UNIVERSITY OF ALBERTA

# ASYNCHRONOUS EARLY GROSS MOTOR DEVELOPMENT: ITS IMPACT ON LATER MOTOR SKILLS

BY

JANICE L. EVANS

A thesis submitted to the Faculty of Graduate Studies and Research in partial fulfilment of the requirements for the Degree of MASTER OF SCIENCE.

DEPARTMENT OF PHYSICAL THERAPY

EDMONTON, ALBERTA

FALL, 1993

ISBN 0-315-88401-0

UNIVERSITY OF ALBERTA

RELEASE FORM

NAME OF AUTHOR: Janice L. Evans

TITLE OF THESIS: Asynchronous Early Gross Motor Development: Its Impact On Later Motor Skills

DEGREE: Master of Science

YEAR THIS DEGREE GRANTED: 1993



Jan Evans

59 Thorncrest Cres.
London, Ontario, N6J 1K4

Date: June 22, 1993

UNIVERSITY OF ALBERTA

FACULTY OF GRADUATE STUDIES AND RESEARCH

The undersigned certify that they have read, and recommend to the Faculty of Graduate Studies and Research for acceptance, a thesis entitled ASYNCHRONOUS EARLY GROSS MOTOR DEVELOPMENT: ITS IMPACT ON LATER MOTOR SKILLS submitted by JANICE L. EVANS in partial fulfilment of the requirements for the degree of MASTER OF SCIENCE.

Martha Piper

Dr. Martha Piper

Joyce Magill-Evans

Dr. Joyce Magill-Evans

Sharon Warren

Dr. Sharon Warren

Date: June 11, 1993

ABSTRACT

The purpose of this study was to determine the prevalence of asynchronous gross motor development in early infancy and to determine the impact of early asynchrony on later gross and fine motor performance. The prevalence was determined from a stratified random sample of infants, 3-12 months of age (n=1691), based upon their Alberta Infant Motor Scale (AIMS) scores. Asynchronous gross motor development was defined as one AIMS subscore ≤ -1 standard deviation below the mean, all other AIMS subscores and AIMS total score > -1 standard deviation below the mean. A cohort of infants who were asynchronous in the prone postural plane (n=19) or in the sit postural plane (n=21) were followed prospectively to determine their motor outcomes in their second year of life.

Asynchronous gross motor development occurred in 15% of the population. The frequency of asynchrony in the sit, stand, and supine postural planes varied as a function of age. The frequency of asynchrony in the prone postural plane was consistent across ages. The prone asynchronous infants were significantly different from their matched controls on age of walking (p=.02), while the sit asynchronous infants did not differ. No significant difference was found between asynchronous infants and their matched controls on gross motor or fine motor performance in the second year of life, as measured by the Peabody Developmental Motor Scales (PDMS) and by the Minnesota Child Development Inventory (MCDI).

It is not uncommon for the 4 postural planes of movement to develop at asynchronous rates. Asynchronous early gross motor development does not have a negative impact on the motor performance of infants in their second year of life. This finding provides support to the assumptions of the dynamic motor theory that development is nonlinear and asynchronous. Infants marked by early asynchronous prone skills are slower to walk but catch-up in their motor performance before their second birthday. These infants follow a distinct developmental pathway and are worthy of future study.

ACKNOWLEDGEMENTS

I wish to express my thanks and appreciation to the following people and institutions for their support and assistance in completing this thesis.

To my advisor, Dr. Martha Piper, for inspiring and challenging my ideas and thoughts, for assisting me in determining the topic for this thesis, and for modelling exceptional research, and writing skills. I would especially like to thank her for providing supervision to my studies in the midst of her very busy and challenging responsibilities.

To my committee member, Dr. Sharon Warren, for assisting me in unravelling the complexities of research design and statistical interpretation. Special thanks for her consistently positive and encouraging demeanor.

To my committee member, Dr. Joyce Magill-Evans, for her interest and enthusiasm for my topic, for her very thorough reviews of the drafts, and for her encouragement and support throughout my studies.

To Dr. Jean Wessel, Chairman of the Graduate Program, for being readily available and helpful.

To Annette Kujda, for orienting me to the pediatrics lab, for assisting me in numerous tasks, and for her patience while providing me access to the AIMS Norming data.

To all the families who willing gave of their time to assist in this research.

To the members of the Logos group who provided ongoing support, encouragement, and prayer throughout my thesis journey.

And finally to my friends across the miles, especially Ellie and my Mom, who believed I could complete the project and supported me through all the many ups and downs.

Appreciation is also extended to NHRDP, the funding agency that provided the grants for the AIMS Norming Study from which my data originated.

TABLE OF CONTENTS

APPENDICES

LIST OF TABLES

## LIST OF FIGURES

# CHAPTER 1

## PROBLEM STATEMENT

Although average ages of attainment of specific motor milestones have been defined, tremendous variability exists in these norms. The pursuit of a clear definition of abnormal development and its predictors continues to intrigue researchers. While Illingworth (1987) cautions clinicians not to make hasty conclusions concerning infants who present with atypical patterns of development, the question remains as to the limits of variability in normal development.

Physical therapists are often called upon to assess infants whose gross motor development varies from the accepted norm. Typically, early motor development progresses simultaneously in all four postural planes; supine, prone, sitting, and standing. Occasionally parents or a physician identify an infant who is lagging behind in one postural plane, but progressing well in the others. These asynchronously developing infants cause concern for parents and professionals alike. It is unclear whether or not such atypical gross motor development represents abnormality or acceptable normal variability. Some physical therapists attribute little significance to asynchronous development, while others provide intervention in an attempt to fill in the gaps in the infant's development.

A better understanding of the relationship between development in the four postural planes will contribute to our knowledge of early motor development and the assumptions underlying early motor development theory. Implicit in pediatric physical therapy assessment and treatment are the assumptions of an invariant gross motor development sequence and the relationship between developmental skills in the postural planes. Recently physical therapists have begun to question these assumptions and their resulting treatment implications (Attermeier, 1991; Atwater, 1991; Van Sant, 1991).

The aim of this study is to describe asynchronous gross motor development in early infancy and to determine empirically its impact on later gross and fine motor performance.

# CHAPTER 2

# LITERATURE REVIEW

## Introduction

Infants with asynchronously developing gross motor skills have not been previously described in the literature. In general, variations from the predicted motor development sequence have been de-emphasized in the motor development literature (Newell & van Emmerik, 1986). The focus has been on the uniformity of motor development. Theories of motor development can be used to make predictions concerning the developmental outcome of infants demonstrating atypical development. The most commonly cited theory of infant motor development is the neuromaturational theory. The tenets of this theory will be presented and, in turn, the developmental predictions generated by this theory.

Studies describing infants with variable motor development will then be discussed. These variations include alternative locomotor strategies used by infants prior to independent walking and environmentally induced atypical motor development sequences. Lastly, a new perspective on motor development generated by the dynamic motor theory, will be introduced. This theory provides the basis for a different prediction for the developmental outcome of asynchronously developing infants.

The Neuromaturational Theory of Motor Development

The theoretical foundation of pediatric physical therapy is the neuromaturational theory (Heriza, 1991). The normal developmental principles drawn from this theory form the basis for therapists' clinical decision making and intervention strategies.

The neuromaturational theory of motor development evolved from Gesell's (1954) and McGraw's (1943) observations of normally developing infants. Both of these developmentalists drew a similar conclusion; maturation of the central nervous system (CNS) is the major contributor to gross motor development. This prescriptive model assumes that behaviours are derived solely from instructions originating in the brain.

The observations made by these researchers are the foundation for the prescribed timing and sequence of developmental milestones, the basic components of most standardized gross motor assessments. Many of the commonly held assumptions concerning motor development find their origins in the work of Gesell and McGraw. Such assumptions include: reflexive control precedes voluntary control, movement progresses in a cephalocaudal direction and from proximal to distal, the sequence of motor development is predictable and invariant, and its rate is consistent for each individual (Piper & Darrah, in press).

The assumptions that underlie the evaluation of the asynchronously developing infant are directly related to the proposed invariant sequence and consistent intraindividual rate of development.

The developmental sequence and the relationship between the postural planes are central to our traditional therapeutic approaches. Rood identified several items in the developmental sequence as crucial for higher level performance (Attermeier, 1984). For example, she stated that prone extension and four point kneeling incorporate critical motor competencies leading to ambulation. Bly (1981), a proponent of the neurodevelopmental therapy (NDT) approach, described the relationship between developing motor competencies in each of the postural planes, and the emergence of specific motor skills. For example, prone antigravity extension abilities combined with supine antigravity flexion abilities result in the emergence of independent sitting in the 6 month old. Similarly, pediatric physical therapy textbooks (Campbell, 1984; Scherzer & Tscharnuter, 1990; Tecklin, 1989;) all cite the critical importance of the developmental sequence in understanding and evaluating normal development.

An invariant sequence of motor development implies that development is linear and continuous. Early sequential behaviours are believed to be critical to the emergence of later more advanced skills. Scherzer and Tscharnuter (1990) stated, "Motor development should be seen as a succession of integrated milestones leading to more complex and independent function. Each stage is interdependent and relates closely to progressive control of higher centers of the nervous system and reduced influence of fixed reflex behavior " (p. 24). A cause-effect relationship between stages is suggested. According to this principle, sitting precedes crawling, crawling precedes walking, and sitting and crawling are prerequisites for the emergence of walking. These assumptions are incorporated into treatment. It is a common practice for physical and occupational therapists to facilitate components of movement in one position to prepare for more advanced motor skills in another position. For example, crawling and kneeling activities are used to improve pelvic control in preparation for standing and walking.

It is interesting to note that both Gesell and McGraw documented a considerable interindividual variability in the acquisition of gross motor skills in the infants that they observed. Benson (1991) has recently made the point that researchers working with Gesell acquired data that identified infants who skipped various motor stages. In spite of these findings, the early developmental researchers strongly adhered to the principle of a universal intransitive sequence of motor development. Acceptance of this assumption continues to prevail in the field of motor development today.

The asynchronously developing infant viewed from a neuromaturational perspective demonstrates evidence of delayed maturation of the appropriate part of the nervous system. The explanation for aberrant behavior must be cognitively or neurologically defined, according to this prescriptive theory. Given the proposed interplay between the postural planes, an asynchronous lag could conceivably delay the progression of more advanced gross and fine motor skills. These conclusions imply that therapists should provide intervention for these infants to minimize the effects of their aberrant development.

Variations in the Motor Development Sequence

Some researchers have documented their observations of variations in the motor development sequence. Touwen (1976) observed omissions and reversals in the developmental sequence. He identified some infants who could stand before sitting up and some infants who did not crawl before walking.

In the development of postural reactions a deviation from the normal sequence has also been noted. Haley (1986) observed considerable variability between nonhandicapped infants and reversals in the expected sequence. He concludes a general sequence can be described but a significant number of infants do not follow this order.

Infants who display locomotor strategies other than crawling prior to independent walking have been studied by many researchers (Bottos et al., 1989; Largo et al., 1985; Robson, 1984). These children are of interest because they demonstrate that the presumed invariant developmental sequence can, in fact, vary. While all of these infants are delayed in their prone development, many also lag behind in their development of sitting and standing.

The presence of four point crawling in the developmental sequence appears to be common but not mandatory. Eighteen percent of Robson's (1984) full term sample, 28% of Bottos' et al. (1989) preterm and full term sample, and 13% of Largo's et al. (1985) preterm and full term sample, did not crawl prior to independent walking. The alternative locomotor strategies observed in infants before walking included rolling, creeping, shuffling, and no locomotion prior to walking.

Shuffling refers to a movement across the floor in the sitting position where the hands and/or feet are used for propulsion (Robson & MacKeith, 1971). While shuffling has been associated with diplegic and hemiplegic cerebral palsy, it has also been reported in infants who have no neurological symptoms (Largo et al., 1985; Robson & MacKeith, 1971; Robson, 1984). Robson (1970) followed a cohort of infants who shuffled in their first year of life. These infants walked significantly later then infants who crawled but had a normal gait pattern by age 3. Bottos et al.(1989) followed a cohort of preterm and full term infants until they were 5 years of age. The locomotor strategies used by each infant prior to walking were recorded. The shufflers and creepers walked later than children who crawled. However, a few infants who 'just stood up and walked', walked at an earlier age then the crawlers. Language development and IQ were evaluated at the 5 year examination. They concluded that non-creeping and non-crawling strategies did not have a negative impact on later development.

The studies cited above suggest that motor development does not always follow one pathway; rather several options are possible. While alternative prelocomotor strategies appear to be a slower route to the attainment of independent walking, the long term outcome of these children appears normal. The outcome typically reported in the studies evaluating prelocomotor strategies was age of independent walking. The possible effect of atypical early motor development on motor performance has not been systematically investigated.

Environmentally Induced Variations in Gross Motor Development

Child-rearing practices have been shown to be associated with variations in the motor development sequence. Crouchman's study (1986) found the use of baby walkers was significantly associated with a delay in the development of prone locomotion, and some infants were seen to miss the prone mobility stage completely. The age of independent walking for these atypically developing infants did not differ from the normally developing control infants. No other outcome measures were evaluated in this study.

Super (1976) observed a group of infants in western Kenya who were specifically taught by their parents to sit and walk. These babies were taught to sit beginning around the fifth or sixth month. The parents dug a special hole in the ground and sat their infants in the hole such that their backs were supported. Jumping activities in the parents' laps and assisted stepping were also frequently practised. The motor development of these infants was observed to be asynchronous; they sat and walked alone earlier than American babies, while their attainment of prone skills was delayed.

Cross cultural deprivation studies provide some interesting insights into the relationship between early gross motor experience and later motor development. Balinese infants (Cintas, 1989) are not permitted to creep or crawl. In spite of this lack of experience in the prone position these infants when studied were found to attain standing and walking at the expected age. The Hopi Indian society has been studied by several researchers due to their unusual practise of strapping their infants to cradle boards for the first 4-6 months of life. Infants subjected to cradling were not found to be delayed in their age of independent walking when compared to noncradled Hopi infants (Harriman & Lukosius, 1982). Thus, milestone omissions due to environmental circumstances did not alter the time of emergence of independent walking.

The findings from the above studies challenge the assumption that early gross motor milestones are prerequisite to later motor development. When asynchronous motor development is environmentally induced it appears not to have an impact on the acquisition of independent walking. Gross and fine motor development performance were not formally evaluated in these studies.

## The Dynamic Motor Theory of Motor Development

In the last decade the dynamic motor theory has been extended into the field of motor development (Heriza, 1991). This new perspective views motor development as the result of dynamic interactions between many subsystems. This contrasts with previous theories that see motor behavior as the product of prescribed instructions originating in the CNS. The CNS is seen as a necessary component of the system, but it acts in cooperation with biomechanical, psychological, and environmental elements (Heriza, 1991).

The major principles of the dynamic motor theory are described below.

1) Motor behaviours result from the input of many different subsystems. No one element is independently

responsible for action. Consideration must be given to the contribution of the CNS, perceptual system, postural control system, musculoskeletal components and affective system. Thus, this theory recognizes the role of nonneural components in the organization of movement.

2) Dynamic systems are non-linear. Knowledge of one element in the system is not sufficient to make predictions concerning behaviours. The subsystems may mature asynchronously, that is, one system may be maturing rapidly while another is maturing slowly.

3) Systems exhibit self organizing autonomous properties. Structures involved in a movement operate synergistically and autonomously; centrally coordinated instructions are not sufficient to account for the complexity of motor acts (Thelan, 1987). Control is seen to be distributed between many structures or sites such that commands can be both initiated and revised at many different levels (Keshner, 1991). The interactions of the subsystems result in motor acts not possible through these subsystems acting independently.

4) Systems are organized in a task specific manner. The nature of the task directly affects the outcome of the multidimensional system. The instructions can be revised in response to the task requirements. The functional goal rather than the instructions drive the action.

The dynamic motor theory provides us with an alternative perspective from which we can view atypical motor development. This theory provides many possible explanations for the variability seen in motor development. The theory expects development to be nonlinear and asynchronous (Thelen, 1987).

The pathway to independent walking chosen by a specific infant could be a reflection of their biological characteristics. For example, an infant with unusual body proportions, a hypotonic infant, or one with hypermobile joints may choose shuffling rather than crawling as a locomotor strategy (Bottos et al., 1989). Each infant is embarking on the same task, independent locomotion; however, individual differences in biological characteristics can lead to different patterns of movement to achieve the same task.

The dynamic motor theory provides an explanation for the avoidance of a certain plane of movement such as prone or sitting. Certain biological characteristics may be one factor explaining this phenomenon. Infants may avoid prone lying due to weakness in their neck muscles or trunk extensors. A disproportionate head size could also be causing an apparent weakness. Sitting may be avoided due to muscle shortening, joint hypomobility, or hypotonia.

Environmental experiences such as parental training, parental positioning and handling, or movement deprivation are other factors recognized by the dynamic motor theory as important contributors to motor development. Research findings demonstrating the association between environmental experiences and atypical motor development have been cited above.

The dynamic motor theory also recognizes the influence of psychological variables on motor development. These variables include the infant's emotional state, level of motivation, and cognitive abilities (Piper & Darrah, in press).

