSTONES
1.	1	3	70.80	49.99	52.30	45.80	50.50	55.82
2.	2	3	48.70	63.85	62.23	64.61	55.85	61.91
3.	1	3	60.12	40.98	63.58	47.63	43.79	62.26
4.	1	3	57.07	71.47	63.56	60.02	50.50	63.33
5.	1	3	60.12	62.46	41.47	68.74	55.87	42.94
6.	1	3	67.75	45.14	35.60	38.00	71.64	63.33
7.	1	3	51.73	51.37	58.62	48.55	59.56	49.38
8.	2	3	45.63	45.83	46.43	55.44	57.55	63.33
9.	1	3	54.02	50.68	58.17	58.19	53.86	63.33
10.	2	3	54.02	45.14	63.13	48.55	55.53	77.28
11.	2	4	63.94	43.06	58.17	41.67	49.16	51.53
12.	1	4	55.55	59.00	44.18	47.17	41.10	41.87
13.	2	4	41.82	45.14	57.26	41.21	49.49	65.48
14.	1	4	44.10	65.92	37.86	41.21	50.50	47.24
15.	2	4	41.05	54.84	55.91	50.85	50.50	51.53
16.	1	4	52.49	49.99	41.02	59.11	71.31	56.89
17.	2	4	40.29	50 68	51.40	47.17	49.83	37.58
18.	2	4	43.34	52.07	41.02	49.47	70.30	52.60
19.	2	4	57.07	41.67	39.21	52.68	38.42	34.36
20.	2	4	47.92	43.75	35.60	48.09	43.45	62.26
21.	2	4	48.70	38.21	59.97	91.23	42.11	47.24

(sex*: 1 represents boys and 2 represents girls)

APPENDIX C (continued)

TEST sex*	age	SHOULDER	HIP	STICKBAL	BOARDBAL	BEAMWALK	STSTONES
22. 1	4	50.21	52.07	58.62	58.19	45.13	60.11
23. 2	4	35.71	65.23	35.60	37.08	41.44	47.24
24. 2	4	63.17	52.07	57.26	54.52	43.79	56.89
25. 2	4	43.34	36.13	53.65	46.72	40.77	47.24
26. 1	4	52.49	55.53	58.17	47.63	47.82	37.58
27. 1	5	42.58	51.37	57.72	67.37	61.24	51.52
28. 1	5	44.10	48.60	58.62	47.63	36.07	50.46
29. 1	5	34.19	41.67	50.50	57.27	68.29	41.87
30. 2	5	57.83	32.66	63.58	38.45	50.84	46.16
31. 2	5	48.70	56.22	35.60	67.83	44.80	42.94
32. 1	5	34.19	26.92	60.87	45.34	48.15	34.36
33. 1	5	57.83	63.85	53.20	57.27	69.63	61.19
34. 2	5	48.70	49.99	45.08	41.21	45.80	59.04
35. 1	5	39.53	42.36	60.87	47.17	37.41	35.79
36. 1	5	57.83	48.60	55.91	56.35	46.81	54.75
37. 1	5	46.39	26.92	64.03	42.59	59.22	53.68
38. 1	5	63.94	65.93	35.60	42.59	76.00	38.65
39. 1	5	32.66	38.90	45.98	44.88	40.77	39.72
40. 2	5	52.49	38.21	35.60	39.91	46.14	34.36
41. 2	5	34.95	66.62	61.33	53.60	45.13	42.94
42. 2	5	66.99	69.39	41.47	49.93	39.09	44.02

(sex*: 1 represents boys and 2 represents girls)

APPENDIX C (continued)

TEST sex*	age	SHOULDER	HIP	STICKBAL	BOARDBAL	BEAMWALK	STSTONES
43. 1	6	32.66	51.37	44.63	47.17	47.14	37.58
44. 1	6	50.21	39.59	40.57	41.67	58.90	45.09
45. 1	6	63.94	58.30	39.67	49.47	46.14	57.97
46. 2	6	37.24	38.21	37.41	52.68	40.10	42.94
47. 1	6	56.31	62.46	59.97	47.63	49.83	45.09
48. 2	6	38.00	52.76	35.60	40.75	43.12	55.82
49. 1	6	44.87	48.60	41.02	39.91	40.43	36.50
50. 1	6	33.42	36.82	41.47	37.08	40.10	51.53
51. 1	6	58.60	40.28	49.59	46.72	39.09	46.16

(sex*: 1 represents boys and 2 represents girls)