The intraindividual variability seen in infants' gross motor development may be explained by the asynchronous nature of complex systems (Thelen, 1987). A specific subsystem may be developing slower than other subsystems thus delaying the acquisition of certain motor skills. A 'catch up' may then occur when the slowest component matures. Therefore, an infant presenting with atypical motor development early in life could demonstrate normal motor performance later in life.

Conclusion

It is uncertain whether or not early asynchronous gross motor development is detrimental to the future developmental progress of infants. It has been assumed that early motor behaviors are prerequisite to later more complex gross and fine motor activities. This assumption has often guided treatment planning (Attermeier, 1991). Specific research to test this assumption has not previously been reported.

Related research has identified alternative locomotor pathways which have not resulted in detrimental effects to the developing infant. Also asynchronous early motor development has been described by researchers in association with specific child care practices. These infants subsequently progressed to independent walking in the expected time span. These findings suggest that infants can develop subsequent motor skills in spite of early gaps in their development. However, all of these studies used age of independent walking as the only motor outcome measure. Gross and fine motor performance were not specifically evaluated.

The neuromaturational theory of motor development and the dynamic motor theory of motor development provide different predictions for the outcome of these infants. If motor development is driven by neuromaturation alone, then infants who do not follow the normal developmental pathway in the first year of life should demonstrate below average motor performance later on in their lives. If the four postural planes of movement interact to achieve the various motor milestones, then a lag in one postural plane should have a detrimental effect on the performance of higher level motor skills. If on the other hand, motor development is the result of the interaction between a number of systems and subsystems then asynchronous motor development may reflect a problem in one particular subsystem only, and may result in only a temporary setback. Therefore, future motor development could proceed normally.

The data obtained in this study will first of all provide a description of asynchronous motor development. It will be determined if this pattern of motor development is atypical or common, at what ages it is manifested, and in which postural planes it occurs. Second, the empirical data will be used to test theoretical constructs of the neuromaturational and the dynamical motor theory. If the results match the theoretical predictions of these theories then they will in turn be supported. Lastly, the results will help clinicians make more accurate predictions following their assessment of infants with asynchronous patterns of early gross motor development.

# CHAPTER 3

# METHOD

## Overall Objectives

1. To determine the frequency of asynchronous motor development in infants under 12 months of age and to describe infants with asynchronous motor development in terms of age, gender, ethnicity, birthweight, and gestational age.

2. To determine if asynchronous gross motor development in the first year of life affects gross and fine motor development in the second year of life.

## Specific Objectives

1. To determine the prevalence of asynchronous infants (those whose gross motor development in one postural plane, is behind their development in the other 3 postural planes) in a sample of infants aged 5-9 months.

2. To describe the above infants according to their gender, ethnicity, gestational age, and birthweight. To compare these asynchronous infants to synchronous infants on the above characteristics.

3. To determine whether infants with asynchronous prone skills or asynchronous sit skills at 5-9 months of age, differ from infants, identified with synchronous gross motor skills at 5-9 months of age, in their gross motor development at 15-21 months of age.

4. To determine whether infants, identified with asynchronous prone skills or asynchronous sit skills at 5-9 months of age, differ from infants, identified with synchronous gross motor skills at 5-9 months of age, in their fine motor development at 15-21 months of age.

Research Hypotheses

1. The asynchronous group of infants will have poorer gross motor performance at 15-21 months than the synchronous group of infants.

a) The asynchronous prone and the asynchronous sit group of infants will have lower mean gross motor age equivalent and raw scores than the synchronous group of infants as measured by the Minnesota Child Development Inventory and the Peabody Developmental Motor Scales.

b) The asynchronous prone and the asynchronous sit group of infants will have attained independent walking at a later age than the synchronous group of infants.

2. The asynchronous prone and the asynchronous sit group of infants will have poorer fine motor performance at 15-21 months than the synchronous group of infants.

a) The asynchronous prone and the asynchronous sit group of infants will have lower mean fine motor age equivalent and raw scores than the synchronous group of infants as measured by the Minnesota Child Development Inventory and the Peabody Developmental Motor Scale.

3. More infants in the asynchronous prone and asynchronous sit group than in the synchronous group will have used a pre-locomotor strategy other than crawling.

4. The number of parents who express developmental concerns regarding their infants will be equal between the asynchronous and synchronous group of infants.

Alberta Infant Motor Scale (AIMS) Norming Study

The AIMS (Piper & Darrah, in press) has been developed over the last 4 years by pediatric researchers in the Department of Physical Therapy at the University of Alberta. This scale is a 58 item observational assessment of motor development from birth to independent walking. (A score sheet which outlines the items is provided in Appendix A.) Infants are assessed in four postural planes; prone, supine, sitting, and standing. Each item is scored dichotomously as either 'observed' or 'not observed', on the basis of specific criteria. The least mature item demonstrated by the child and the most mature item demonstrated by the child are identified in each postural plane. All items between the least and the most mature items, must be demonstrated during the assessment period and subsequently scored as 'observed' or 'not observed'. To score the test, all items scored as 'observed' are credited with one point and all items previous to the least mature item are credited with one point. The points are then tallied for each of the 4 postural planes to obtain the subscores or positional scores. The 4 subscores are then added together to obtain the total score. (See Appendix B for a scoring example.)

The psychometric properties of this scale are impressive (Pinnell, Piper, Darrah, Maguire, Byrne, 1990). The reliability correlations are .99 for inter-rater reliability, and .99 for test-retest reliability. Concurrent validity has been evaluated by comparing the AIMS to the Bayley Psychomotor Developmental Scale (Bayley, 1969) and the Peabody Developmental Gross Motor Scale (Folio & Fewell, 1983). Correlation coefficients of $r=.98$ and $r=.97$ were obtained. Other validity studies are in process.

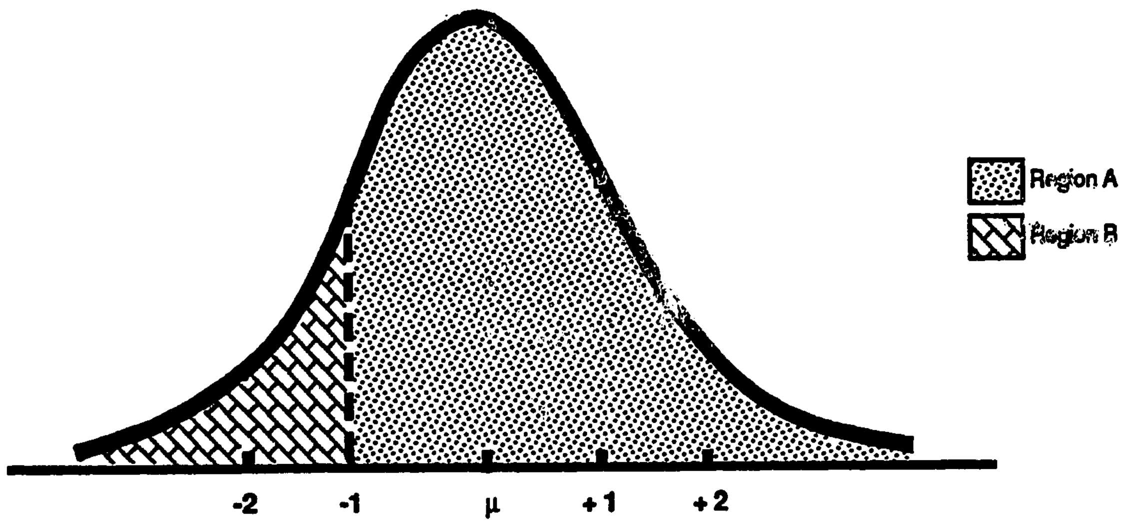
Normative data for the AIMS were collected between Sept. 1991, and June 1992, on a cross-sectional representative sample of 2200 Albertan infants between birth and 18 months of age, stratified for age, gender, and geographic location. From this data, mean scores have been established for total scores and subscores at each age month. Raw scores can be converted into percentile scores. An individual raw score can then be compared to the performance of a normative sample of comparable age. (See Appendix Ci and Cii for norms.)

Definition of 'Asynchronous' and 'Synchronous'

Infants were labelled 'asynchronous' if they met the following criteria: AIMS total score is > -1 standard deviation below the appropriate age mean, with one subscore being ≤ -1 standard deviation below the mean, and the other 3 AIMS subscores being > -1 standard deviation below the mean. Infants were labelled 'synchronous' if they met the following criteria: AIMS total score and each subscore being > -1 standard deviation below the appropriate age mean. (see Fig 1) (From previewing the data it was determined that a cut off of -2 standard deviations below the mean for the subscores would result in too small a sample size.)

## Figure 1

## DEFINITION OF ASYNCHRONOUS AND SYNCHRONOUS




Definition of Asynchronous:

AIMS total score falls in region A
One AIMS subscore falls in region B

Definition of Synchronous:

AIMS total score and all subscores fall in region A

## Study Design

This study is comprised of 2 parts. First, the AIMS norming data were analyzed to determine the frequency and characteristics of infants with asynchronous scores who were 3-12 months old at the time of their AIMS assessment.

Second, a cohort of infants presenting with asynchronous motor development was followed prospectively to determine gross and fine motor performance outcomes. Infants aged 5-9 months, living in Edmonton with asynchronous prone or sit subscores were identified and their parents were contacted requesting their participation in a follow-up study. Two control infants living in Edmonton, with synchronous motor development were identified and matched with each asynchronous infant according to age at the time of the AIMS assessment, date of birth (month and year), and gender. Of the two matched control group infants, the one with the smallest ID number was contacted first and if they were unavailable the second control group infant was contacted. The families of all identified infants were sent an introductory letter and contacted by phone to obtain their consent to participate in the study. Each willing participant was asked to bring their child to the University of Alberta for an assessment of their gross and fine motor skills by a pediatric physical therapist. Each parent completed a developmental questionnaire prior to their child's assessment. The outcome data were then analyzed to see if the asynchronously developing infants differed from the synchronously developing infants in their gross and fine motor performance.

Follow-up Sample

From previewing the AIMS normative data it was determined that the majority (77%) of infants with asynchronous scores were 5-9 months of age. The postural planes of prone and sit were chosen for follow-up due to their clinical significance. Early prone skills are often associated with developing gross motor skills, and early sit skills are often associated with developing fine motor skills. Therefore, cases ('asynchronous infants') were identified from the AIMS normative study sample, who were 5-9 months at the time of their AIMS assessment, whose families lived in Edmonton, and whose prone or sit subscore was ≤ -1 standard deviation below the mean with their other 3 subscores and their total score being > -1 standard deviation below the mean.

The control infants ('synchronous infants') were also chosen from the AIMS normative study sample. These infants obtained total scores and all subscores that were > -1 standard deviation below the mean score. Control group infants were matched to asynchronous infants according to age at the time of their AIMS assessment, date of birth (month and year), and gender.

At the time of outcome measurement the infants ranged in age from 15-21 months. The youngest infants had their outcomes measured in the last month of the data collection to ensure that they were 15 months of age.

Data Collection : Measures

Dependent and Independent Variables

The major independent variable was asynchronous gross motor development (sitting or prone) as measured by the AIMS.

The following other independent variables that may have had an influence on gross and/or fine motor development were measured:

a) gender

b) ethnicity - Caucasian, Oriental, Native, Black, other (Capute et al., 1985). Ethnicity was determined in the AIMS norming study through parental report.

c) gestational age at birth in weeks

d) birthweight in grams

Many studies have identified these factors as significantly related to motor outcome (Illingworth, 1987). The above information was extracted from the AIMS norming study information sheet (see Appendix D).

The dependent variables of gross motor performance and fine motor performance were evaluated. Both the Minnesota Child Development Inventory (MCDI) (Ireton & Thwing, 1974) and the Peabody Developmental Motor Scale (PDMS) (Folio & Fewell,

1983) were used to measure these two variables. The PDMS is a direct observational assessment and the MCDI is a parent report measure.

Age of independent walking and prelocomotor strategy were also determined as a measure of gross motor performance. These latter two measures are variables of interest due to their common inclusion in the related literature.

Minnesota Child Development Inventory

The MCDI was used to evaluate gross and fine motor performance. Consenting parents were asked to complete the gross motor and fine motor sections of the Minnesota Child Development Inventory (MCDI) (Ireton & Thwing, 1974). This inventory was mailed to the parents for them to complete prior to their assessment date. The raw scores were calculated and then transformed into age equivalents.

The MCDI was developed for use with children one to six years of age. It uses a parent report format and has been used in mass mailings (Byrne et al., 1986; Glascoe, 1991; Kopparthi et al., 1991) and interviews (Long, 1992). The MCDI contains 320 statements describing behavior and development in the areas of language, comprehension, fine motor skills, gross motor skills, and personal-social development. Parents are instructed to answer 'yes' to statements that describe their child's past or present behaviors. There are 34 items in each of the gross and fine motor subscales. (See Appendix E for a copy of the MCDI gross and fine motor items.)

The MCDI is a standardized measure. It has been estimated that completion of the questionnaire requires a seventh grade reading level and requires 10 - 15 minutes to complete the gross and fine motor sections. Byrne and colleagues (1986) used the inventory with a sample of middle-to-low-income families and reported no difficulty with these parents completing the questionnaire. Reliability coefficients were determined by the split half method only and yielded values of .78 on the gross motor scale and .62 on the fine motor scale for the age range of 12-23 months (Ireton & Thwing, 1974).

Discriminative validity is demonstrated by the mean scores for each scale showing a systematic increase with increase in age throughout the entire age range (Ireton & Thwing, 1974). Concurrent validity has been tested for the MCDI in the infant population by comparing MCDI scores with scores on the Bayley Scales of Infant Development (BSID) (Bayley, 1969). Saylor & Brandt (1986) compared each individual MCDI subscale to the BSID Mental Scale in a sample of infants age 13-20 months. The reported correlation coefficients were r=.67 and r=.72 for the gross motor and fine motor subscales respectively. Kopparthi and colleagues (1991) reported correlation coefficients of r=.84 and r=.80 for the gross and fine motor MCDI subscales respectively relative to the BSID Mental Scale. They reported correlation coefficients of r=.92 and r=.81 for the gross and fine motor MCDI subscales respectively relative to the BSID Psychomotor Scale. Problems have been identified in the literature with the MCDI's ability to correctly categorize infants as abnormal. Sensitivity and specificity levels of 69% and 50% respectively (Byrne et al., 1986) and poor positive predictive values (Kopparthi et al., 1991) have been reported.

In spite of the psychometric weaknesses of the MCDI, it is frequently recommended as a parent report measure of infant development in the literature (Glascoe, 1991; Long, 1992). The MCDI was chosen above other parent report measures because it provides separate gross and fine motor scales, and it has been widely used both clinically and for research purposes.

Peabody Developmental Motor Scale

Gross and fine motor performances were evaluated by the Peabody Developmental Motor Scale. Raw scores were obtained and then converted into percentile rankings and age equivalents.

The PDMS is a standardized measure with separate fine motor and gross motor scales requiring 40-60 minutes to administer both scales. It is useful for evaluating infants and children up to 7 years of age.

Test-retest reliability coefficients of .95 for the Gross Motor Scale and .80 for the Fine Motor Scale and inter-rater reliability coefficients of .97 for the Gross Motor Scale and .94 for the Fine Motor Scale have been reported (Folio & Fewell,1983). Reasonable content, construct and concurrent validity has been demonstrated for the test (King-Thomas & Hacker, 1987). (See Appendix F for a copy of the PDMS items and score sheet.)

Age of Independent Walking

Age of independent walking was ascertained by the parent report questionnaire. Each parent was asked "is your child now walking independently"; if there was a 'yes' response they were then asked "at what age did your child walk independently?". Age was recorded in months. Walking independently was defined as 'taking 5 or more steps unsupported'. All infants were walking prior to their PDMS assessment.

Although mothers may have difficulty recalling their child's age of acquisition of developmental milestones, Hart and colleagues (1978) reported that 100% of mothers accurately recalled the walking milestone when their infants were 18 months old and 96% of mothers recalled this milestone when their infants were 24 months old.

Prelocomotor Strategy

Prelocomotor strategy was assessed as part of the parent questionnaire. Each parent was asked " how did your child move around on the floor prior to walking?". Answers to this question were categorized as 'crawl' or 'other'. Answers of rolling, shuffling, belly crawling, or no mobility prior to walking were categorized as 'other'; crawling on hands and knees or bear walking were categorized as 'crawl'.

General Developmental Screening

In order to obtain a very general developmental screening of each infant their parent was asked to respond to the following question included in the questionnaire: "are you happy with your child's development?". This was an open-ended question in order not to bias or confuse the parents. All answers were categorized as 'yes' or 'no' and the specific concerns were recorded. A study by Glascoe, Altemeier, and MacLean (1989) suggested that parental concerns about child development could provide a simple and brief prescreening of child development.

Any comments made by the parent related to the child's general development at the time of their assessment were also recorded by the examiner.

## Data Collection : Procedures

Infants meeting the criteria for follow-up were identified from the AIMS norming data. Families of these infants were mailed an introductory letter (Appendix G) and parent questionnaire (Appendix H), which included the MCDI gross and fine motor items. In order to concur with the procedures approved by the ethical review committee of the Department of Physical Therapy, Faculty of Rehabilitation Medicine, University of Alberta, names of these children and their parents were not revealed to the principal investigator until these families had received their introductory letters and had 2 weeks time to refuse involvement in the study. Following this time the names were released and each family was contacted by phone to determine their willingness to participate in the study and to set up an assessment date.