APPENDIX D

Means plots on performance according to age

Figure 2

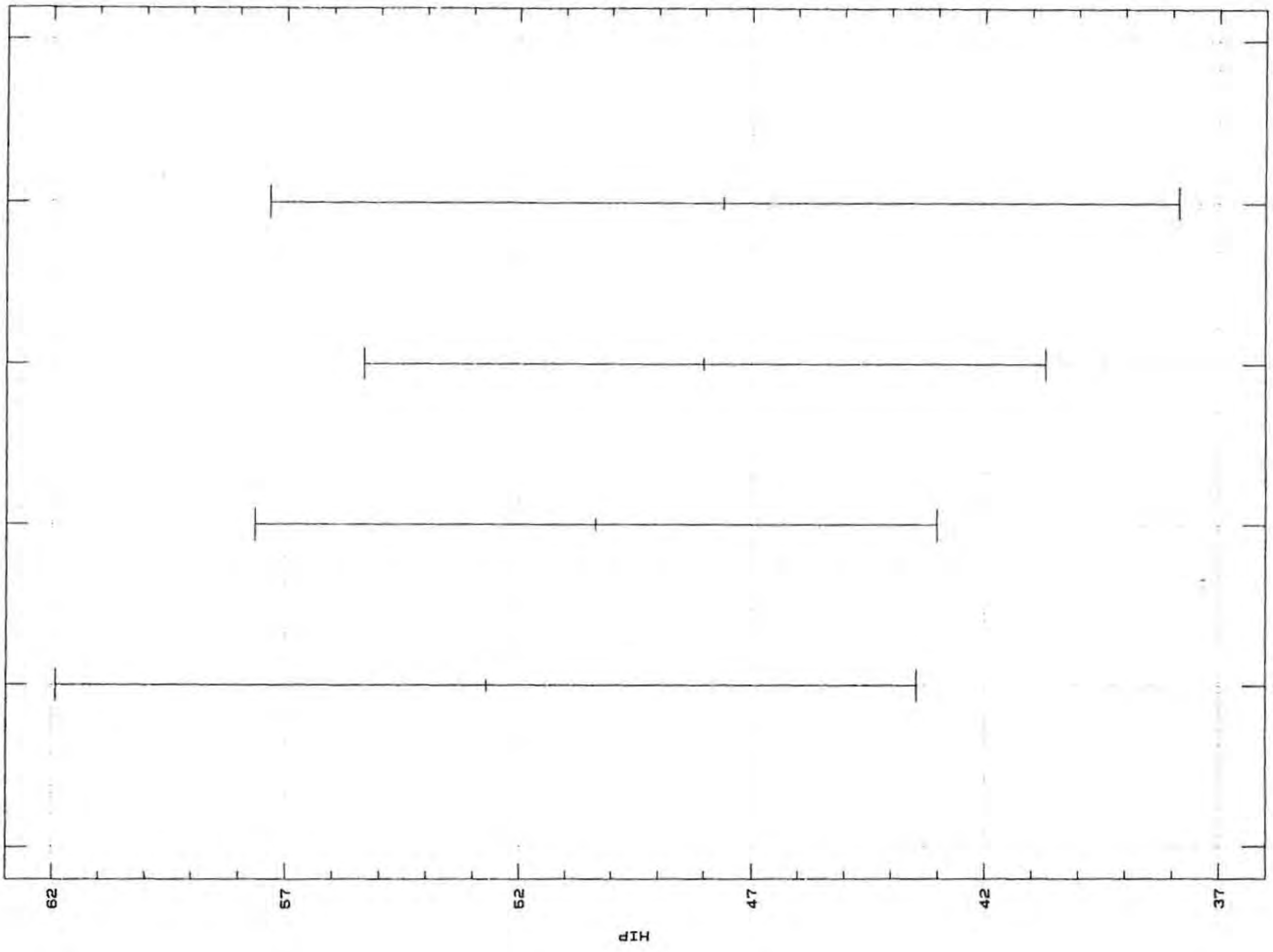


Figure 1