Data collection was carried out between Nov. 1992 and Feb. 1993. Infants ranged in age from 15-21 months at the time of their assessments. All testing took place in the pediatric laboratory in the Faculty of Rehabilitation Medicine, at the University of Alberta. Upon arrival at the testing laboratory all parents were asked to read and sign the Consent Form (Appendix I) after all questions had been answered. Each parent was asked to bring their completed developmental questionnaire with them on their assessment date. If the parent forgot to bring their questionnaire they were asked to complete one before the PDMS testing began. It took the parents approximately 5 minutes to complete the questionnaire. If the parents had completed the questionnaire more than one week prior to their child's assessment they were asked to update their responses to ensure they reflected the child's current performance. All parents were given verbal feedback concerning their children's scores at the end of the testing session.

Two pediatric physical therapists, experienced in administration of the PDMS performed these evaluations. Inter-rater reliability was established by having the two examiners rate a child simultaneously. Two infants external to the study cohort and two infants from the sample were assessed. Differences of only one point in the total raw scores were obtained between the two examiners on both the fine and gross motor scales.

# CHAPTER 4

# RESULTS

## Part A - Descriptive

The first overall objective of the study was to determine the frequency of asynchronous motor development in infants under 12 months of age and to describe the characteristics of these infants. Data from 1691 infants, age 3-12 months, assessed in the AIMS Norming Study, were used to determine the frequency and characteristics of asynchronous infants.

The infants in this sample were categorized as follows:

1) 'Asynchronous' (n=257 /15%) Those infants who were asynchronous in one postural plane (one subscore was ≤ -1 standard deviation below the mean, all other scores were > -1 standard deviation below the mean). Nineteen of these infants had one subscore below -2 standard deviation below the mean, and all other scores > -1 standard deviation below the mean.

2) 'Synchronous' (n=1153 /68%) Those infants who were synchronous in all postural planes (all subscores and total score were > -1 standard deviation below the mean).

3) 'Suspicious/Abnormal' (n=238 /14%) Those infants whose total scores were ≤ -1 standard deviation below the mean.

4) 'Other' (n=43 /3%) Those infants who were asynchronous in two postural planes (two subscores were ≤ -1 standard deviation below the mean, and total score was > -1 standard

deviation below the mean).

Each of the above groups of infants are mutually exclusive. The last two groups of infants were excluded from the data analysis. The "Suspicious/Abnormal' group of infants were excluded because their total scores fell below -1 standard deviation below the mean, suggesting a possible overall gross motor delay; the 'Other' group of infants were excluded because they did not fit the definition for asynchronous or synchronous. All the infants included in the study had total AIMS scores that would categorize them as 'normal' (total score > -1 standard deviation below the mean or >16th percentile).

The 'Asynchronous' group of infants were further subcategorized according to their asynchronous subscore.
The number of infants in each asynchronous subcategory is presented by age in Table 1. Included in this table are the prevalence figures reported as percentages. In the total sample (n=1691), 15% of the infants were seen to be asynchronous in one postural plane. Asynchrony is least common in the prone postural plane (2%). For the prone infants the frequency ranges from 0%- 5% between 3 and 12 months of age. For the other infants the frequency of asynchrony has a much broader range from 0%- 20%, between 3 and 12 months.

Table 1b outlines the 95% confidence intervals for the frequencies presented in Table 1. These confidence intervals give the range of true values for the total population, and defines the degree of precision of the estimates of prevalence given in Table 1a.

The prevalence patterns are variable for all the groups except the prone group across the age range. The frequency in the sit group peaks at 7 months, in the supine group there is a peak at 4 months, and in the stand group there is a peak at 5 months. The frequency in the prone group remains relatively constant throughout the 3-12 month range. Figure 2 illustrates the contrast between the prevalence patterns of the prone and sit group across the age range.

The characteristics of the asynchronous and synchronous infants are presented in Table 2 in terms of gender, ethnicity, gestational age and birthweight. In the total sample (n=1691), 10% of the infants were non-Caucasian, 5% of the infants had a gestational age ≤ 36 weeks, and 6% of the infants had a birthweight ≤ 2500 grams. The asynchronous infants and the synchronous infants were compared on the above characteristics. The asynchronous group of infants had a statistically lower mean birthweight than the synchronous group of infants ($p = .02$). However, when infants were categorized as either low birth weight (≤ 2500 gms) or average birthweight (>2500 gms) a statistical difference was not found between the two groups.

The characteristics of the 4 asynchronous groups are presented in Table 3. These groups were compared on the characteristics of gender, ethnicity, gestational age and birthweight. There were no statistical differences found between the groups on any of the demographic variables except birthweight. The frequency of infants in the low birth weight category was below the expected frequency for the prone asynchronous group and above the expected frequency for the supine asynchronous group. These differences were not evident when birthweight mean scores were compared between the 4 groups.

Table 1

Asynchronous Infants - Frequency by Age

| | 3 MON | 4 MON | 5 MON | 6 MON | 7 MON | 8 MON | 9 MON | 10 MON | 11 MON | 12 MON | TOTAL |
|---|---|---|---|---|---|---|---|---|---|---|---|
| TOT N= | 90 | 122 | 189 | 225 | 222 | 220 | 189 | 155 | 155 | 124 | 1691 |
| ASYN PRON | 3 (3%) | 0 (0%) | 9 (5%) | 6 (3%) | 8 (4%) | 8 (4%) | 4 (2%) | 2 (1%) | 0 (0%) | 2 (2%) | 42 (2%) |
| ASYN SIT | 0 (0%) | 3 (2%) | 12 (6%) | 11 (5%) | 31 (14%) | 5 (2%) | 0 (0%) | 10 (6%) | 5 (3%) | 3 (2%) | 80 (5%) |
| ASYN SUPIN | 1 (1%) | 16 (13%) | 4 (2%) | 6 (3%) | 5 (2%) | 6 (3%) | 8 (4%) | 1 (1%) | 1 (1%) | 0 (0%) | 50 (3%) |
| ASYN STAND | 5 (6%) | 1 (1%) | 37 (20%) | 19 (8%) | 0 (0%) | 5 (2%) | 11 (6%) | 3 (2%) | 1 (1%) | 5 (4%) | 85 (5%) |
| ASYN TOT | 9 (10%) | 20 (16%) | 62 (33%) | 42 (19%) | 44 (20%) | 24 (11%) | 23 (12%) | 16 (10%) | 7 (6%) | 10 8% | 257 (15%) |

% = <u>number of asynchronous infants in age group</u>
total number of infants in age group

Table 1b

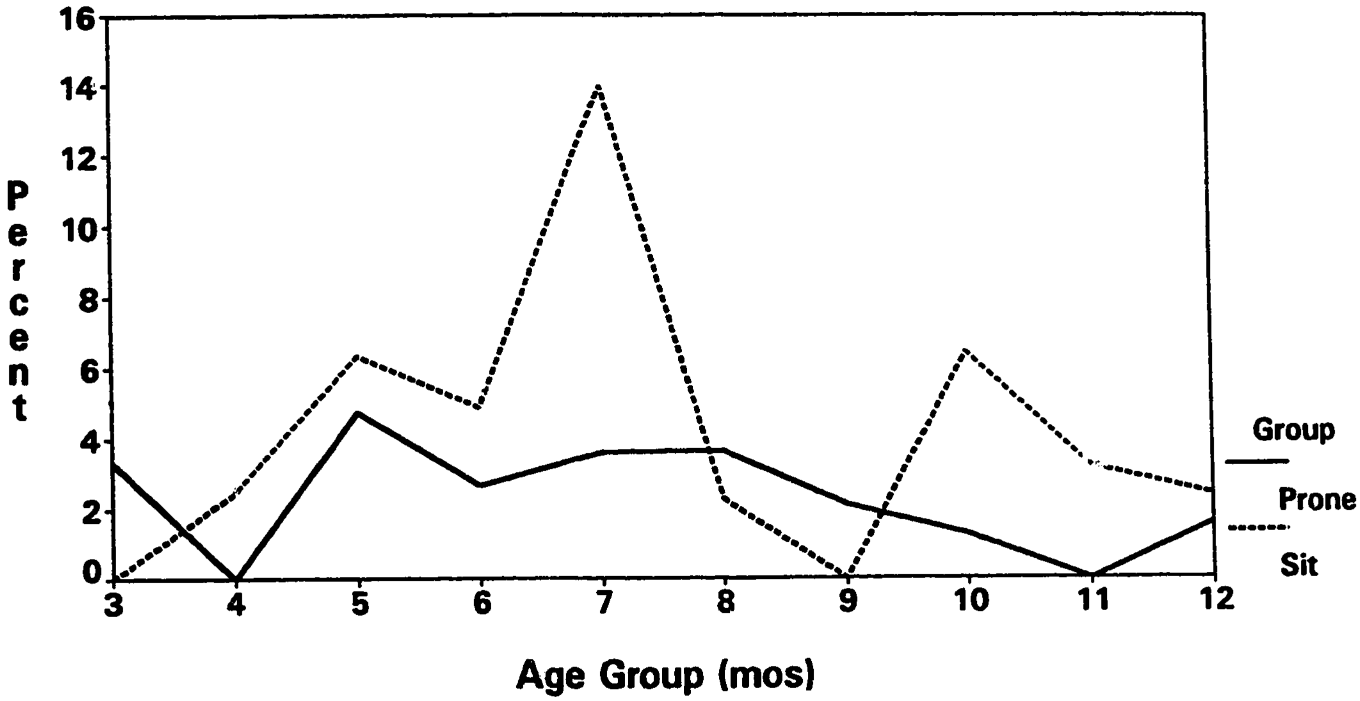
Confidence Intervals for Frequency by Age Table

| | 3M | 4M | 5M | 6M | 7M | 8M | 9M | 10M | 11M | 12M | TOT |
|---|---|---|---|---|---|---|---|---|---|---|---|
| ASYN PRON | 0-6 | 0 | 2-8 | 1-5 | 1-7 | 1-7 | 0-4 | 0-3 | 0 | 0-4 | 1-3 |
| ASYN SIT | 0 | 0-4 | 3-9 | 2-8 | 9-19 | 0-4 | 0 | 2-10 | 0-6 | 0-4 | 4-6 |
| ASYN SUPIN | 0-3 | 7-19 | 0-4 | 1-5 | 0-4 | 1-5 | 1-7 | 0-4 | 0-3 | 0 | 2-4 |
| ASYN STAND | 1-11 | 0-3 | 14-26 | 4-12 | 0 | 0-4 | 3-9 | 0-3 | 0-3 | 1-7 | 4-6 |
| ASYN TOT | 4-16 | 9-23 | 26-40 | 14-24 | 15-25 | 7-15 | 7-17 | 5-15 | 2-10 | 3-13 | 13-17 |

Notes- Numbers in table represent 95% confidence interval expressed in percents.

Figure 2

FREQUENCY BY AGE GROUP




Percent = no. infants in asynchronous group/total no. infants in agegrp

Table 2

Characteristics of Asynchronous Infants
Comparison with Synchronous Infants

| Characteristic | Asyn Infants N = 257 | Synch Infants N = 1153 | Statistic\ p Value |
|---|---|---|---|
| Gender | | | |
| Male (n) | 127 | 559 | $x^2 = .56$ |
| Female (n) | 130 | 554 | p = .45 |
| Ethnicity | | | |
| Caucasian (n) | 227 | 1031 | $x^2 = .13$ |
| Other (n) | 27 | 113 | p = .72 |
| Gestational Age at Birth (wks) | | | |
| Mean | 39.3 | 39.5 | t = -1.35 |
| SD | 1.7 | 1.7 | p = .18 |
| ≤ 36 wks (n) | 12 | 63 | $x^2 = .27$ |
| > 36 wks (n) | 245 | 1090 | p = .61 |
| Birthweight (grams) | | | |
| Mean | 3359.2 | 3446.7 | t= -2.37 |
| SD | 546.8 | 532.5 | p=.02* |
| ≤ 2500 gms (n) | 16 | 63 | $x^2 = .22$ |
| > 2500 gms (n) | 241 | 1090 | p =.64 |

*p=significant if ≤ .05

Table 3

Comparison of Asynchronous Infants

| Variable | Asyn Prone N = 42 | Asyn Sit N = 80 | Asyn Supine N = 50 | Asyn Stand N = 85 | Stat/ p value |
|---|---|---|---|---|---|
| Gender | | | | | |
| Male(n) | 24 | 45 | 24 | 34 | $x^2$=5.55 |
| Female(n) | 18 | 35 | 26 | 51 | p =.14 |
| Ethnicity | | | | | |
| Caucasian (n) | 36 | 69 | 43 | 79 | $x^2$=2.33 |
| Other (n) | 6 | 8 | 7 | 6 | p =.51 |
| Gestational Age (wks) | | | | | |
| Mean | 39.5 | 39.2 | 39.3 | 39.4 | F = .22 |
| SD | 1.3 | 1.9 | 1.8 | 1.5 | p = .88 |
| ≤ 36 wks (n) | 2 | 5 | 3 | 2 | $x^2$=1.67 |
| > 36 wks (n) | 40 | 75 | 47 | 83 | p =.64 |
| Birthweight (grams) | | | | | |
| Mean | 3393.6 | 3417.4 | 3309.5 | 3316.6 | F = .66 |
| SD | 446.7 | 603.5 | 607.0 | 499.3 | p =.57 |
| ≤ 2500 gms (n) | 0 | 5 | 7 | 4 | $x^2$=8.30 |
| > 2500 gms (n) | 42 | 75 | 43 | 81 | p =.04* |

* p=significant if ≤ .05

Part B - Follow-up of Cohort

Sample Characteristics

A cohort of infants was identified from the larger sample of infants for prospective follow-up. This cohort consisted of all asynchronous sit or prone infants who were 5-9 months at the time of their AIMS assessment, and whose families lived in Edmonton. There were 23 asynchronous prone infants (55% of the prone sample) and 35 asynchronous sit infants (44% of the sit sample). Four of the prone infants and 14 of the sit infants refused to participate in the study. Due to the number of non-participants and the difficulties associated with replacing them, some cases were assessed but not their matched control and vice versa. At the completion of the study, the sample consisted of 19 prone infants and 19 matched controls, and 21 sit infants and 22 matched controls.

The infants ranged in age from 15 to 21 months at the time of their follow-up assessment; 80% of the sample was 15-17 months. The follow-up interval, or time between the AIMS assessment and their follow-up assessment, ranged from 8-13 months, with a mean of 9.52 months.

Prior to data collection it was determined that the plane of asynchrony, sit or prone, may act as a moderator variable in the motor outcome. Therefore, the asynchronous prone and the asynchronous sit group of infants were analyzed separately.

The summary characteristics of the prone and sit group samples are recorded in Tables 4 and 5. (Detailed data of characteristics of infants in these samples is outlined in Appendix J). To determine if there were any differences between the cases and controls they were compared on the independent variables used in the matching process: age at the time of PDMS and MCDI assessment, age at the time of AIMS assessment, and gender. They were also compared on the independent variables of ethnicity, gestational age, and birthweight. No statistical differences were found between the cases and their controls.

To confirm a difference did exist between cases and controls on the independent variable of gross motor asynchrony, the raw AIMS subscores were compared. Since this comparison required multiple t-tests an adjusted alpha level was determined by the Bonferroni procedure to prevent an inflated Type 1 error rate (Ottenbacher, 1991). According to this procedure the previously set alpha level (.05) is divided by the number of comparisons (5) to arrive at an adjusted alpha level (.01) for each subscore comparison. Tables 6 and 7 demonstrate that the prone infants differed from their controls in their prone and total scores (p=.007 and p=.000 respectively), and the sit infants differed from their controls in their sit and total scores (p=.000 and p=.001 respectively). (Detailed data on infants' individual AIMS scores is available in Appendix K).

Since there were many sit cases who declined participation (14/35) the sit group non-participants were compared to the sit group participants to determine if there were any differences. The two groups were compared on the variables of gender, ethnicity, gestational age, weight, age at the time of their AIMS assessment, and AIMS scores. No significant differences were found between the two groups on any of the above variables.