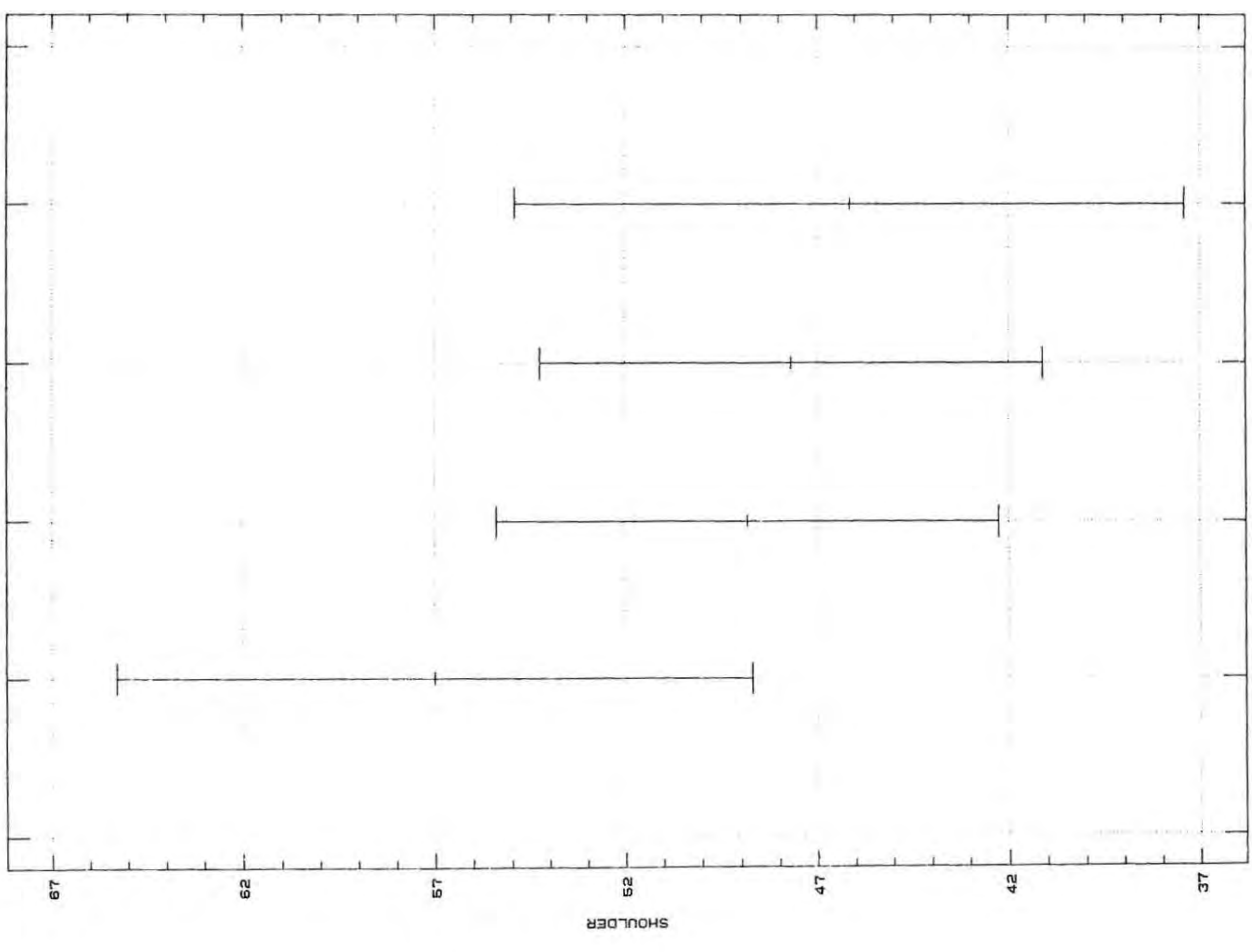


Figure 3

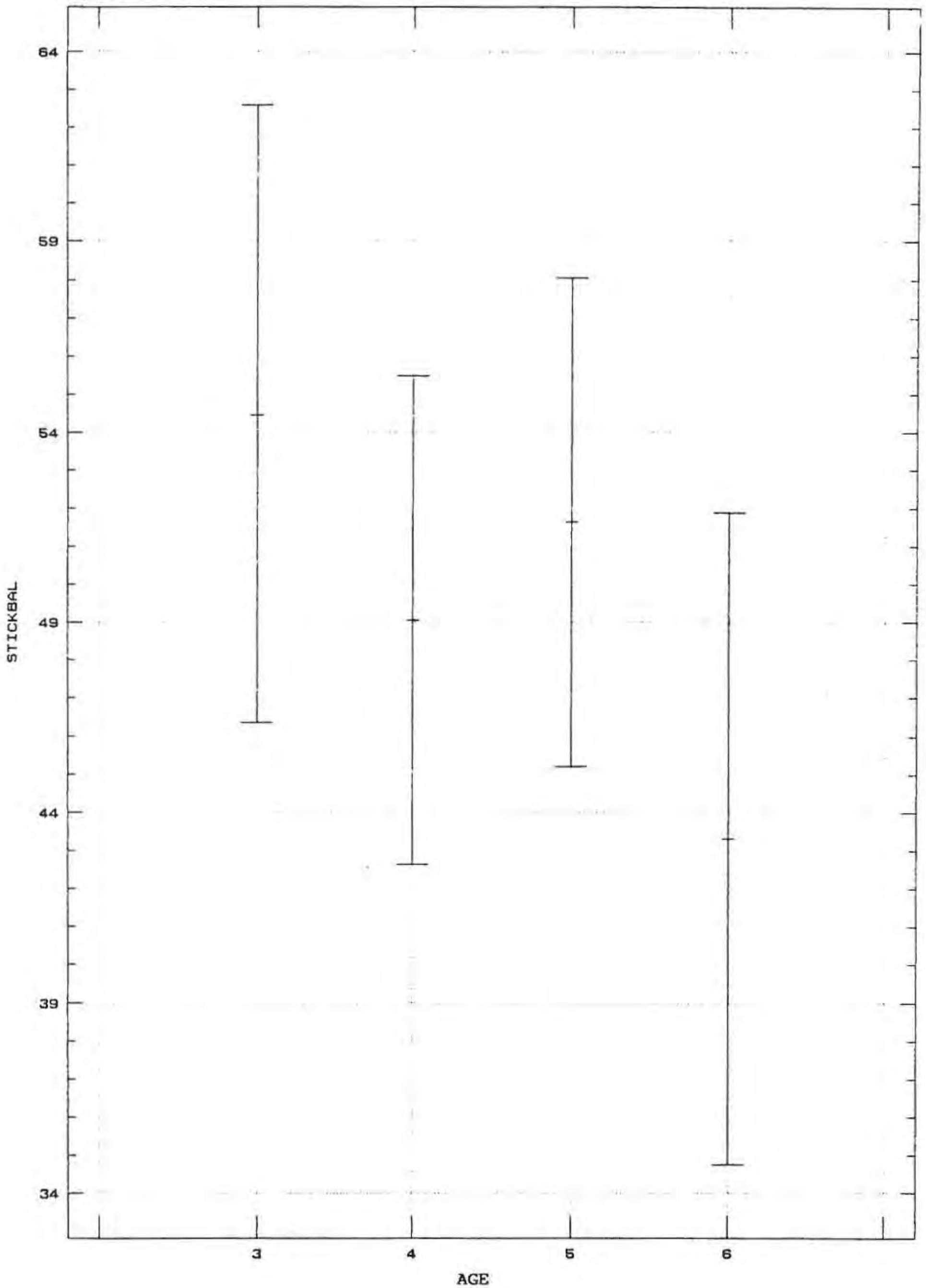
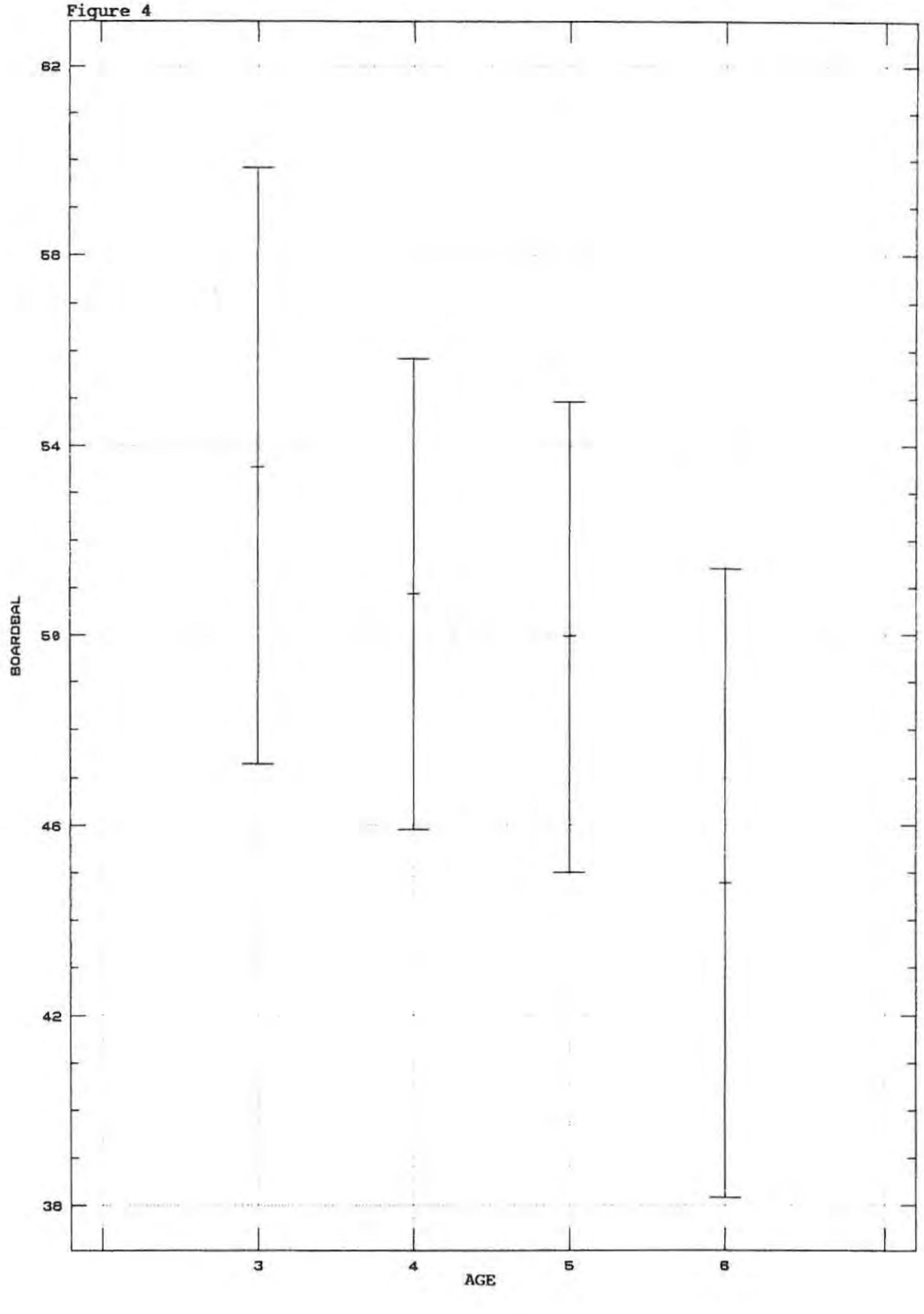


Figure 4



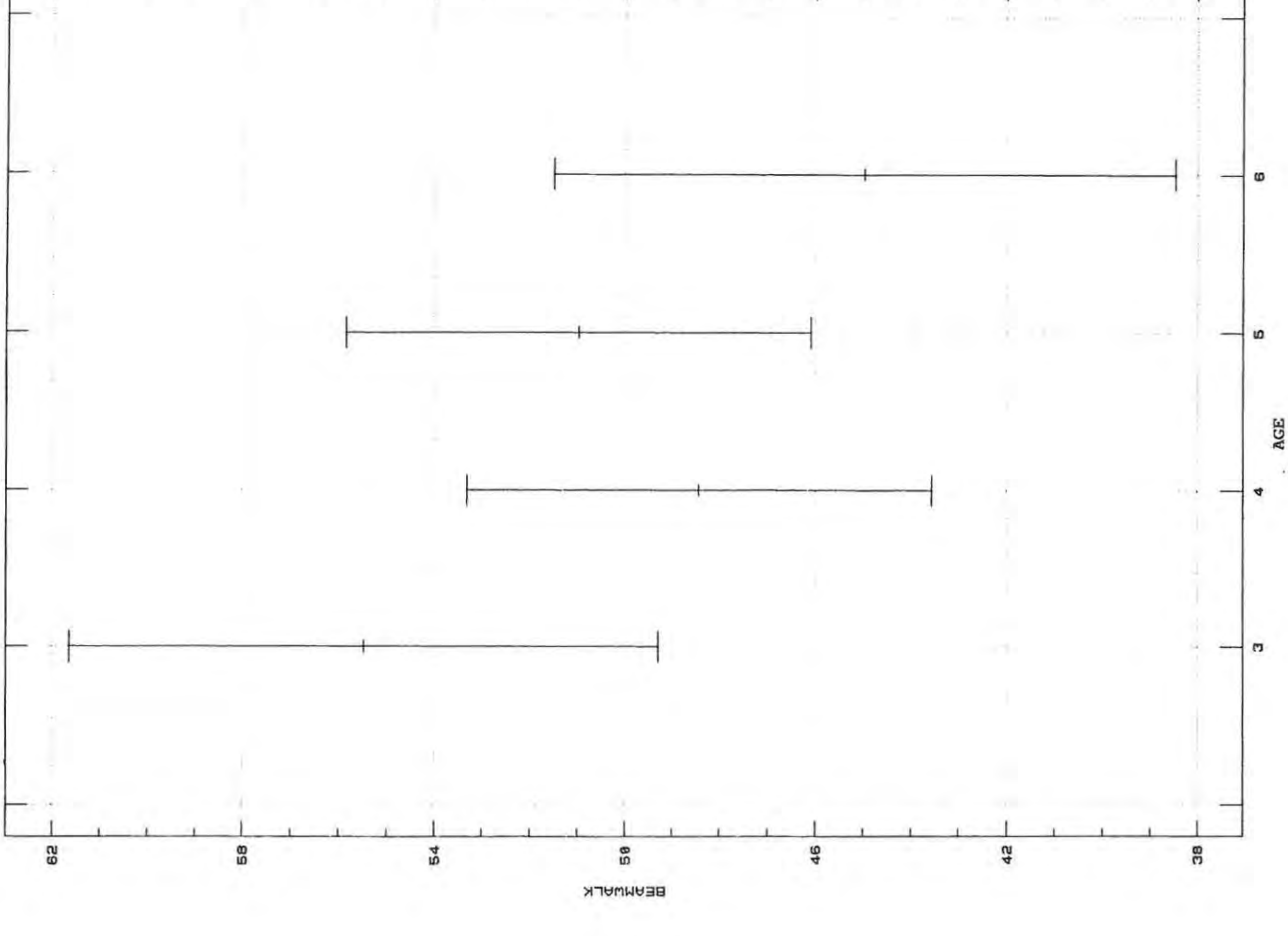


Figure 5

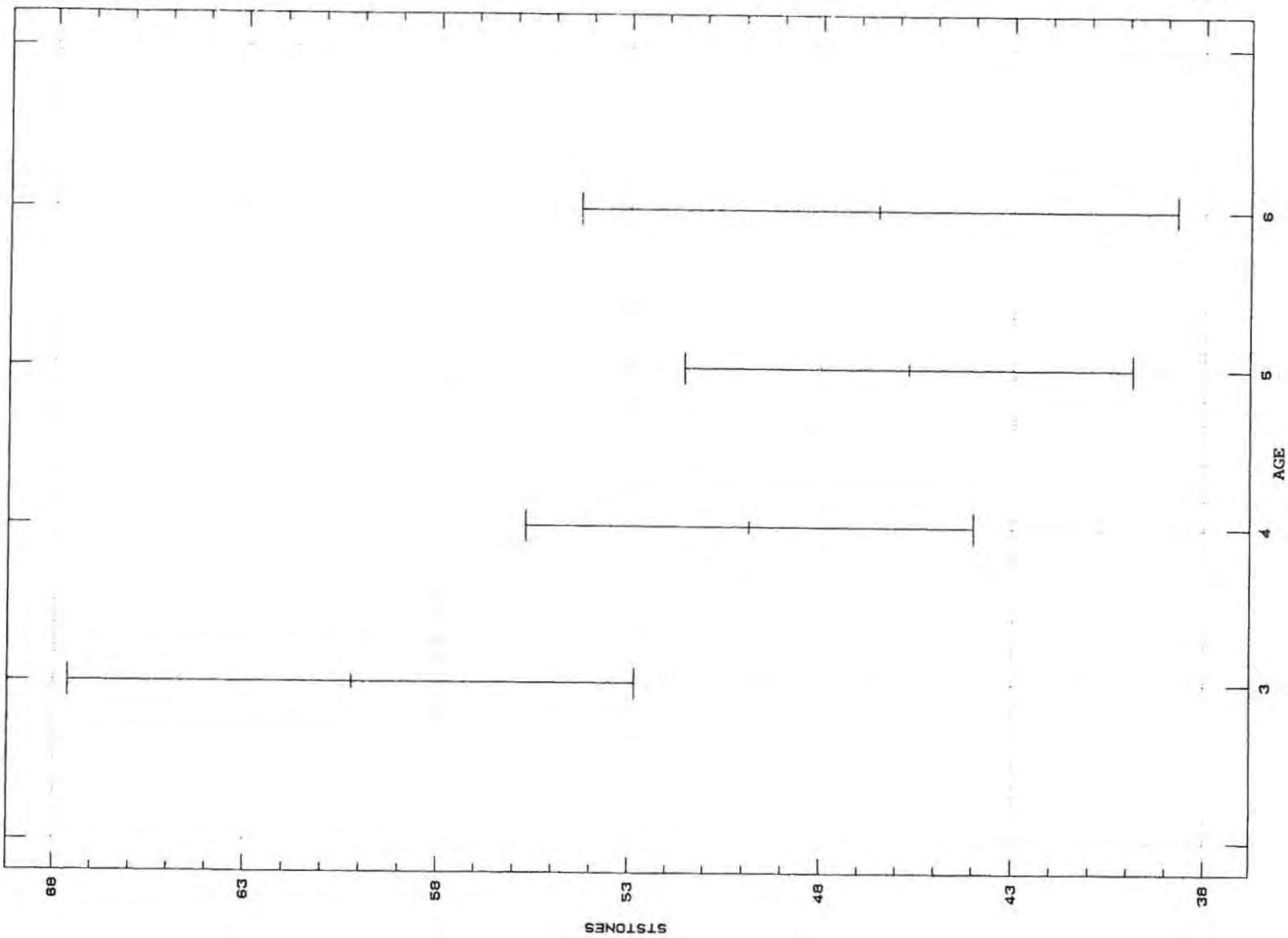


Figure 6

APPENDIX E

Means plots on performance according to gender

Figure 1

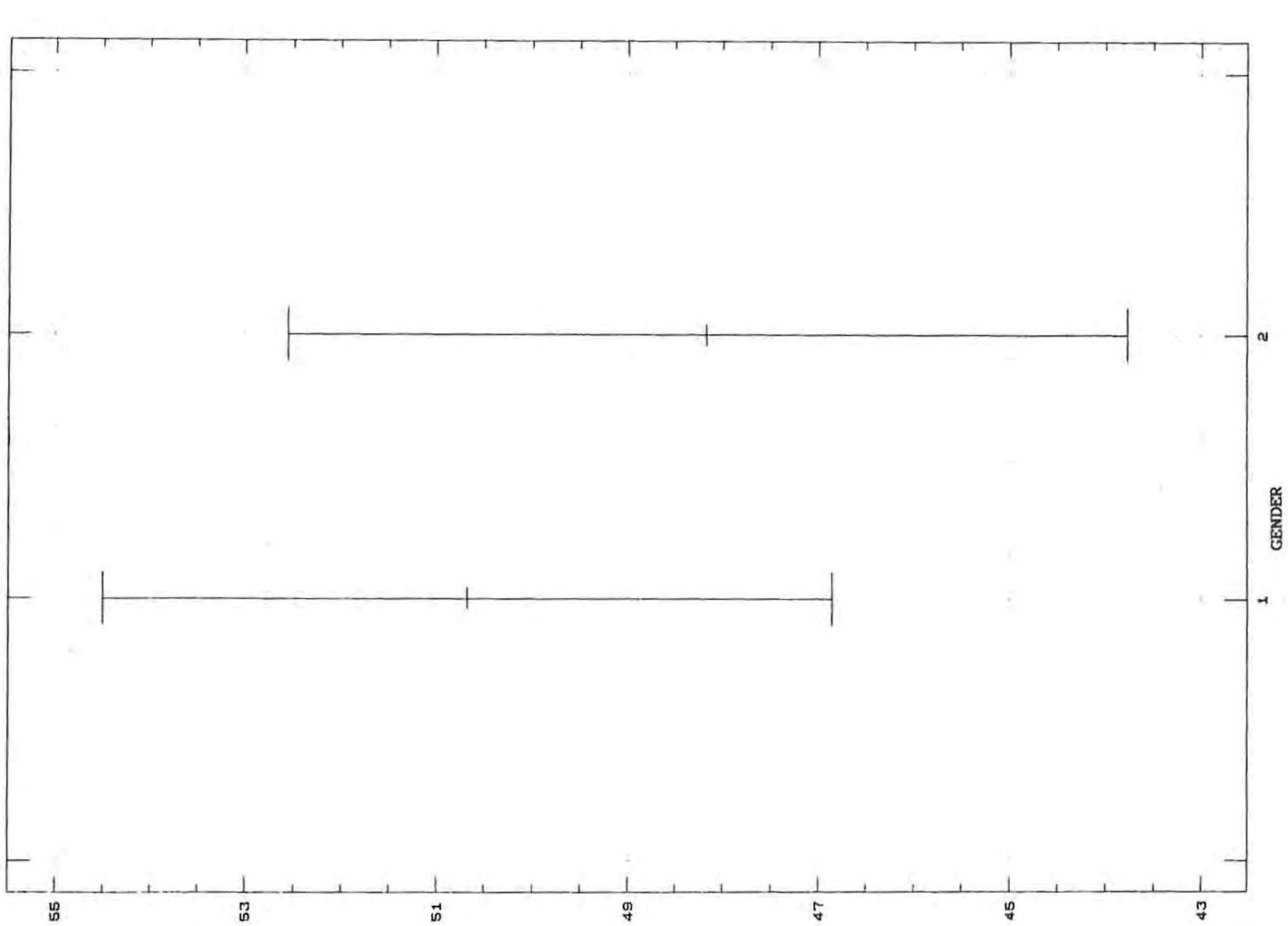


Figure 2

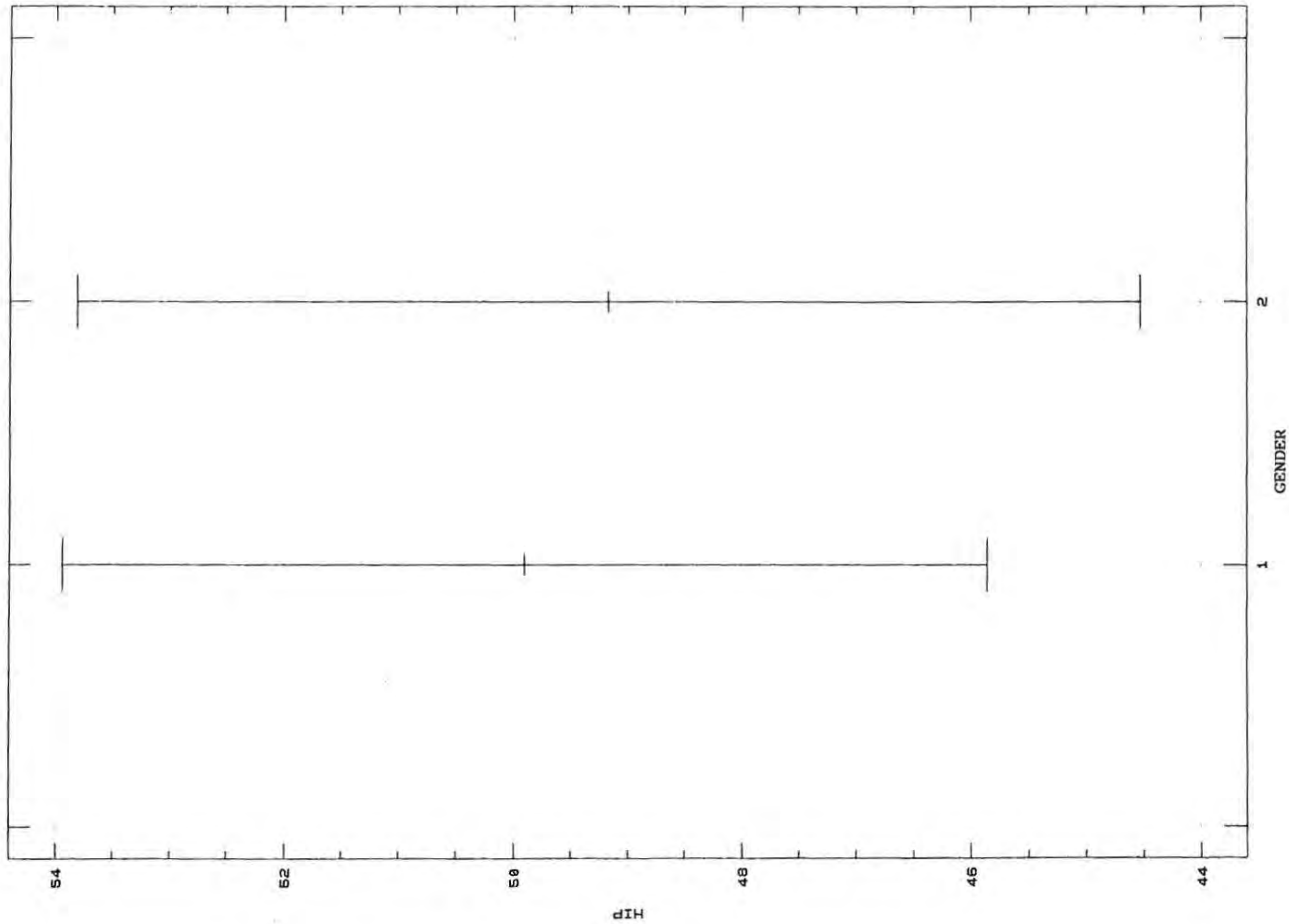


Figure 3