Table 4

Comparison of Prone and Control Group Samples

| Variable | Prone Group N = 19 | Control Group N = 19 | Statistic | P value |
|---|---|---|---|---|
| *Age at time of follow-up (mos) | | | | |
| Mean | 16.8 | 17.1 | t = -.36 | p = .72 |
| SD | 1.8 | 1.8 | | |
| *Age at time of AIMS assessment (mos) | | | | |
| Mean | 7.2 | 7.2 | t = .13 | p = .90 |
| SD | 1.2 | 1.3 | | |
| *Gender | | | | |
| Male (n) | 11 | 10 | $x^2$ = .10 | p = .74 |
| Female (n) | 8 | 9 | | |
| Ethnicity | | | | |
| Caucasian(n) | 16 | 18 | $x^2$ = 1.11 | p = .29 |
| Other (n) | 3 | 1 | | Fish=.30 |
| Gestational Age at Birth (wks) | | | | |
| Mean | 39.6 | 40.2 | t = -1.53 | p = .14 |
| SD | 1.3 | 1.0 | | |
| Birthweight (grams) | | | | |
| Mean | 3520.5 | 3475.6 | t = .28 | p = .78 |
| SD | 449.9 | 538.7 | | |

p=significant if ≤ .05
Note Fish = Fisher test
*matching variables

Table 5

Comparison of Sit and Control Group Samples

| Variable | Sit Group N = 21 | Control Group N = 22 | Statistic | P value |
|---|---|---|---|---|
| *Age at time of follow-up (mos) | | | | |
| Mean | 15.9 | 16.0 | t = -.66 | p = .51 |
| SD | .9 | .9 | | |
| *Age at time of AIMS assessment (mos) | | | | |
| Mean | 6.5 | 6.8 | t = -.91 | p = .37 |
| SD | .9 | .9 | | |
| *Gender | | | | |
| Male (n) | 12 | 8 | $x^2$ =1.86 | p = .17 |
| Female (n) | 9 | 14 | | |
| Ethnicity | | | | |
| Caucasian(n) | 21 | 19 | $x^2$=3.07 | p = .08 |
| Other (n) | 0 | 3 | | Fish=.12 |
| Gestational Age at Birth (wks) | | | | |
| Mean | 39.6 | 39.7 | t = -.39 | p = .70 |
| SD | 1.5 | 1.1 | | |
| Birthweight (grams) | | | | |
| Mean | 3508.5 | 3491.1 | t = .12 | p = .91 |
| SD | 484.2 | 508.3 | | |

p=significant if ≤ .05

Notes Fish = Fisher test

*matching variables

Table 6

Comparison of Mean AIMS Subscores
Prone and Control Group Infants

| Subscore | Prone Group N = 19 | Control Group N = 19 | Statistic p Value |
|---|---|---|---|
| Supine | | | |
| Mean | 8.1 | 8.3 | t=-.77 |
| SD | .88 | .82 | p=.45 |
| Stand | | | |
| Mean | 3.5 | 5.2 | t=-2.19 |
| SD | 1.5 | 3.1 | p=.038 |
| Sit | | | |
| Mean | 8.6 | 9.1 | t=-.67 |
| SD | 1.7 | 2.6 | p=.51 |
| Prone | | | |
| Mean | 9.1 | 14.7 | t=-4.44 |
| SD | 2.5 | 4.9 | p=.007* |
| Total | | | |
| Mean | 29.3 | 37.3 | t=-2.95 |
| SD | 5.5 | 10.5 | p=.000* |

* p=significant if ≤ .01 (adjusted alpha)

Table 7

Comparison of Mean AIMS Subscores
Sit and Control Group Infants

| Subscore | Sit Group N = 21 | Control Group N = 22 | Statistic p Value |
|---|---|---|---|
| Supine | | | |
| Mean | 8.2 | 8.4 | t=-.55 |
| SD | .77 | .73 | p=.59 |
| Stand | | | |
| Mean | 3.3 | 3.8 | t=-1.07 |
| SD | .96 | 2.1 | p=.29 |
| Sit | | | |
| Mean | 4.7 | 9.1 | t=-9.81 |
| SD | 1.2 | 1.8 | p=.000* |
| Prone | | | |
| Mean | 11.8 | 13.8 | t=-1.79 |
| SD | 3.2 | 4.0 | p=.08 |
| Total | | | |
| Mean | 28.0 | 35.1 | t=-3.76 |
| SD | 4.8 | 7.3 | p=.001* |

* p=significant if ≤ .01 (adjusted alpha)

Follow-up Motor Outcomes

To determine if asynchronous gross motor development in the first year of life affects gross and fine motor development in the second year of life the apriori research hypotheses were tested. Since the research hypotheses were directional (asynchronous infants were expected to have poorer scores than synchronous infants), the significance levels have been reported as one tail values. Due to multiple t-testing the alpha levels had to be adjusted to reduce the type I error rate. To avoid a high type II error rate an Ordered Bonferroni procedure was used for calculating adjusted alpha levels (Ottenbacher, 1991). According to this procedure the comparisons are ordered according to their priority to the research question and new alpha levels are set separately for each comparison. The order of priority of the top 4 contrasts was established as follows: age of walking, PDMS gross motor raw score, PDMS gross motor age equivalent score, and MCDI raw score. The new alpha levels are recorded in each of the tables. (The method and calculations for adjusting the alpha levels is outlined in Appendix L.)

Before initiating data collection a power analysis was calculated to determine the minimum sample size required to detect an effect size equal to 1 standard deviation on the PDMS raw scores with a beta level of .20. This calculation (see Appendix M) yielded a sample size requirement of ≥ 16 subjects. Therefore the number of subjects in both the prone (n=19) and sit groups (n=21) provides sufficient power to determine if a significant difference exists between the groups.

Hypothesis 1a and 1b were tested by using paired t-tests to compare the cases and controls in terms of gross motor performance. PDMS and MCDI mean raw and age equivalent scores, and mean age of walking are recorded in Table 8 and 9 (detailed data available in Appendix N) for the prone and sit cases and their matched controls respectively. Although all scores were higher for the control groups only age of walking in the prone group reached statistical significance. The null hypothesis was therefore rejected for age of independent walking for the prone group; the remaining null hypotheses were not rejected.

hypothesis 2 was tested by using paired t-tests to compare cases and controls in terms of fine motor performance. PDMS and MCDI mean raw and age equivalent scores are recorded in Tables 10 and 11 (detailed data available in Appendix O) for the prone and sit cases and their matched controls respectively. Again the mean scores were consistently higher for the control groups however none of the differences approached statistical significance. Therefore the null hypothesis concerning fine motor performance could not be rejected.

Table 8

T-tests between Prone and Control Groups
Gross Motor Scores and Walking Age

| Score | Prone Group N = 19 | Control Group N = 19 | t Value | p Value (1 tail) |
|---|---|---|---|---|
| P Raw GM | | | | |
| Mean | 158.3 | 161.9 | -1.41 | .088 |
| SD | 7.3 | 10.3 | | |
| P Age GM | | | | |
| Mean | 16.2 | 16.8 | -1.21 | .122 |
| SD | 1.3 | 1.9 | | |
| M Raw GM | | | | |
| Mean | 19.4 | 20.7 | -1.97 | .032 |
| SD | 2.5 | 2.7 | | |
| M Age GM | | | | |
| Mean | 17.1 | 19.3 | -2.11 | .025 |
| SD | 3.2 | 4.1 | | |
| Walk Age | | | | |
| Mean | 12.7 | 11.4 | 2.36 | .015* |
| SD | 1.8 | 1.4 | | |

*p= significant if ≤ .025

Notes PRawGM=Peabody raw gross motor; PAgeGM=Peabody age equivalent gross motor; MRawGM=MCDI raw gross motor; MAgeGM=MCDI age equivalent gross motor; Walk Age=age first walked (months).

Adjusted alpha levels: Walk Age = .025, PRawGM = .022, PAgeGM = .019, MRawGM = .016, all others <.016.

Table 9

T-tests between Sit and Control Groups
Gross Motor Scores and Walking Age

| Score | Sit Group N = 21 | Control Group N = 21 | t Value | p Value (1 tail) |
|---|---|---|---|---|
| P Raw GM | | | | |
| Mean | 155.7 | 159.0 | -1.88 | .038 |
| SD | 6.0 | 7.2 | | |
| P Age GM | | | | |
| Mean | 15.8 | 16.2 | -1.31 | .103 |
| SD | 1.0 | 1.3 | | |
| M Raw GM | | | | |
| Mean | 19.3 | 20.3 | -1.71 | .051 |
| SD | 1.9 | 2.1 | | |
| M Age GM | | | | |
| Mean | 17.0 | 18.4 | -1.83 | .042 |
| SD | 2.3 | 2.8 | | |
| Walk Age | | | | |
| Mean | 11.9 | 11.4 | 1.25 | .113 |
| SD | 1.4 | 1.5 | | |

*p= significant if ≤ .025

Notes PRawGM=Peabody raw gross motor; PAgeGM=Peabody age equivalent gross motor; MRawGM=MCDI raw gross motor; MAgeGM=MCDI age equivalent gross motor; Walk Age=age first walked (months).

Adjusted alpha levels: Walk Age = .025, PRawGM = .022, PAgeGM = .019, MRawGM = .016, all others <.016.

Table 10

T-tests between Prone and Control Groups
Fine Motor Scores

| Score | Prone Group N = 19 | Control Group N = 19 | t Value | p Value (1 tail) |
|---|---|---|---|---|
| P Raw FM | | | | |
| Mean | 129.7 | 131.5 | -.84 | .205 |
| SD | 7.2 | 7.6 | | |
| P Age FM | | | | |
| Mean | 17.8 | 18.2 | -.78 | .222 |
| SD | 1.8 | 1.9 | | |
| M Raw FM | | | | |
| Mean | 25.8 | 26.5 | -.71 | .245 |
| SD | 3.5 | 2.0 | | |
| M Age FM | | | | |
| Mean | 20.5 | 21.5 | -.46 | .324 |
| SD | 6.7 | 5.4 | | |

*p=significant if ≤ .016

Notes

PRawFM=Peabody raw fine motor; PAgeFM=Peabody age equivalent fine motor; MRawFM=MCDI raw fine motor; MAgeFM=MCDI age equivalent fine motor

Table 11

T-tests between Sit and Control Groups
Fine Motor Scores

| Score | Sit Group N = 21 | Control Group N = 21 | t Value | p Value (1 tail) |
|---|---|---|---|---|
| P Raw FM | | | | |
| Mean | 125.3 | 127.2 | -.71 | .242 |
| SD | 9.0 | 8.8 | | |
| P Age FM | | | | |
| Mean | 16.8 | 17.2 | -.71 | .243 |
| SD | 2.0 | 1.9 | | |
| M Raw FM | | | | |
| Mean | 24.8 | 25.1 | -.66 | .260 |
| SD | 2.4 | 2.1 | | |
| M Age FM | | | | |
| Mean | 18.2 | 18.6 | -.49 | .314 |
| SD | 4.4 | 4.1 | | |

*p=significant if ≤ .016
Notes PRawFM=Peabody raw fine motor; PAgeFM=Peabody age equivalent fine motor; MRawFM=MCDI raw fine motor; MAgeFM=MCDI age equivalent fine motor

Walking age demonstrates the only significant difference between the cases and controls. The mean walking age was statistically different between the prone group and their controls but not between the sit group and their controls. The youngest walking age was 8 months and the oldest was 17 months. Figure 3 graphically portrays the tendency for prone asynchronous infants to walk at later ages than their matched controls.

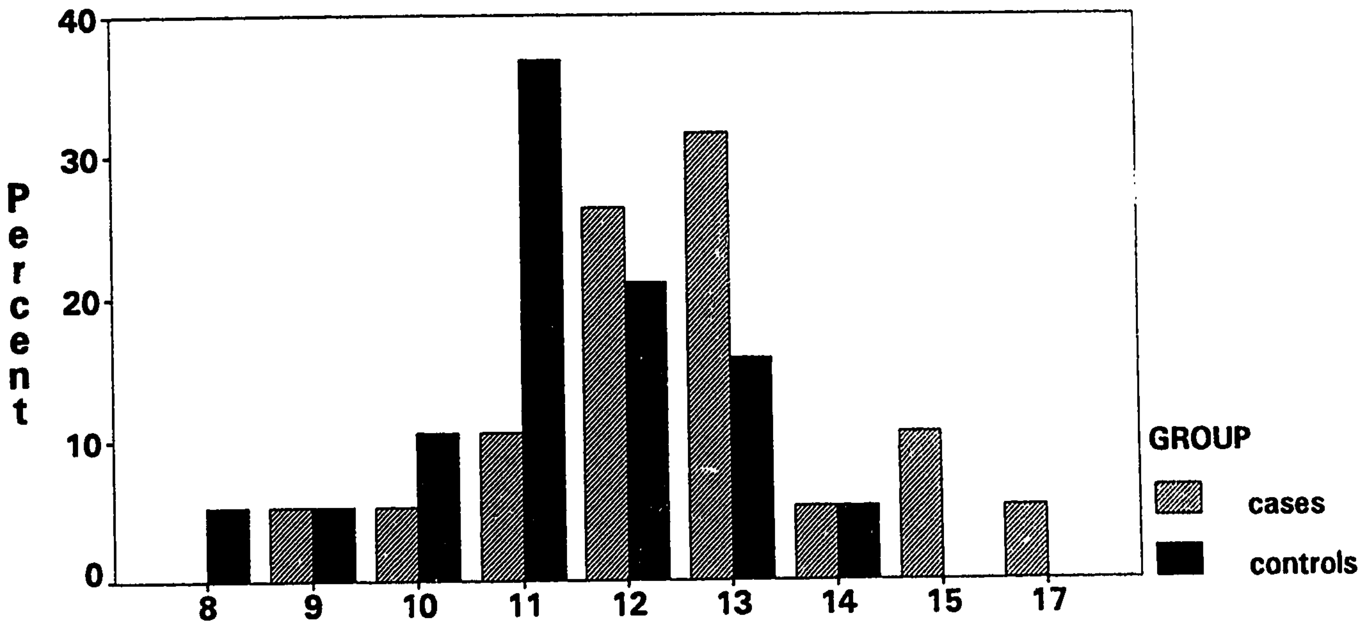
There were 23 infants who walked at an age ≥ 13 months, 10 from the prone group, 4 from the prone control group, 5 from the sit group, and 4 from the sit control group. Of these 23 infants, 3 walked at 15 months, 2 from the prone group, and 1 from the sit group. One infant from the prone group walked at 17 months.

Infants were categorized as either 'early' or 'late' walkers by comparing their walking age to the mean walking age (mean=11.84 months, standard deviation= 1.57) for the total cohort (n=81). A walking age equal to one standard deviation above the sample mean (13.4 months) was used for the cut off between 'early' and 'late' walkers. Therefore, 'early' walkers were those who walked at ≤ 12 months and 'late' walkers were those who walked at ≥ 13 months. A chi square test was used to determine if there was a significant difference between 'early' and 'late' walkers in both prone and sit groups, as recorded in Table 12. The prone group had significantly more 'late' walkers than their matched controls (p= .044); the sit group did not differ from their controls in terms of 'late' versus 'early' walkers.

Hypothesis 3 and 4 were tested using chi-squares to compare group differences on the variables of prelocomotor strategy and parental developmental concerns respectively. Table 13 (detailed data available in Appendix N) and Table 14 (detailed data available in Appendix O) present the data for these variables. Nine of the 81 infants (11%) used a prelocomotor strategy other than crawling. Three of these infants bottom hitched, 2 commando crawled, 2 just stood up and walked, 1 crawled on two knees, and 1 rolled prior to walking. There were no statistical differences found between the prone or sit cases and controls on this variable. None of the parents from any of the groups expressed concerns regarding their child's developmental status. The hypothesis of no difference between asynchronous and synchronous infants in their prelocomotor strategies and parental developmental concerns, could not be rejected from these results.

Figure 3

PRONE INFANTS WALK AGE




Walk Age (months)

(5% = .05% all other percents as shown)

Table 12

Comparison of Walking Category by Group Status

| Walk Category | Prone Group N = 19 | Control Group N = 19 | Statistic (p value) |
|---|---|---|---|
| Early ≤ 12mons | 9 | 15 | chi sq= 4.07 |
| Late ≥ 13mons | 10 | 4 | p = .044* |
| | Sit Group N = 21 | Control Group N = 22 | |
| Early ≤ 12mons | 16 | 18 | chi sq=.205 |
| Late ≥ 13mons | 5 | 4 | p = .65 |

*p=significant if ≤ .05

Table 13

Chisquares between Prone and Control Groups
Prelocomotor Strategy and Developmental Status

| Outcome Measure | Prone Group N = 19 | Control Group N = 19 | Chisquare Value | p Value |
|---|---|---|---|---|
| Prelocomotor Strategy | | | | |
| Crawl (n) | 15 | 16 | .18 | .67 |
| Other (n) | 4 | 3 | | Fish=.50 |
| Developmental Status | | | | |
| OK (n) | 19 | 19 | - | - |
| Concerns (n) | 0 | 0 | | |

*p=significant if ≤ .05
Note Fish = Fisher test

Table 14

Chisquares between Sit and Control Groups
Prelocomotor Strategy and Developmental Status

| Outcome Measure | Sit Group N = 21 | Control Group N = 22 | Chisquare Value | p Value |
|---|---|---|---|---|
| Prelocomotor Strategy | | | | |
| Crawl (n) | 20 | 21 | .00 | .97 |
| Other (n) | 1 | 1 | | Fish=.74 |
| Developmental Status | | | | |
| OK (n) | 21 | 22 | - | - |
| Concerns (n) | 0 | 0 | | |

*p=significant if ≤ .05
Note Fish = Fisher test

# CHAPTER 5

# DISCUSSION

## Introduction

The purpose of this study was to describe asynchronous motor development and to determine if infants who are asynchronous in either their prone or sit skills in their first year of life differ from synchronously developing infants in terms of their gross and fine motor performance in the second year of life. Four conclusions have been drawn from the results. First, it is not uncommon for infants in the normal population to exhibit asynchronous early gross motor development. Second, asynchronous motor development in the first year of life does not have a significant detrimental effect on gross or fine motor performance in the second year of life. Third, asynchronous development of prone skills at 5-9 months of age results in a delay in the emergence of independent walking. Fourth, prone asynchrony represents an alternative and distinctive course of early motor development.

## Prevalence of Asynchronous Motor Development in the First Year of Life

Fifteen percent (257/1691) of infants under one year of age demonstrated asynchronous gross motor development. As a result, while motor asynchrony early in life cannot be considered commonplace or usual, neither can it be considered exceptional or rare. Asynchronous infants are equally represented in both genders, various ethnic groups, and term and preterm infants. Lags in a specific postural plane occur most commonly when infants are between 5 and 9 months of age. This occurs during a period in development when an infant's motor repertoire is expanding exponentially.

A lower prevalence of infants was found to be asynchronous in the prone plane as compared to the other postural planes. The frequency of infants asynchronous in the sit, supine, or stand planes varies as a function of age, whereas the frequency of infants asynchronous in the prone plane does not vary with age. This suggests that there is more variability in the development of sit, supine, and stand skills in the first year of life than in the development of prone skills. It may be that asynchrony in the sit, stand, and supine planes is rapidly corrected in the normal developmental course either through organismic changes or environmental influences. On the other hand, the consistency in the prevalence rates over the first year of life for prone asynchrony indicates that this phenomena may be more deeply ingrained. Although the infants in this study were sampled cross sectionally to determine the prevalence rates, the consistency in the rate of infants across ages who exhibited prone asynchrony implies that these infants who were asynchronous at 5 months remained asynchronous for many months. This finding suggests that prone asynchrony represents a unique and distinguishable entity in early motor development.

<u>Motor Performance of Asynchronous Infants</u>

Developmental test scores were lower for cases than controls in both the prone and sit groups on all gross motor outcome measures performed in the second year of life. While a few of the group differences were significant with alpha levels at .05, none of these values achieved significance when alpha levels were adjusted to account for multiple testing. Furthermore, the mean scores between groups only differed by 1-3 points for raw scores and 1-2 months for age equivalent scores. The magnitude of these differences can not be considered clinically significant. It can be concluded that asynchrony in the sit postural plane does not have an impact on gross motor performance in the second year of life. Asynchrony in the prone postural plane, while delaying the attainment of independent walking, does not ultimately impact on those gross motor skills typically assessed in the second year of life.

Similarly developmental test scores were lower for cases than controls in both groups on all fine motor outcome measures. The differences between cases and controls did not approach significance even prior to adjusting the alpha levels. It can be concluded that asynchronous gross motor development in the first year of life does not have an impact on fine motor performance in the second year of life. The failure of this study to confirm any relationship between early gross motor skills and later fine motor skills is congruous with earlier studies (Case-Smith, Fisher, & Bauer, 1989; Wilson & Tremblay, 1984) that were unable to demonstrate a definitive relationship between proximal and distal motor control. This finding challenges the common therapeutic assumption held by a variety of treatment approaches, including NDT, which states that previous gross motor experience plays an integral role in the development of reach and grasp.

The intraindividual rate of gross motor development in asynchronous infants is not consistent in the first 2 years of life. The asynchronous infants as a group demonstrated a catch up of gross motor skills or a 'self-righting' process following their initial AIMS assessment. In this study all infants had their gross motor performance measured at three points in time. The first indicator of performance was obtained from the AIMS assessment at an average age of 7 months. At this time both the prone and sit group of infants had significantly poorer gross motor performance than their matched controls. The second indicator of performance was obtained from parental report of walking age (mean age = 12 months). At this time the prone group of infants continued to demonstrate significantly poorer performance, while the sit group of infants did not differ from their matched control group. The third indicator of performance was obtained from the PDMS and MCDI assessments at an average age of 16 months. Both the prone or sit group of infants had lower mean scores at this time but the differences failed to reach significance. Therefore, the prone and sit group of infants had a different pattern of self-righting. The sit group of infants self-righted rapidly, prior to their first birthday, while the prone group of infants self-righted in their second year of life, following their acquisition of independent walking.

A variable rate of motor development is not consistent with the neuromaturational view of development which attributes all progress to brain maturation (Heriza, 1991). Other factors must be at play to produce a developmental course that is nonlinear. The dynamic motor theory expects development to be nonlinear and asynchronous (Thelen, 1987); some elements may follow a rapid developmental course while others mature more slowly. If we consider the 4 postural planes of gross motor development as separate elements, they were seen in this study to develop at asynchronous rates by a sizable number of infants. The dynamic motor theory has identified environmental, biomechanical, cognitive, motivational, and neurological factors as possible contributors to rate variations in motor progression. The factors responsible for altering the synchrony of development in the 4 postural planes is at present undetermined. This study was only able to determine that birthweight, gestational age, gender, and ethnicity were not related to asynchrony in early gross motor skills.

Relationship between Prone Asynchrony and Delayed Walking

The association of prone asynchrony with delayed walking provides some information concerning the relationship between two milestones in the developmental sequence. The role of the normal developmental sequence as a basis for physiotherapy treatment was recently questioned in a conference on motor control problems (Lister, 1991). The assumption that one skill is prerequisite to another due to it's preexistence has not been tested empirically (Van Sant, 1991). One method for assessing the effect of the development of one skill on another is to restrict the development of one of the skills (Bigelow, 1992). In this study a naturally occurring restriction of prone skills was associated with a delay in the emergence of independent walking, while a restriction in sit skills was not associated with a delay. These results confirm a relationship of interdependence between prone skill development and the development of walking. Since prone skills are predominately mobility skills and sit skills are predominately stability skills, it seems logical to find prone performance more strongly related to the achievement of walking.

In this study non-crawling prelocomotor strategies were not found to be associated with prone asynchron While prone asynchrony did not alter the usual sequence of crawl before walk, it did act as a rate limiting factor to the attainment of walking. A rate limiting factor is defined by Thelen, Kelso & Fogel (1987) as a component that must reach a critical value before a new level of behavior can emerge.

Studies of non-crawlers (Bottos et al., 1989; Largo et al., 1985; Robson, 1984) demonstrated that prone mobility skills are not mandatory prerequisites for the emergence of independent walking. The infants in these studies who skipped prone mobility skills had a similar outcome to the prone asynchronous infants of this study; they were found to walk at a later age than the population norm. Prone skills while not necessary, appear to play a facilitative role in the development of independent walking, that is they permit the emergence of walking at an earlier age.

The importance of prone skills in the developmental course is reflected in their prominence in descriptions of early motor development. Gesell and Ames' (1940) emphasized the contribution of prone skills as they outlined 23 stages of prone progression. Similarly McGraw (1943) provided detailed descriptions of 9 stages of prone development. The newly developed AIMS assessment also emphasizes prone skills by including 21 prone items as compared to 9 supine items, 12 sit items, and 16 stand items.

Delays in prone skills have been found to be more predictive of later gross motor abilities than delays in skills derived from other postural planes (Touwen, 1971). In a recent study Allen and Alexander (1992) identified creep as the milestone with the best specificity and positive predictive value for later cerebral palsy in a sample of high risk infants.

## Prone Asynchrony - An Alternative Developmental Course

The prone infants were distinct from both the sit infants and their matched controls, in terms of prevalence rate and pattern, and gross motor performance. Prone asynchrony occurs less frequently than asynchrony in any of the other postural planes, it has a consistent rather than variable prevalence rate in the first year of life, it has an impact on the timing of walking, and it delays self-righting of motor performance until the second year of life. These distinctions suggest that prone asynchrony represents an alternative and distinctive course of early motor development. The developmental course of the asynchronous sit infants, on the other hand, rapidly merges with that of the traditional norms.

Thelen (1990) has suggested that identifying individual developmental pathways may make it possible to "cluster subjects not on the basis of outcome, but on the basis of route" (p.39). The prone asynchronous infants appear to form such a cluster. In lieu of the ongoing search for early markers of later developmental aberrations this cluster may be worthy of further study. Although these infants failed to demonstrate significant differences from their controls in their gross motor outcomes at 15-21 months, that does not rule out the possibility that these infants could show subtle impairments in development by school age. In the study by Bottos and colleagues (1989) the group of infants marked by late crawling were found to be slow to walk and had the highest incidence of motor sequelae when assessed at age 5. It is possible that these infants fit the definition used in this study to identify prone asynchronous infants.

Clinical Implications

The prevalence of asynchronous motor development in the first year of life is sufficiently high (15%) to ensure that healthcare professionals involved in developmental screening will see these infants in their routine practice. When an infant is identified with asynchronous sit skills it can be expected that their gross motor skills will only briefly veer from the 'normal' developmental pathway. These infants need not cause concern for parents or professionals. When an infant is identified with asynchrony in his/her prone skills, the expectation for his/her future course of gross motor development is different. It can be expected that these infants will be slower than average in their attainment of independent walking, but will progress to within normal limits in their gross and fine motor performance before their second birthday. There is no evidence to suggest that these infants require any therapeutic intervention or can be classified as 'abnormal'. Many years ago Touwen (1976) warned clinicians against labelling infants as rapid or slow, early or late developers. He acknowledged a large degree of variability in the developmental rate and low relationships between different developmental items. This study supports Touwen's findings and reiterates the advice for clinicians to avoid classifying infants on the basis of variations from 'normal' patterns of development in the first year of life.

Therapists must maintain a broad definition of normal in order to prevent the misclassification of infants. Improperly labelling infants as 'abnormal' has detrimental effects on the child and family (Cadman, Chambers, Walter, Ferguson, Johnston, Mcnamee, 1987) and unduly taxes health care resources.

Clinicians are searching for ways to predict motor outcome from development in the first year of life. Recent studies (Aylward, Gustafson, Verhulst, & Colliver, 1987; Harris, 1987; Piper, Darrah, Pinnell, Watt, & Byrne, 1991) conclude that predictions made from characteristics early in infancy are not always reliable. The results of this study aid only in the prediction of 'normalcy'.

Treatment protocols aimed at the advancement of prone skills may be beneficial to clients who are delayed in their achievement of independent walking. Although prone skills are not necessary to the development of walking they were seen in this study to be facilitative. Recent studies (Benson, 1991; Campos & Bertenthal, 1989) have also identified the significant contributions of self-produced locomotion (via creep or crawl) to the development of cognitive, spatial, and perceptual abilities. Thus, the advancement of prone mobility skills may have a facilitative effect on many developmental domains.

## Conclusions

Early motor skills do not necessarily develop simultaneously in the four postural planes. A proportion of infants demonstrate asynchronous early gross motor development in their first year of life. Infants with asynchronous prone skills follow a unique developmental course but demonstrate a convergence of outcome with 'normally' developing infants before their second birthday. Infants with asynchronous sit skills only briefly stray from the usual pattern of gross motor development.

These findings do not support the neuromaturational theory of motor development which assumes that variations in gross motor development represent abnormality. The inter- and intraindividual variability of developmental rate and sequence identified in this study may be better explained by the dynamic motor theory of motor development. These results support the assumption derived from this theory that individual differences are expected and linear predictions of outcome from a beginning state may not be reliable (Thelen, 1990).

Evidence for a relationship between prone skills and the emergence of independent walking was suggested by the results of this study. When prone skills lagged behind the development of other gross motor skills, infants tended to walk at a later age. The possible mechanisms behind this relationship require further study.

The results of this study have served to broaden our definition of 'normal' to include infants who follow an asynchronous developmental pathway. Second, they have provided further support to the assumptions of the dynamic motor theory that suggest development is nonlinear and asynchronous. Third, they have identified prone skills as potentially facilitative for the emergence of independent walking. Lastly, infants marked by early asynchronous prone skills, have been identified as a distinctive cluster worthy of future study.

Limitations

The matching was not perfect for all variables due to the difficulties replacing subjects who cancelled. The therapist who performed the bulk of the follow-up assessments was not blinded to the infants' group status. The follow-up assessments were not performed at a uniform age for all subjects. Follow-up only occurred into the infants' second year of life.

REFERENCES

Allen, M. C. & Alexander, G.R. (1992). Using gross motor milestones to identify very preterm infants at risk for cerebral palsy. Developmental Medicine and Child Neurology,34, 226-232.

Aylward, G. P., Gustafson, N., Verhulst, S. J., & Colliver, J. A. (1987). Consistency in the diagnosis of cognitive, motor, and neurological function over the first 3 years. Journal of Pediatric Psychology, 12(1), 77-98.

Attermeier, S. M. (1984). Evaluation of sensorimotor dysfunction.In S. K. Campbell (Ed.) Pediatric neurological physical therapy. (pp. 37-54). New York: Churchill Livingstone.

Attermeier, S. M. (1991). Should the normal developmental sequence be used as a theoretical model in patient treatment? In M. J. Lister (Ed.), Contemporary management of motor control problems. Proceedings of the II Step conference. (pp. 85-87). Alexandria, VA: Foundation of Physical Therapy.

Atwater, S. W. (1991). Should the normal developmental sequence be used as a theoretical model in pediatric physical therapy? In M. J. Lister (Ed.), Contemporary management of motor control problems. Proceedings of the II Step conference. (pp. 89-93). Alexandria, VA: Foundation of Physical Therapy.

Bayley, N. (1969). Manual for the Bayley Scales of Infant Development. New York: The Psychological Corporation.

Benson, J. B. (1991). The significance and development of crawling in human infancy. In J.E. Clark, J.H. Humphrey (Eds.), Advances in motor development research 3. (pp. 91-142). New York: AMS Press.

Bigelow, A. E. (1992). Locomotion and search behavior in blind infants. Infant Behavior and Development, 15, 179-189.

Bly, L. (1981). The components of normal movement during the first year of life. In D. S. Slaton (Ed.), Development of movement in infancy. (pp. 85-123). Chapel Hill: Division of Physical Therapy, University of North Carolina.

Bottos, M., Dalla Barba, B., Stefani, D., Pettena, G., Tonin, C., & D'Este, A. (1989). Locomotor Strategies preceding independent walking. Developmental Medicine and Child Neurology, 31, 25-34.

Byrne, J. M., Backman, J. E., & Smith, I. M. (1986). Developmental assessment: The clinical use and validity of parental report. Journal of Pediatric Psychology, 11, 549-559.

Cadman, D., Chambers, L. W., Walter, S. D., Ferguson, R., Johnston, N., & McNamee, J. (1987). Evaluation of public health preschool child developmental screening: The process and outcomes of a community program. American Journal of Public Health, 77, 45-51.

Campbell, S. K. (1984). Central nervous system dysfunction in children. In S. K. Campbell (Ed.), Pediatric neurological physical therapy. (pp. 1-12). New York: Churchill Livingstone.

Campos, J. J. & Bertenthal, B. I. (1989). Locomotion and Psychological development in infancy. In F. J. Morrison, C. Lord, & D. P. Keating (Eds.), Applied developmental psychology. (pp. 230-258). Toronto: Academic Press.

Capute, A. J., Shapiro, B. K., Palmer, F. B., Foss, A., & Wachtel, R. C. (1985). Normal gross motor development: the influences of race, sex and socioeconomic status. Developmental Medicine and Child Neurology, 27, 635-643.

Case-Smith, J. Fisher, A. G. & Bauer, D. (1989). An analysis of the relationship between proximal and distal motor control. American Journal of Occupational Therapy,43, 657-662.

Cintas, H. (1989). Cross Cultural Variation in Infant Motor Development. Physical & Occupational Therapy in Pediatrics, 8, 1-20.

Crouchman, M. (1986). The effects of babywalkers on early locomotor development. Developmental Medicine and Child Neurology, 28, 757-761.

Folio, M. R., & Fewell, R. R. (1983). Peabody Developmental Motor Scales and activity cards. Allen, Texas: DLM Teaching Resources.

Gesell, A. (1954). The ontogeny of infant behavior. In L. Carmichael (Ed.) _Manual of child psychology._ (2nd Ed., pp.335-373). London: Wiley.

Gesell, A. & Ames, L. (1940) The ontogenetic organization of prone behavior in human infancy. _Journal of Genetic Psychology, 56,_ 247-263.

Glascoe, F. P. (1991). Developmental screening: Rationale, methods, and application. _Infants and Young Children, 4,_ 1-10.

Glascoe, F. P., Altemeier, W. A., & MacLean, W. E. (1989). The importance of parents' concerns about their child's development. _American Journal of Diseases in Children, 143,_ 955-958.

Haley, S.M. (1986). Sequential analyses of postural reactions in nonhandicapped infants. _Physical Therapy, 66,_ 531-536.

Harriman, A. E. & Lukosius, P. A. (1982). On why Wayne Dennis found Hopi infants retarded in age at onset of walking. _Perceptual and Motor Skills, 55,_ 79-86.

Harris, S. R., (1989). Early detection of cerebral palsy: Sensitivity and specificity of two motor assessment tools. _Journal of Perinatology, 7,_ 11-15.

Hart, H., Bax, M., & Jenkins, S.l. (1978). The value of a developmental history. _Developmental Medicine and Child Neurology, 20,_ 442-452.

Heriza, C. (1991). Motor development: Traditional and contemporary theories. In M. J. Lister (Ed.), _Contemporary management of motor control problems. Proceedings of the II Step conference,_ (pp. 99-126). Alexandria, VA: Foundation of Physical Therapy.