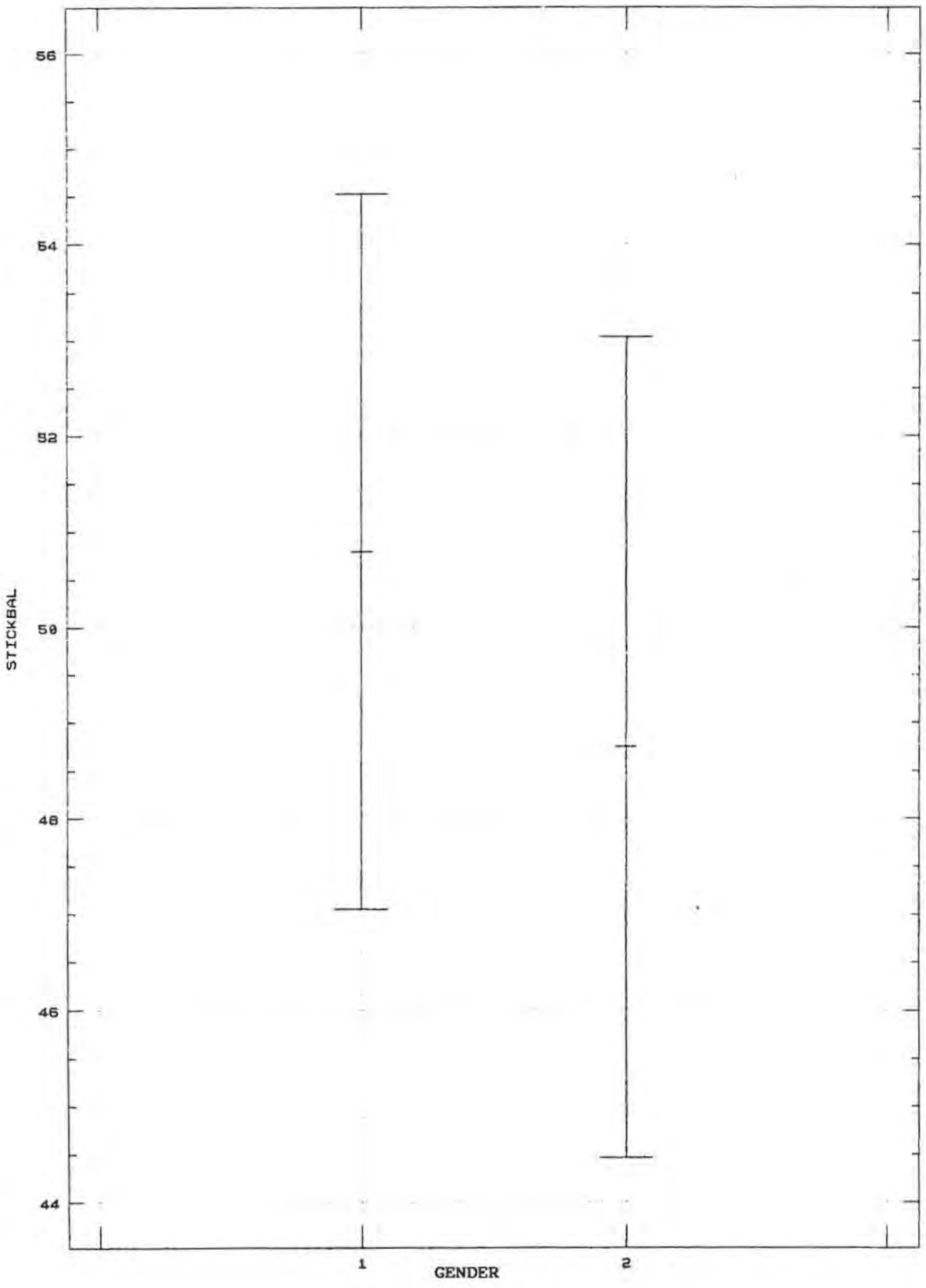


Figure 4

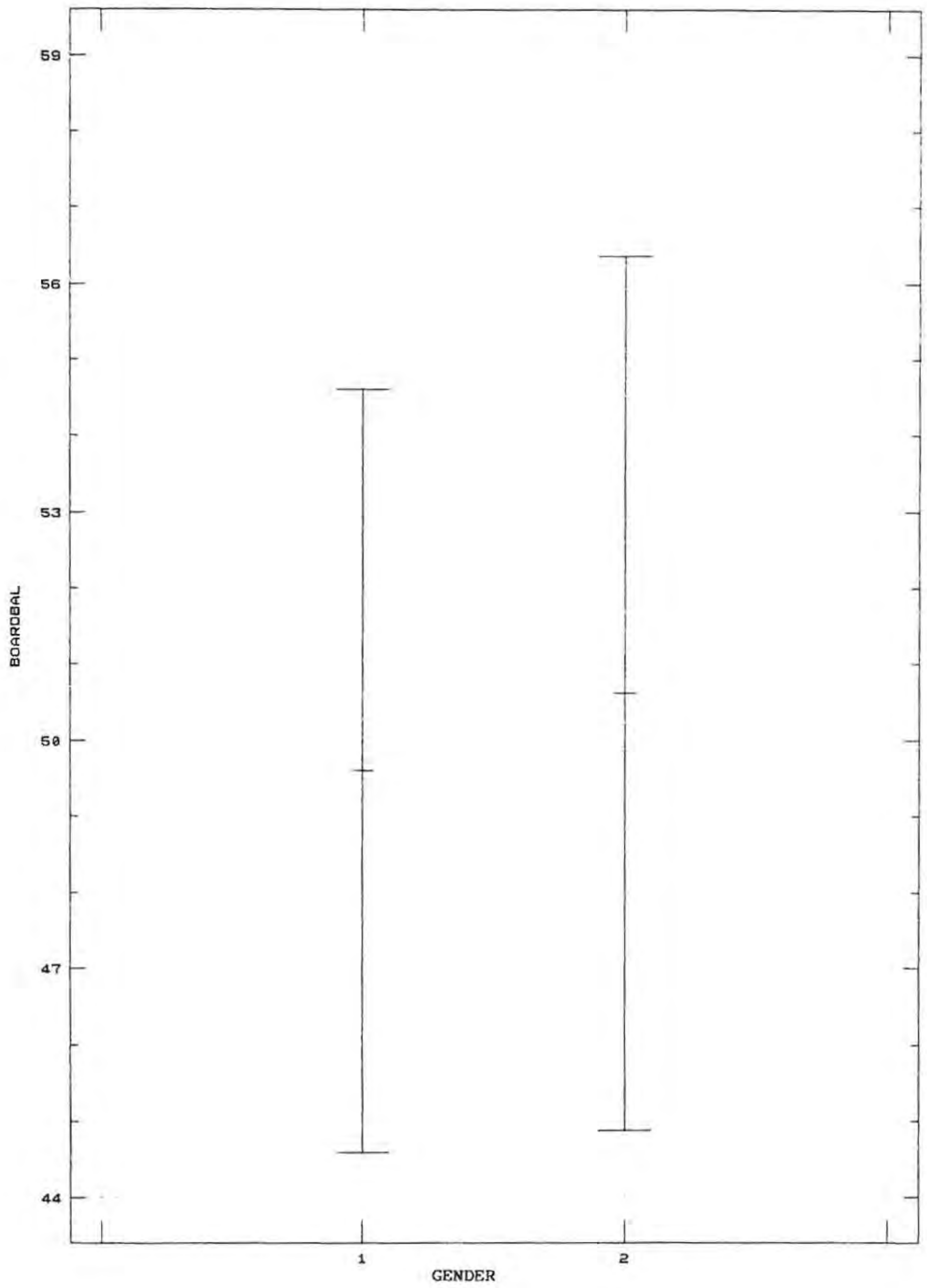


Figure 5

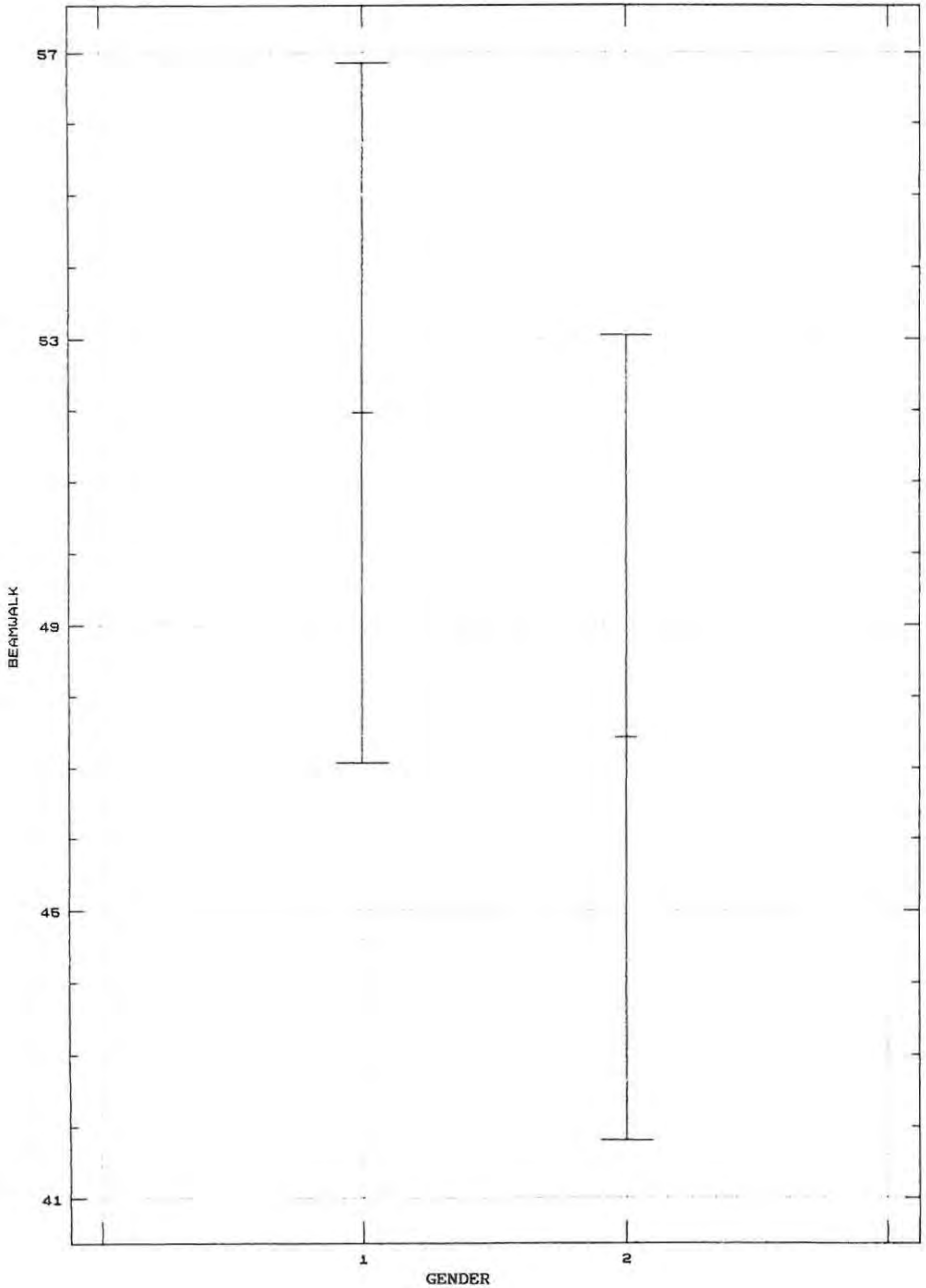
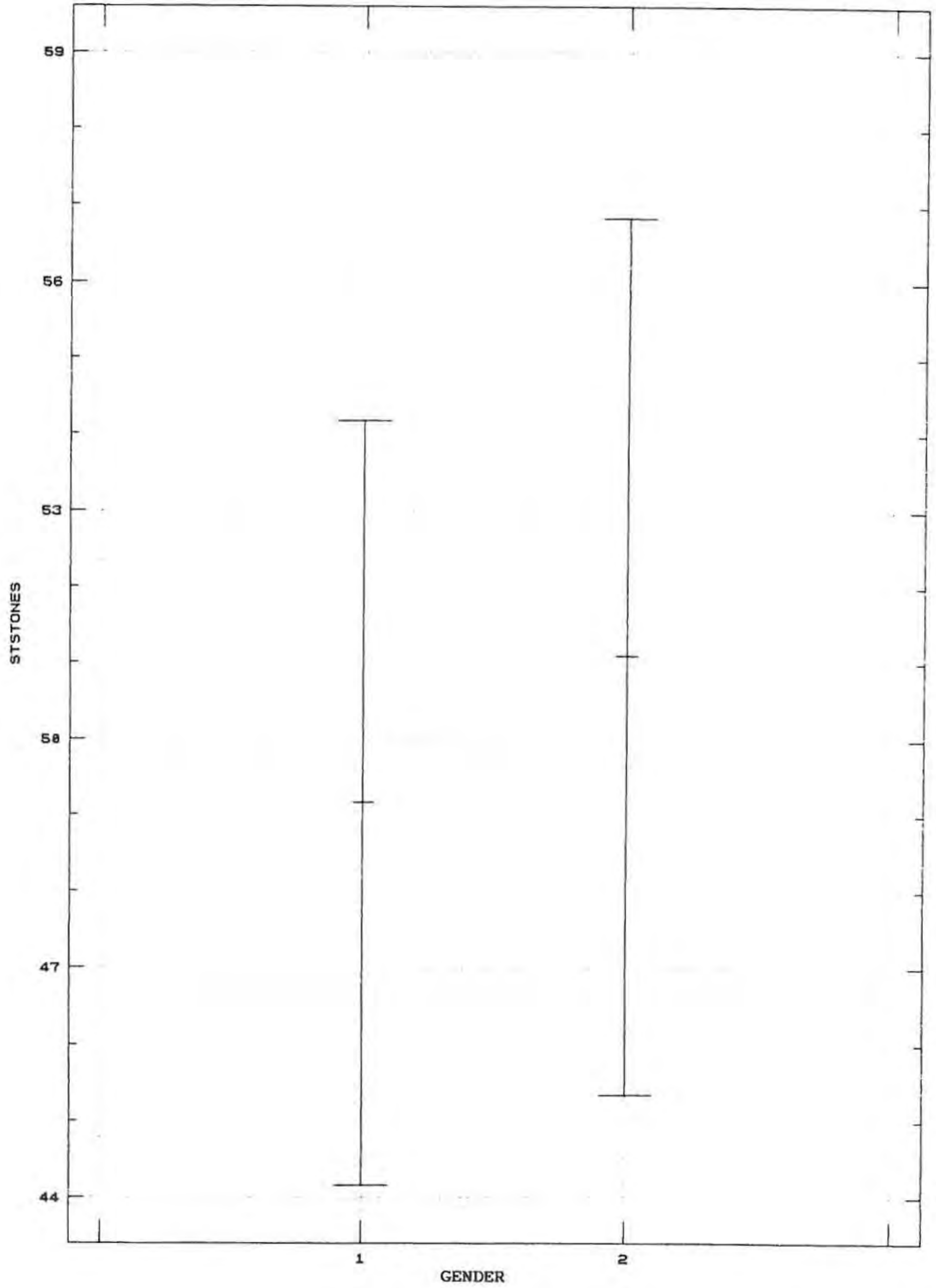


Figure 6



APPENDIX F

Individual scores showing direction of error in kinesthetic tests.

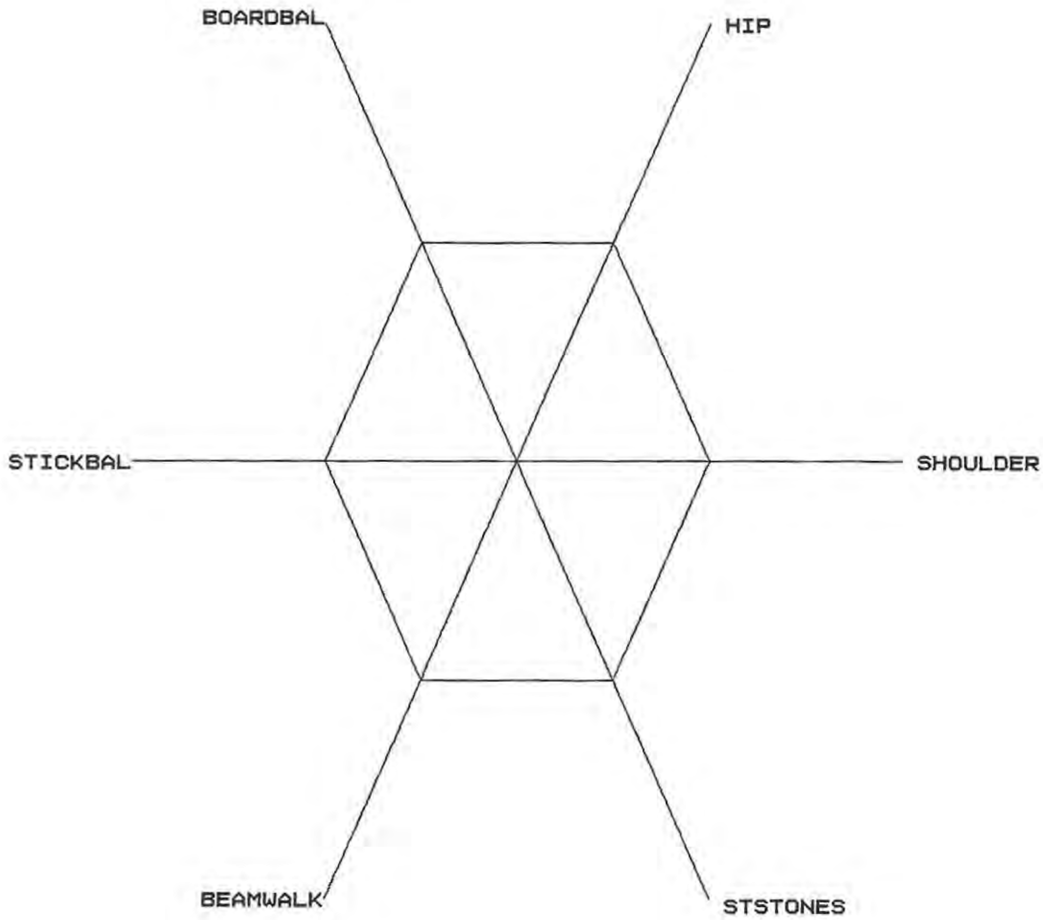