Illingworth, R. S. (1987). _The development of the infant and young child_ (9th ed.). New York: Churchill Livingstone.

Ireton, H. & Thwing, E. (1974). _Manual for the Minnesota Child Development Inventory._ Minneapolis: Behavior Science Systems.

Keshner, E. A. (1991). How theoretical framework biases evaluation and treatment. In M. J. Lister (Ed.), Contemporary Management of motor control problems. Proceeding of the II Step Conference. (pp. 37-48). Alexandria, VA: Foundation of Physical Therapy.

King-Thomas, L. & Hacker, B. J. (1987). A therapist's guide to pediatric assessment. Toronto: Little, Brown and Company.

Kopparthi, R., McDermott, C., Sheftel, D. M., & Lenke, M. C. (1991) The Minnesota Child Development Inventory: Validity and reliability for assessing development in infancy. Journal of Developmental and Behavioral Pediatrics, 12, 217-222.

Largo, R. H., Molinari, L., Weber, M., Comenale Pinto, L., & Duc, G. (1985). Early development of locomotion: Significance of prematurity, cerebral palsy and sex. Developmental Medicine and Child Neurology, 27, 183-191.

Lister, J. (1991). Contemporary management of motor control problems. Proceeding of the II Step conference. Alexandria, VA: Foundation of Physical Therapy.

Long, T. M. (1992). The use of parent report measures to assess infant development. Pediatric Physical Therapy, 4, 74-77.

McGraw, M. B. (1943). The neuromuscular maturation of the human infant. New York: Hafner Press.

Neligan, G. & Prudham, D. (1969). Norms for four standard developmental milestones by sex, social class, and place in family. Developmental Medicine and Child Neurology, 11, 413-422.

Newell, K. M., & van Emmerik, R. E. A., (1990). Are Gesell's developmental principles general principles for the acquisition of coordination? In J. E. Clark & J. H. Humphrey (Eds.), Advances in motor development research. (pp. 143-164). New York: AMS Press.

Ottenbacher, K. J., (1991). Statistical conclusion validity multiple inferences in rehabilitation research. American Journal of Physical Medicine & Rehabilitation, 70, 317-322.

Piper, M. C., Darrah, J. (in press). Motor Assessment of the Developing Infant: Alberta Infant Motor Scale (AIMS). Philadelphia: Saunders.

Piper, M. C., Darrah, J., Pinnell, L., Watt, M. J., & Byrne, P. (1991). The consistency of sequential examinations in the early detection of neurological dysfunction. Physical and Occupational Therapy in Pediatrics, 11, 27-44.

Pinnell, L., Piper, M., Darrah, J., Maguire, T., & Byrne, P. (1990). Reliability and validity testing of the Alberta Infant Motor Scale (AIMS). Paper presented at the Annual Canadian Physiotherapy Congress, Charlottetown, P.E.I.

Pocock, S. J. (1983). Clinical Trials A Practical Approach. New York: John Wiley & Sons.

Robson, P. (1970). Shuffling, hitching, scooting or sliding; some observations in 30 otherwise normal children. Developmental Medicine and Child Neurology, 12, 608-617.

Robson, P. (1984). Prewalking locomotor movements and their use in predicting standing and walking. Child: Care, Health and Development, 10, 317-330.

Robson, P. & MacKeith, R. C. (1971). Shufflers with spastic cerebral palsy: A confusing clinical picture. Developmental Medicine and Child Neurology, 13, 651-659.

Saylor, C. F. & Brandt, B. J. (1986). The Minnesota Child Development Inventory: A valid maternal-report form for assessing development in infancy. Developmental and Behavioral Pediatrics, 7, 308-311.

Scherzer, A. L. & Tscharnuter, I. (1982). Early diagnosis and therapy in cerebral palsy. New York: Marcel Dekker.

Super, C. M. (1976). Environmental affects on motor development: The case of 'African infant precocity'. Developmental Medicine and Child Neurology, 18, 561-567.

Tecklin, J. S. (1989). Pediatric physical therapy. Philadelphia: Lippincott.

Thelen, E. (1987). The role of motor development in developmental psychology: A view of the past and an agenda for the future. In N. Eisenberg (Ed.), Contemporary topics in developmental psychology. (pp. 3-33). New York: Wiley.

Thelen, E. (1990). Dynamical systems and the generation of individual differences. In J. Colombo & J. Fagen (Eds.), Individual differences in infancy : reliability, stability, prediction. (pp. 19-43). Hillsdale: Lawrence Erlbaum Associates.

Thelen, E., Kelso, J. A. S., & Fogel, A. (1987). Self-organizing systems and infant motor development. Developmental Review, 7, 39-65.

Touwen, B. C. L. (1971). A study of the development of some motor phenomena in infancy. Developmental Medicine and Child Neurology, 13, 435-446.

Touwen, B. C. L. (1976). Neurological development in infancy. Clinics in Developmental Medicine No. 58 Philadelphia: J B Lippincott.

Van Sant, A. F. (1991). Neurodevelopmental Treatment and Pediatric Physical Therapy: A commentary. Pediatric Physical Therapy, 3, 137-141.

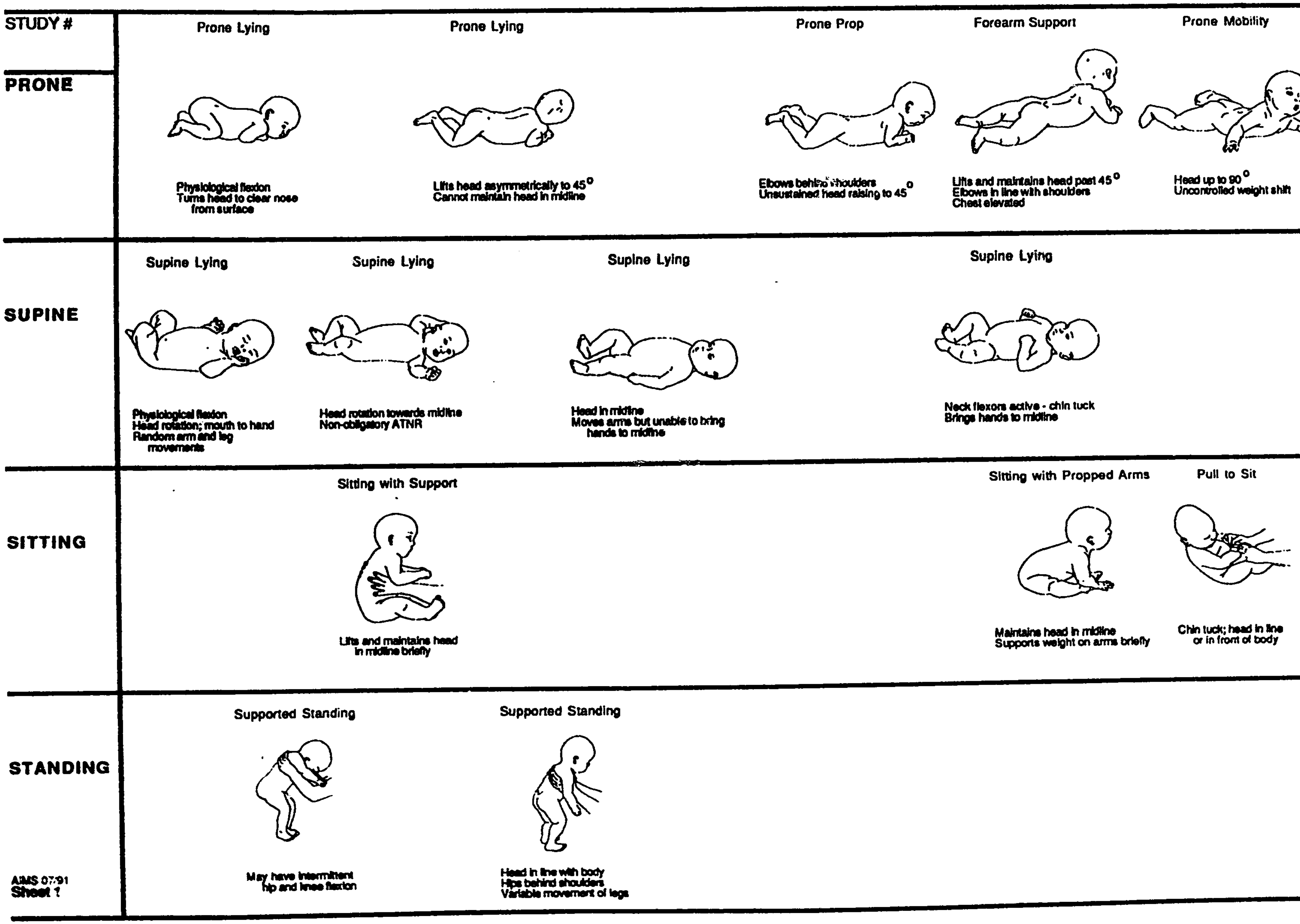
Wilson, B. W. & Trombly, C. A. (1984). Proximal and distal function in children with and without sensory integrative dysfunction: An EMG study. Canadian Journal of Occupational Therapy, 51, 11-17.

# APPENDICES

# APPENDIX A

## Alberta Infant Motor Scale Items

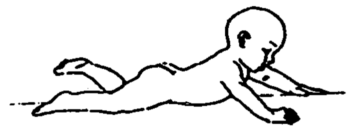
# Alberta Infant Motor Scale



Forearm Support

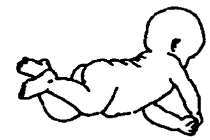
Elbows in front of shoulders
Active chin tuck with neck elongation

Extended Arm Support



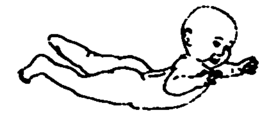
Arms extended
Chin tuck and chest elevation
Lateral weight shift

Rolling Prone to Supine



Movement initiated by head
Trunk moves as one unit

Swimming



Active extensor pattern

Hands to Knees

Chin tuck
Reaches hands to knees
Abdominals active

Active Extension

Pushes into extension with legs

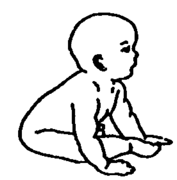
Hands to Feet

Can maintain legs in mid-range
Pelvic mobility present

Unsustained Sitting

Scapular adduction and humeral extension
Topples forward or to side

Sitting with Arm Support

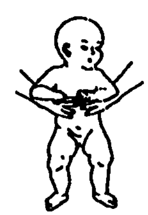


Thoracic spine extended
Head movements free from trunk; propped on extended arms

Unsustained Sitting without Arm Support

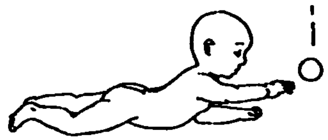
Cannot be left alone in sitting indefinitely

Supported Standing



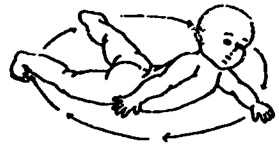
Hips in line with shoulders
Active control of trunk
Variable movements of legs

**Reaching from Forearm Support**

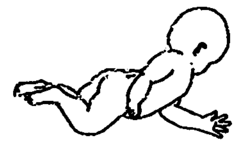


Active weight shift to one side
Controlled reach with free arm

**Pivoting**

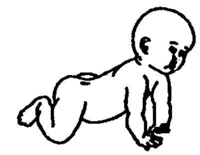


Pivots
Movement in arms and legs
Lateral trunk flexion



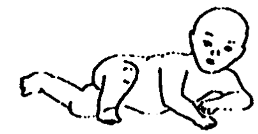
Trunk rotation

**Four Point Kneeling**



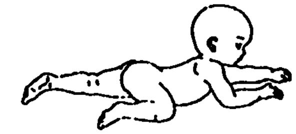
Legs flexed, abducted and externally rotated
Lumbar lordosis
Maintains position

**Propped Sidelying**



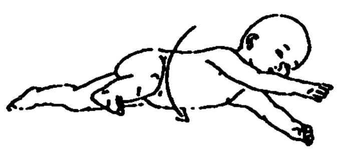
Dissociation of legs
Shoulder stability
Rotation within body axis

**Reciprocal Crawling**



Reciprocal arm and leg movements with trunk rotation

**Rolling Supine to Prone without Rotation**

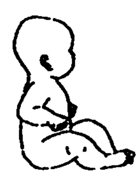


Lateral head righting
Trunk moves as one unit

**Rolling Supine to Prone with Rotation**

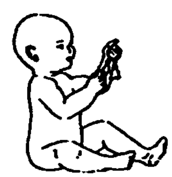
Trunk rotation

**Weight Shift in Unsustained Sitting**



Weight shift forward, backward, or sideways
Cannot be left alone

**Sitting without Arm Support**

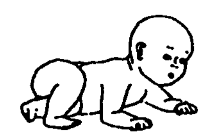


Arms move away from body
Can play with a toy
Can be left alone in sitting

**Reach with Rotation in Sitting**

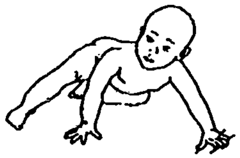
Sits independently
Reaches for toy with trunk rotation

**Sitting to Prone**



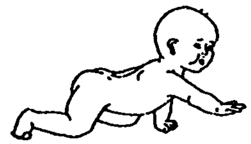
Moves out of sitting to achieve prone lying
Pulls with arms; legs inactive

**Four Point Kneeling to Sitting or Half Sitting**



Plays in and out of position
May get to sitting

**Reciprocal Creeping**

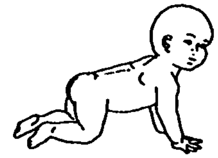


Legs abducted and externally rotated
Lumbar lordosis; weight shift side to side with lateral trunk flexion

**Reaching from Extended Arm Support**

Reaches with extended arm
Trunk rotation

**Four Point Kneeling**

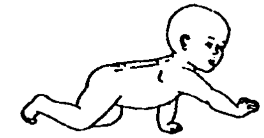


Hips aligned under pelvis; flattening of lumbar spine

**Modified Four Point Kneeling**

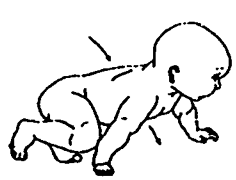
Plays in position
May move forward

**Reciprocal Creeping with Rotation**



Lumbar spine flat
Moves with trunk rotation

**Sitting to Four Point Kneeling**

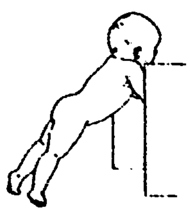


Actively lifts pelvis, buttocks, and unweighted leg to assume four point kneeling

**Sitting without Arm Support**

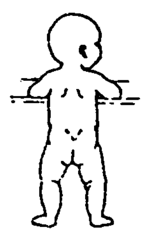
Position of legs varies
Infant moves in and out of positions easily

**Pulls to Stand with Support**



Pushes down with arms and extends knees

**Pulls to Stand/ Stands**

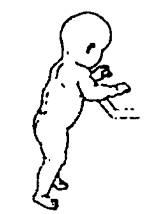


Pulls to stand; shifts weight from side to side

**Supported Standing with Rotation**

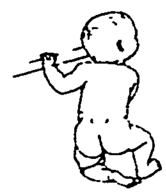
Rotation of trunk and pelvis

**Cruising without Rotation**



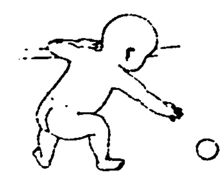
Cruises sideways without rotation

**Half Kneeling**



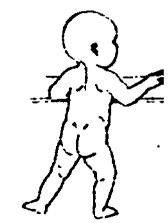
May assume standing or play in position

**Controlled Lowering through Standing**



Controlled lowering from standing

**Cruising with Rota**



Cruises with rotation

**Stands Alone**

Stands alone momentarily
Balance reactions in feet

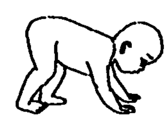
**Early Stepping**

Walks independently; moves quickly with short steps; lateral flexion of trunk

**Standing from Modified Squat**

Moves from squat to standing with controlled flexion and extension of hips and knees

**Standing from Quadruped Position**



Pushes quickly with hands to get to standing

**Walks Alone**

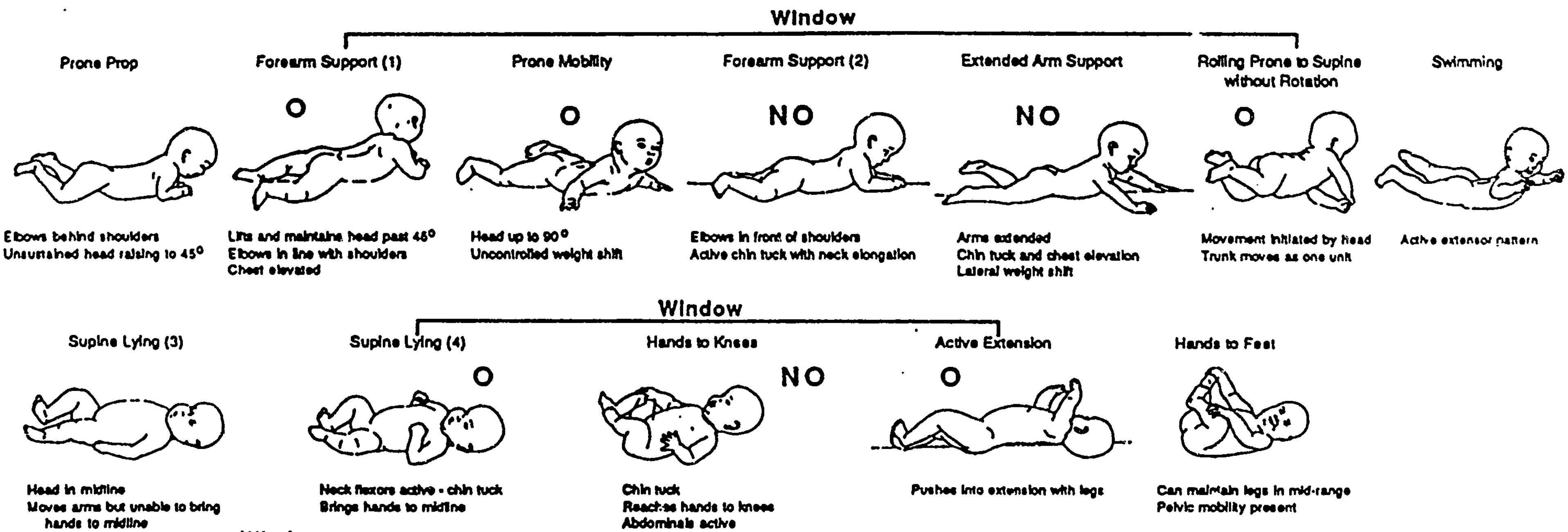
Walks independently

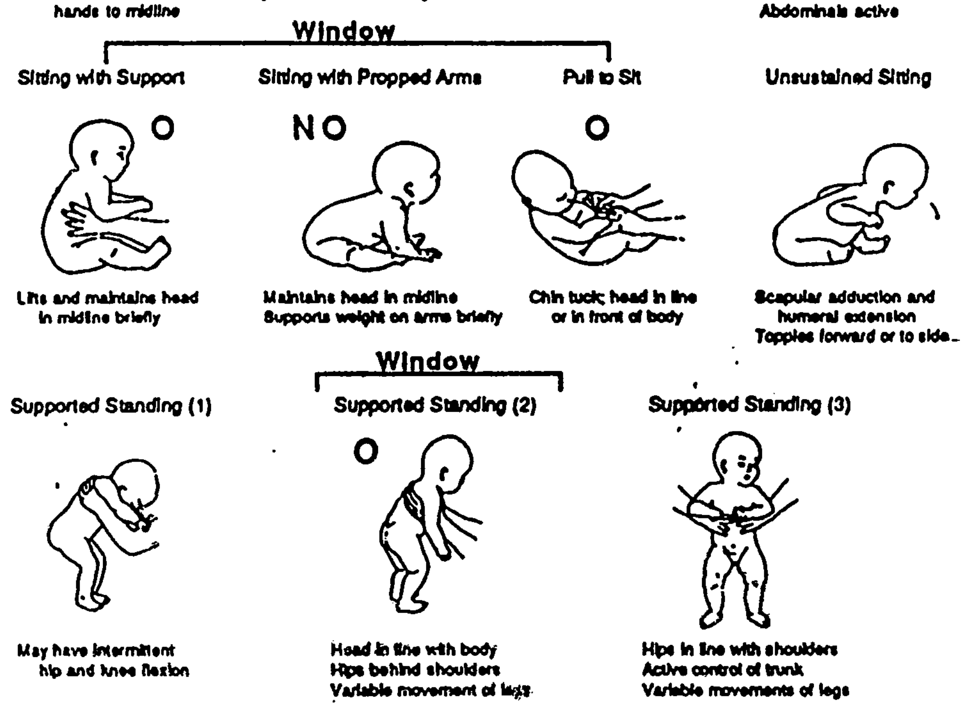
**Squat**

Maintains position by balance reactions in feet and in position of trunk

# APPENDIX B

## Alberta Infant Motor Scale Scoring Example




## Sample Score Sheet - 1

O = "Observed"

NO = "Not Observed"

### Scoring: Sample Score Sheet - 1

| | Previous Items Credited | Items Credited in Window | Subscale Score |
|---|---|---|---|
| Prone | 3 | 3 | 6 |
| Supine | 3 | 2 | 5 |
| Sit | 0 | 2 | 2 |
| Stand | 1 | 1 | 2 |

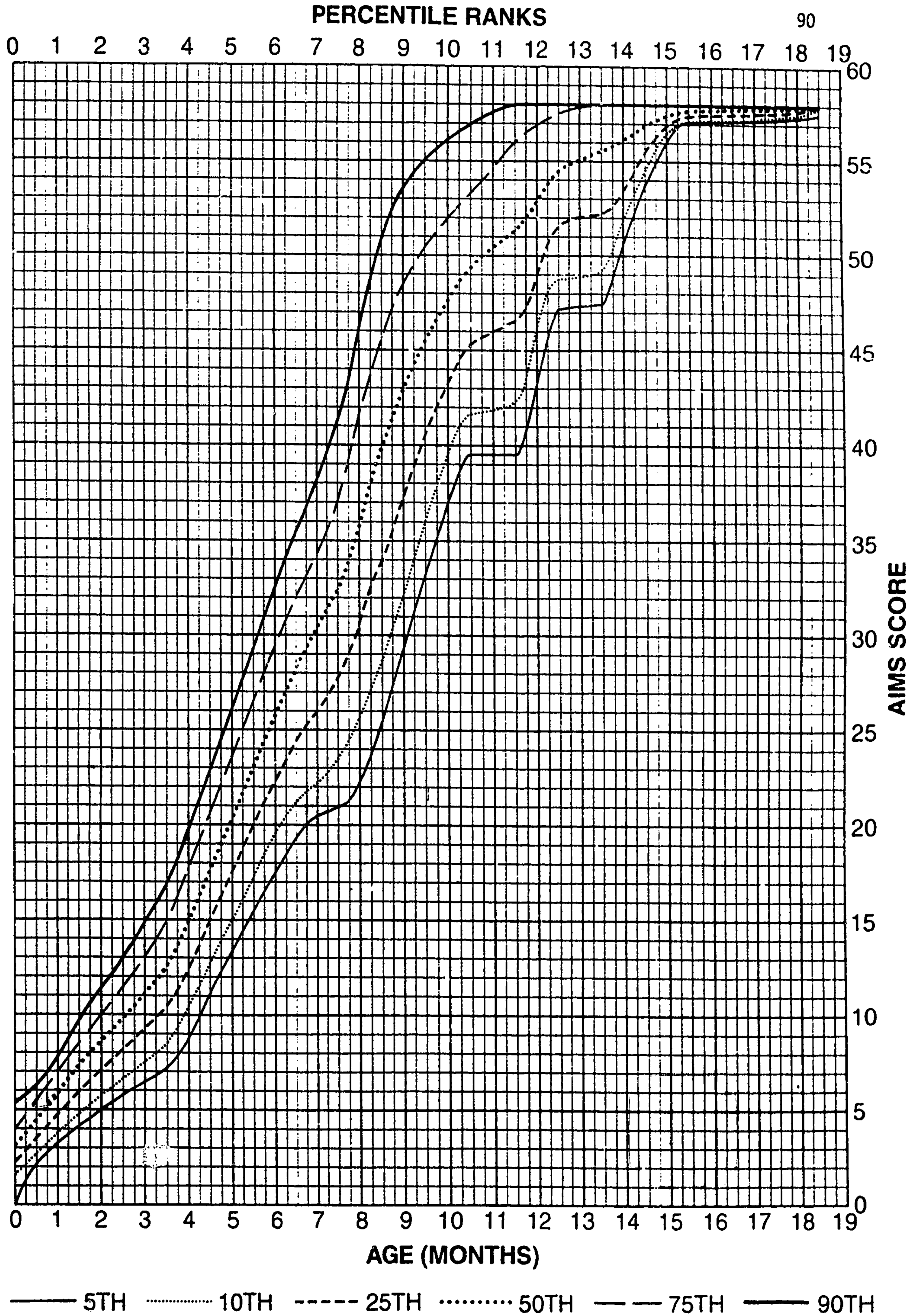
**Total Score 15**

# APPENDIX C

## Alberta Infant Motor Scale Norms

Table 6. Percentile Ranks by Age Grouping

| Raw Score | Age in Months ≥ 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 1 | | | | | | | | | | | | | | |
| 2 | 3 | | | | | | | | | | | | | | |
| 3 | 14 | 1 | | | | | | | | | | | | | |
| 4 | 36 | 4 | 1 | | | | | | | | | | | | |
| 5 | 64 | 12 | 2 | 1 | | | | | | | | | | | |
| 6 | 86 | 25 | 6 | 2 | | | | | | | | | | | |
| 7 | 97 | 43 | 12 | 5 | | | | | | | | | | | |
| 8 | 99 | 63 | 23 | 8 | 1 | | | | | | | | | | |
| 9 | | 80 | 37 | 14 | 2 | | | | | | | | | | |
| 10 | | 91 | 53 | 22 | 3 | | | | | | | | | | |
| 11 | | 97 | 69 | 31 | 5 | | | | | | | | | | |
| 12 | | 99 | 82 | 43 | 8 | 1 | | | | | | | | | |
| 13 | | | 91 | 55 | 12 | 2 | | | | | | | | | |
| 14 | | | 96 | 67 | 17 | 3 | | | | | | | | | |
| 15 | | | 98 | 77 | 24 | 4 | | | | | | | | | |
| 16 | | | 99 | 85 | 32 | 6 | 1 | | | | | | | | |
| 17 | | | | 91 | 41 | 10 | 2 | 1 | | | | | | | |
| 18 | | | | 95 | 51 | 14 | 3 | 2 | | | | | | | |
| 19 | | | | 97 | 60 | 19 | 5 | 3 | | | | | | | |
| 20 | | | | 99 | 69 | 25 | 7 | 4 | 1 | | | | | | |
| 21 | | | | | 77 | 32 | 9 | 5 | 2 | | | | | | |
| 22 | | | | | 84 | 40 | 13 | 7 | 2 | | | | | | |
| 23 | | | | | 89 | 48 | 17 | 9 | 3 | | | | | | |
| 24 | | | | | 93 | 57 | 22 | 11 | 4 | | | | | | |
| 25 | | | | | 96 | 65 | 27 | 15 | 5 | | | | | | |
| 26 | | | | | 97 | 72 | 34 | 18 | 6 | | | | | | |
| 27 | | | | | 99 | 79 | 41 | 22 | 7 | | | | | | |
| 28 | | | | | | 84 | 48 | 27 | 9 | | | | | | |
| 29 | | | | | | 89 | 55 | 32 | 11 | 1 | | | | | |
| 30 | | | | | | 92 | 62 | 37 | 13 | 2 | | | | | |
| 31 | | | | | | 95 | 69 | 43 | 16 | 3 | | | | | |
| 32 | | | | | | 97 | 75 | 48 | 19 | 4 | | | | | |
| 33 | | | | | | 98 | 81 | 54 | 22 | 5 | | | | | |
| 34 | | | | | | 99 | 85 | 60 | 26 | 6 | | | | | |
| 35 | | | | | | | 89 | 66 | 29 | 8 | 1 | 1 | | | |
| 36 | | | | | | | 92 | 71 | 33 | 10 | 1 | 2 | | | |
| 37 | | | | | | | 94 | 76 | 38 | 13 | 2 | 2 | | | |
| 38 | | | | | | | 96 | 80 | 42 | 16 | 3 | 3 | | | |
| 39 | | | | | | | 97 | 84 | [illegible] | 19 | 4 | 4 | | | |
| 40 | | | | | | | 98 | 89 | 51 | 23 | 6 | 6 | | | |
| 41 | | | | | | | 99 | 90 | 56 | 27 | 8 | 8 | | | |
| 42 | | | | | | | | 92 | 60 | 32 | 11 | 10 | | | |
| 43 | | | | | | | | 94 | 64 | 37 | 14 | 12 | | | |
| 44 | | | | | | | | 96 | 69 | 42 | 18 | 15 | 1 | 1 | |
| 45 | | | | | | | | 97 | 73 | 47 | 23 | 19 | 2 | 2 | |
| 46 | | | | | | | | 98 | 76 | 52 | 29 | 23 | 3 | 3 | |
| 47 | | | | | | | | 98 | 80 | 58 | 35 | 27 | 5 | 4 | |
| 48 | | | | | | | | 99 | 83 | 63 | 41 | 32 | 7 | 6 | |
| 49 | | | | | | | | | 86 | 68 | 48 | 38 | 11 | 9 | |
| 50 | | | | | | | | | 88 | 73 | 54 | 43 | 15 | 13 | |
| 51 | | | | | | | | | 90 | 77 | 61 | 48 | 21 | 18 | |
| 52 | | | | | | | | | 92 | 81 | 67 | 54 | 28 | 24 | 1 |
| 53 | | | | | | | | | 94 | 84 | 73 | 60 | 36 | 30 | 2 |
| 54 | | | | | | | | | 95 | 87 | 79 | 65 | 45 | 37 | 7 |
| 55 | | | | | | | | | 96 | 90 | 83 | 70 | 54 | 45 | 17 |
| 56 | | | | | | | | | 97 | 92 | 87 | 75 | [illegible] | 53 | 32 |
| 57 | | | | | | | | | 98 | 94 | 90 | 79 | 70 | 61 | 52 |
| 58 | | | | | | | | | >98 | >95 | >93 | >83 | >77 | >68 | >71 |


PERCENTILE RANKS
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19
60 55 50 45 40 35 30 25 20 15 10 5 0
AIMS SCORE
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19
AGE (MONTHS)
5TH
10TH
25TH
50TH
75TH
90TH

# APPENDIX D

## Alberta Infant Norming Study Information Sheet

# AIMS Norming Study
# Information Sheet

| | Year | Month | Day |
|---|---|---|---|
| Date of Assessment: | ______ | ______ | ______ |
| Date of Birth: | ______ | ______ | ______ |

Name: ____________________

Study Number: ______________

Health Centre: ______________

Therapist: ________________

Sex: ☐ Male ☐ Female

Gestational Age at Birth: __________ Weeks

Birth Weight: __________ Grams

Ethnic Origin:
- ☐ Caucasian
- ☐ Oriental
- ☐ Native
- ☐ Black
- ☐ Other (please specify) ________________

Congenital anomaly, if present:
- ☐ Down's syndrome
- ☐ Spina bifida
- ☐ Limb deficiency
- ☐ Cleft palate
- ☐ Blindness
- ☐ Deafness
- ☐ Major congenital heart defect
- ☐ Other (please specify) ________________

Assessment of Infant's Overall Motor Status:
- ☐ Normal
- ☐ Suspect
- ☐ Abnormal

# APPENDIX E

## Minnesota Child Development Inventory
## Gross and Fine Motor Items

## MCDI GROSS MOTOR SCALE ITEMS

265 Rolls over from stomach to back (5)
242 rolls over from back to stomach (6)
192 While sitting, leans forward to obtain objects out of reach (6)
47 Raises self to crawling position on hands and knees (7)
178 Crawls on hands and knees (8)
273 Makes stepping movements when supported under the arms (8)
124 Pulls self to standing position (9)
234 Makes stepping movements when held by both hands (9)
67 Sidesteps around play-pen or crib while holding onto rails (10)
217 Stands without support (12)
291 Stoops (12)
316 Crawls up stairs (12)
1 Walks without help (13)
162 Walks with a pull toy (14)
229 Climbs into an adult's chair and seats self (15)
163 Runs (15)
237 Dances in response to music (15)
117 Kicks a ball (17)
43 Climbs on playground equipment (20)
289 Walks up and down stairs alone (22)
13 Climbs up and slides down slide without help (24)
97 Stands on one foot without support (26)
21 Runs smoothly, turning sharp corners and making sudden stops with ease (28)
160 Does a forward somersault (30)
190 Walks up and down stairs alone, one foot to a step (31)
4 Rides tricycle using pedals (31)
59 Jumps from steps with feet together (31)
31 Hops on one foot (43)
208 Swings, pumping self (43)
181 Skips F (48)
77 Makes running and standing broadjumps M (48)
302 Jumps rope F (70)
86 Rides a two-wheeled bike (72)

## MCDI FINE MOTOR SCALE ITEMS

136 Holds a toy put in his hand with a firm grasp (3)
114 Shakes a rattle (4)
270 Puts toys or other objects in his mouth (4)
230 Picks up objects with one hand (5)
126 Shakes or crumples paper (5)
36 Bangs toys or other small objects on tray or table (6)
166 Transfers objects from one hand to the other (6)
42 Holds two objects at the same time, one in each hand (7)
154 Uses two hands to pick up large objects (8)
18 Sticks fingers into bottle openings or small holes in other objects (8)
247 Picks up a small glass or cup with two hands (8)
44 Uses forefinger to poke, push, rub, and roll objects on tray or table top (9)
201 Tears paper, using two hands (9)
57 Picks up crumbs or bits of dry cereal, such as Rice Krispies or Cheerios, one at a time (9)
257 Claps hands (10)
199 Puts small objects in a cup, glass, or other container (11)
244 Plays with two or more objects at the same time M (12) F (9)
303 Turns pages of books or magazines two or three at a time (12)
281 Rolls a ball while sitting (12)
143 Picks up two small toys in one hand at the same time (12)
93 Throws a ball while standing (13)
290 Builds a tower of two or more blocks (17)
185 Shows preference in the use of one hand over the other (16)
240 Scribbles with a pencil or crayon (16)
32 Builds a tower of two or more blocks (17)
300 Removes and replaces covers or caps of jars and bottles (17)
248 Plays catch (22)
155 Turns pages of picture books one page at a time (23)
72 Attempts to cut with small scissors (31)
15 Plays with clay or other moulding materials (34)
142 Uses a hammer to pound nails M (36)
84 Draws or copies circles (36)
193 Cuts across paper with scissors from one side to the other (38)
113 Draws simple designs (47)

# APPENDIX F

## Peabody Developmental Motor Scales Scoring Booklet and Items

PAGES 96-102 INCLUSIVE HAVE BEEN REMOVED DUE TO COPYRIGHT RESTRICTIONS. THIS CONTAINED APPENDIX F - SOURCE: TEACHING RESOURCES CORPORATION.