Subject	Shoulder	direction	Hip	direction
THREE YEARS				
1.	11.8	+	6.4	+ (1)
2.	6.0	+	10.4	- (2)
3.	9.0	+	3.8	+ (1)
4.	8.2	-	12.6	+ (1)
5.	9.0	+	10.0	+ (1)
6.	11.0	+	5.0	+ (1)
7.	6.8	-	6.8	+ (1)
8.	5.2	-	5.2	- (2)
9.	2.2	-	6.6	- (1)
10.	7.4	-	5.0	- (2)
FOUR YEARS				
11.	10.0	+	4.4	- (2)
12.	7.8	+	9.0	+ (1)
13.	4.2	-	5.0	- (2)
14.	7.6	-	11.0	+ (1)
15.	4.8	+	7.8	- (2)
16.	4.0	-	6.4	+ (1)
17.	7.0	-	6.6	- (2)
18.	3.8	-	7.0	+ (2)
19.	4.8	-	4.0	- (2)
20.	8.2	-	4.6	+ (2)
21.	5.8	-	3.0	- (2)
22.	6.0	-	7.0	+ (1)
23.	8.4	-	10.8	+ (2)
24.	6.0	-	7.0	- (2)
25.	6.4	-	2.4	+ (2)
26.	2.6	-	8.0	+ (1)

Individual scores showing direction of error in kinesthetic tests (continued).

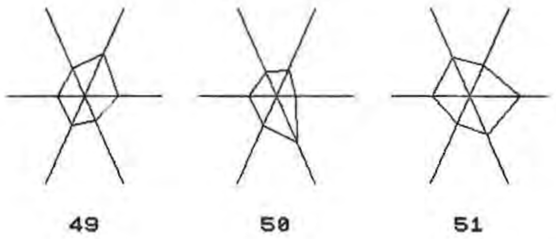
Subject	Shoulder	direction	Hip	direction
FIVE YEARS				
27.	9.8	-	6.8	- (1)
28.	4.6	+	6.0	- (1)
29.	7.0	-	4.0	+ (1)
30.	4.4	-	1.4	+ (2)
31.	4.8	-	8.2	+ (2)
32.	3.0	-	2.8	- (1)
33.	8.4	+	10.4	- (1)
34.	6.0	-	6.4	+ (2)
35.	3.6	-	4.2	- (1)
36.	8.4	-	6.0	+ (1)
37.	5.4	-	2.8	+ (1)
38.	10.0	+	11.0	- (1)
39.	1.8	+	3.2	- (1)
40.	7.0	-	3.0	- (2)
41.	2.4	-	11.2	+ (2)
42.	10.8	-	12.0	- (2)
SIX YEARS				
43.	1.8	+	6.8	+ (1)
44.	6.4	-	3.4	- (1)
45.	10.0	+	8.8	- (1)
46.	3.0	-	3.0	- (2)
47.	8.0	-	10.0	- (1)
48.	3.2	-	7.2	+ (2)
49.	5.0	-	6.0	+ (1)
50.	2.0	+	2.6	- (1)
51.	8.6	-	3.6	- (1)

APPENDIX G

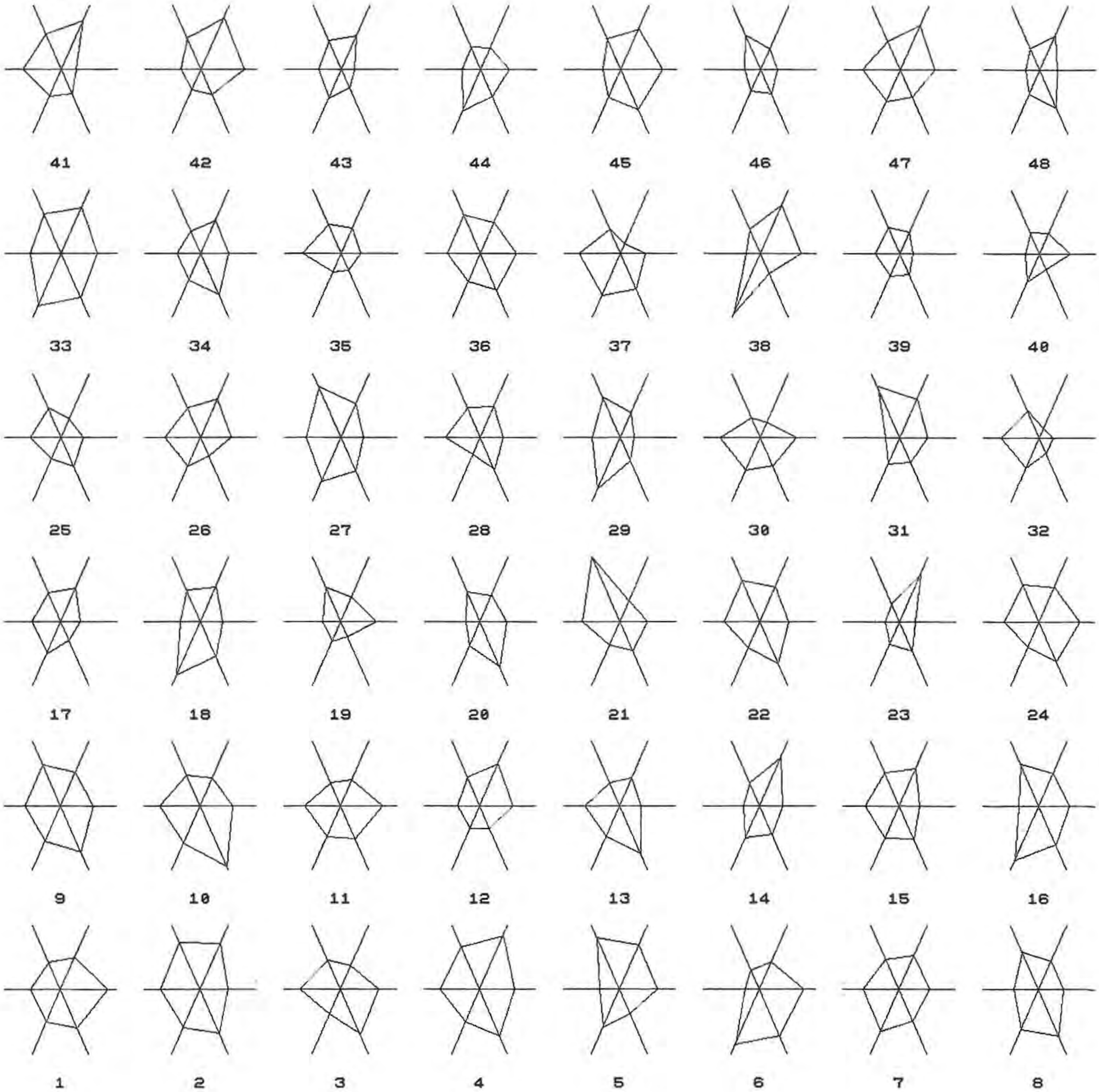
Key to Sunray Plots (p. 186).



This plot represents a 50% error rate on all tests. In the following plots: the closer the points are to the center of the ray, the fewer the errors and therefore the better the performance.



Sunray Plots: indicating individuality of performance on the six tests.



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