# APPENDIX G

## Introductory Letter

INTRODUCTORY LETTER

Dear Parent;

Nov. 1, 1992

Thankyou for your participation in the Alberta Infant Motor Scale Norming Study. As a follow-up to this study one of my graduate students would like to further study your child's motor development. The purpose of this project is to determine if there is a relationship between patterns of infants' gross motor development at 5-9 months and their subsequent motor performance in the second year of life.

If you are willing to participate in this study you will be asked to bring your child to the University of Alberta, Faculty of Rehabilitation Medicine for an assessment by a physiotherapist (**Corbett Hall Rm. 3-70**). Prior to this assessment you will be asked to complete a questionnaire concerning your child's motor development. Completion of the assessment and questionnaire will require approximately one hour of your time.

The developmental questionnaire has been enclosed to help you prepare in advance.

If you do not wish to participate in this study please give my graduate student Ms. Jan Evans a call ( 492-4939) or write me a letter at the address listed below. Your refusal will be kept confidential and will in no way affect your child's future services. If I do not hear from you within 2 weeks I will provide your name and address to Ms. Evans. She will then contact you in the near future to further explain the study and confirm your willingness to participate.

Thank you for considering this matter.

Sincerely,

Dr. M. C. Piper

Principal Investigator
Alberta Infant Motor Scale Norming Study
Phone No: 492-4939
Address: Corbett Hall Rm. 3-70
Faculty of Rehabilitation Medicine
University of Alberta
Edmonton, AB
T6G 2G4

# APPENDIX H

## Developmental Questionnaire

# DEVELOPMENTAL QUESTIONNAIRE

ID No. _______ Child's Name ____________

A/ General Questions

1. Is your child walking independently? yes ___ no _

if yes, At what age did your child begin walking independently? ______________ (months)

2. How did your child move around on the floor prior to walking? crawl ______ other _______

3. Are you happy with your child's development?

yes ___ no ___

if no, Please briefly describe your concerns:

______________________________________________

______________________________________________

B/ Minnesota Child Development Inventory

Your observations of your child can provide important information about your child's development. The Minnesota Child Development Inventory is a means of gathering this information. Only the motor section of this inventory will be used in this study. By reading this list in advance you will be better prepared to answer these statements.

Instructions

The following list contains statements describing behaviors of children. These statements describe the things that children do as a part of growing up. Read each statement carefully. If the statement describes a behavior your child has done in the past or is presently doing circle YES. If the statement describes a behavior your child has never done then circle NO. Answer YES or NO by what you have seen your child do, not by what you think he or she may be able to do.

Many of these statements describe behaviors that are too advanced for your child because your child is too young. Even so, read every statement and circle YES or NO.

# MINNESOTA CHILD DEVELOPMENT INVENTORY

| | | |
|---|---|---|
| Walks without help. | yes | no |
| Rides tricycle using pedals. | yes | no |
| Climbs up and slides down slide without help. | yes | no |
| Plays with clay or other molding materials. | yes | no |
| Sticks fingers into bottle openings or other objects. | yes | no |
| Runs smoothly, turning sharp corners and making sudden stops with ease. | yes | no |
| Hops on one foot. | yes | no |
| Builds a tower of four or more blocks. | yes | no |
| Bangs toys or other small objects on tray or table. | yes | no |
| Holds two objects at the same time, one in each hand. | yes | no |
| Climbs on playground equipment. | yes | no |
| Uses forefinger to poke, push, rub, and roll objects on tray or table top. | yes | no |
| Raises self to crawling position on hands and knees. | yes | no |
| Picks up crumbs or bits of dry cereal, such as Rice Krispies or Cheerios, one at a time. | yes | no |
| Jumps from steps with feet together. | yes | no |
| Sidesteps around play-pen or crib while holding onto rails. | yes | no |
| Attempts to cut with small scissors. | yes | no |
| Makes running and standing broadjumps. | yes | no |
| Draws or copies circles. | yes | no |

| | | |
|---|---|---|
| Sits without support. | yes | no |
| Rides a two-wheeled bike. | yes | no |
| Throws a ball while standing. | yes | no |
| Stands on one foot without support. | yes | no |
| Draws simple designs. | yes | no |
| Shakes a rattle. | yes | no |
| Kicks a ball. | yes | no |
| Pulls self to standing position. | yes | no |
| Shakes or crumples paper. | yes | no |
| Holds a toy put in his/her hand with a firm grasp. | yes | no |
| Uses a hammer to pound nails. | yes | no |
| Picks up two small toys in one hand at the same time. | yes | no |
| Uses two hands to pick up large objects. | yes | no |
| Turns pages of picture books one page at a time. | yes | no |
| Does a forward somersault. | yes | no |
| Walks with a pull toy. | yes | no |
| Runs. | yes | no |
| Transfers objects from one hand to the other. | yes | no |
| Crawls on hands and knees. | yes | no |
| Skips. | yes | no |
| Shows preference in the use of one hand over the other. | yes | no |
| Walks up and down stairs alone, one foot to a step. | yes | no |

| | | |
|---|---|---|
| While sitting leans over to obtain object out of reach. | yes | no |
| Cuts across paper with scissors from one side to the other. | yes | no |
| Puts small objects in a cup, glass, or other container. | yes | no |
| Tears paper, using two hands. | yes | no |
| Swings pumping by self. | yes | no |
| Stands without support. | yes | no |
| Climbs into an adult's chair and seats self. | yes | no |
| Picks up objects with one hand. | yes | no |
| Makes stepping movements when held by both hands. | yes | no |
| Dances in response to music. | yes | no |
| Scribbles with a pencil or crayon. | yes | no |
| Rolls over from back to stomach. | yes | no |
| Plays with two or more objects at the same time. | yes | no |
| Picks up a small glass or cup with two hands. | yes | no |
| Plays catch. | yes | no |
| Claps hands. | yes | no |
| Rolls over from stomach to back. | yes | no |
| Puts toys or other objects in his/her mouth. | yes | no |
| Makes stepping movements when supported under the arms. | yes | no |
| Rolls a ball while sitting. | yes | no |
| Walks up and down stairs alone. | yes | no |
| Builds a tower of two or more blocks. | yes | no |

| | | |
|---|---|---|
| Stoops. | yes | no |
| Removes and replaces covers or caps of jars and bottles. | yes | no |
| Jumps rope. | yes | no |
| Turns pages of books or magazines two or three at a time. | yes | no |
| Crawls up stairs. | yes | no |

# APPENDIX I

## Consent Form

# CONSENT FORM

| | |
|---|---|
| TITLE: | EARLY ASYNCHRONOUS GROSS MOTOR DEVELOPMENT IS IT RELATED TO LATER MOTOR PERFORMANCE? |
| INVESTIGATOR: | Jan Evans, B.Sc. P.T. Phone: 492-4939 (days) 438-1167 (evenings) |
| SUPERVISOR: | Dr. M.C. Piper, Rehabilitation Medicine, University of Alberta Phone: 492-4939 |
| STUDY PURPOSE: | The purpose of this project is to determine if there is a relationship between patterns of infants' gross motor development at 5-9 months and their subsequent motor performance in the second year of life. |

You will be contacted by phone to confirm your agreement to participate in this study. The information you provided during the previous Alberta Infant Motor Scale Norming Study will then be provided to this investigator.

You will be asked to bring your child to the Faculty of Rehabilitation Medicine at the University of Alberta ( Corbett Hall Room # 3-70) for an assessment. A physical therapist will assess your child's motor development. Prior to this assessment you will be asked to complete a questionnaire concerning your child's development. Completion of the assessment and questionnaire will take approximately 60 minutes.

CONSENT: I agree to take part in the above project. I understand that my participation is voluntary and I may withdraw from the study at any time without affecting the future care my child receives.

I understand that all records will be given a code number. No information that can identify my child or family will be released or printed, without my consent.

I have read and understand the information stated above. I sign this consent form willingly.

Any further information concerning the study can be obtained by calling either Jan Evans or Dr. Piper, at the phone numbers above.

______________________________ (Signature of Parent/ Guardian) ____________ (Date)

______________________________ (Signature of Witness) ____________ (Date)

______________________________ (Signature of Investigator) ____________ (Date)

# APPENDIX J

Infant Characteristics

Follow-up Cohort

Raw Data

INFANT CHARACTERISTICS

Prone Cases-

| ID | AGE | AGE[a] | SEX | ETH | GA | BW |
|---|---|---|---|---|---|---|
| 672 | 19.00 | 9.00 | 2 | 1 | 41 | 3000 |
| 852 | 19.00 | 8.00 | 1 | 1 | 40 | 4205 |
| 871 | 18.00 | 8.00 | 2 | 5 | 39 | 3182 |
| 897 | 20.00 | 8.00 | 2 | 2 | 39 | 2600 |
| 1030 | 21.00 | 8.00 | 1 | 1 | 36 | 3523 |
| 1039 | 18.00 | 9.00 | 2 | 1 | 40 | 3466 |
| 1142 | 16.00 | 6.00 | 1 | 1 | 40 | 4091 |
| 1152 | 15.00 | 6.00 | 1 | 5 | 40 | 3892 |
| 1161 | 15.00 | 7.00 | 1 | 1 | 40 | 3295 |
| 1180 | 16.00 | 7.00 | 1 | 1 | 41 | 3551 |
| 1187 | 16.00 | 7.00 | 2 | 1 | 37 | 3580 |
| 1188 | 17.00 | 8.00 | 2 | 1 | 40 | 3409 |
| 1248 | 15.00 | 7.00 | 1 | 1 | 40 | 3239 |
| 1272 | 16.00 | 8.00 | 1 | 1 | 40 | 3864 |
| 1306 | 16.00 | 6.00 | 1 | 1 | 40 | 3026 |
| 1359 | 17.00 | 7.00 | 2 | 1 | 41 | 3949 |
| 1395 | 16.00 | 8.00 | 1 | 1 | 38 | 4347 |
| 1545 | 15.00 | 5.00 | 1 | 1 | 40 | 3210 |
| 1564 | 15.00 | 5.00 | 2 | 1 | 40 | 3460 |

Prone Controls-

| ID | AGE | AGE[a] | SEX | ETH | GA | BW |
|---|---|---|---|---|---|---|
| 743 | 21.00 | 8.00 | 1 | 1 | 40 | 4091 |
| 758 | 18.00 | 8.00 | 2 | 1 | 40 | 2898 |
| 848 | 18.00 | 9.00 | 2 | 1 | 40 | 3466 |
| 863 | 20.00 | 8.00 | 2 | 1 | 40 | 3182 |
| 880 | 20.00 | 9.00 | 1 | 1 | 41 | 3920 |
| 1090 | 16.00 | 7.00 | 1 | 1 | 38 | 3665 |
| 1091 | 16.00 | 7.00 | 2 | 1 | 40 | 3125 |
| 1108 | 18.00 | 7.00 | 2 | 1 | 41 | 3466 |
| 1146 | 16.00 | 6.00 | 1 | 1 | 40 | 3494 |
| 1196 | 16.00 | 7.00 | 1 | 1 | 40 | 3750 |
| 1230 | 16.00 | 7.00 | 1 | 1 | 42 | 4148 |
| 1252 | 16.00 | 8.00 | 1 | 1 | 42 | 4545 |
| 1340 | 16.00 | 6.00 | 1 | 2 | 40 | 3097 |
| 1350 | 18.00 | 8.00 | 2 | 1 | 39 | 2500 |
| 1403 | 17.00 | 8.00 | 1 | 1 | 41 | 2585 |
| 1447 | 17.00 | 8.00 | 2 | 1 | 39 | 3295 |
| 1478 | 15.00 | 5.00 | 2 | 1 | 39 | 3139 |
| 1503 | 15.00 | 5.00 | 2 | 1 | 41 | 4063 |
| 1627 | 15.00 | 5.00 | 1 | 1 | 40 | 3608 |

Notes AGE=age at time of follow-up assessment (mos) AGE[a]=age at time of AIMS assessment (mos) SEX: 1=male 2=female ETH=ethnic: 1=Caucasian 2=Oriental 5=mixed GA=gestational age at birth (wks) BW=birhtweight (grams)

Sit Cases-

| ID | AGE | AGE[a] | SEX | ETH | GA | BW |
|---|---|---|---|---|---|---|
| 1104 | 16.00 | 8.00 | 2 | 1 | 39 | 4034 |
| 1127 | 15.00 | 7.00 | 1 | . | 41 | 4347 |
| 1132 | 17.00 | 7.00 | 1 | 1 | 38 | 3636 |
| 1136 | 17.00 | 7.00 | 1 | 1 | 40 | 3665 |
| 1145 | 15.00 | 6.00 | 2 | 1 | 41 | 3892 |
| 1178 | 15.00 | 7.00 | 2 | 1 | 40 | 2813 |
| 1256 | 16.00 | 7.00 | 1 | 1 | 42 | 3778 |
| 1267 | 16.00 | 6.00 | 1 | 1 | 40 | 3523 |
| 1293 | 17.00 | 7.00 | 1 | 1 | 40 | 3040 |
| 1307 | 16.00 | 6.00 | 1 | 1 | 40 | 3636 |
| 1316 | 16.00 | 6.00 | 2 | 1 | 40 | 2983 |
| 1328 | 15.00 | 7.00 | 1 | 1 | 41 | 4119 |
| 1355 | 18.00 | 8.00 | 1 | 1 | 40 | 3665 |
| 1365 | 16.00 | 7.00 | 2 | 1 | 39 | 3636 |
| 1373 | 17.00 | 6.00 | 1 | 1 | 36 | 2855 |
| 1376 | 16.00 | 7.00 | 2 | 1 | 37 | 2983 |
| 1424 | 15.00 | 7.00 | 1 | 1 | 40 | 3551 |
| 1459 | 15.00 | 6.00 | 2 | 1 | 40 | 3239 |
| 1508 | 15.00 | 5.00 | 2 | 1 | 40 | 3551 |
| 1855 | 15.00 | 5.00 | 1 | 1 | 40 | 4148 |
| 1873 | 15.00 | 5.00 | 2 | 1 | 37 | 2585 |

Sit Controls-

| ID | AGE | AGE[a] | SEX | ETH | GA | BW |
|---|---|---|---|---|---|---|
| 710 | 18.00 | 8.00 | 2 | 1 | 38 | 2727 |
| 714 | 18.00 | 8.00 | 2 | 1 | 39 | 3040 |
| 866 | 17.00 | 8.00 | 1 | 5 | 39 | 3409 |
| 1139 | 16.00 | 7.00 | 1 | 1 | 40 | 4659 |
| 1153 | 16.00 | 8.00 | 2 | 1 | 40 | 3339 |
| 1168 | 16.00 | 6.00 | 2 | 1 | 39 | 2926 |
| 1223 | 15.00 | 6.00 | 2 | 1 | 37 | 2557 |
| 1228 | 16.00 | 7.00 | 1 | 1 | 40 | 3629 |
| 1232 | 16.00 | 7.00 | 2 | 1 | 41 | 3565 |
| 1279 | 16.00 | 7.00 | 2 | 1 | 40 | 3182 |
| 1303 | 15.00 | 6.00 | 2 | 1 | 39 | 3835 |
| 1324 | 15.00 | 7.00 | 2 | 1 | 40 | 3239 |
| 1361 | 15.00 | 7.00 | 2 | 1 | 40 | 3608 |
| 1379 | 16.00 | 7.00 | 2 | 1 | 40 | 3352 |
| 1439 | 17.00 | 7.00 | 1 | 1 | 40 | 4261 |
| 1442 | 16.00 | 7.00 | 2 | 5 | 40 | 3409 |
| 1443 | 16.00 | 7.00 | 1 | 1 | 41 | 4090 |
| 1456 | 17.00 | 7.00 | 1 | 1 | 42 | 3580 |
| 1460 | 17.00 | 7.00 | 1 | 1 | 38 | 3545 |
| 1532 | 15.00 | 5.00 | 2 | 1 | 40 | 3494 |
| 1540 | 15.00 | 5.00 | 1 | 1 | 41 | 4261 |
| 1556 | 15.00 | 5.00 | 2 | 5 | 40 | 3097 |

Notes AGE=age at time of follow-up assessment (mos) AGE[a]=age at time of AIMS assessment (mos) SEX: 1=male 2=female ETH=ethnic: 1=Caucasian 2=Oriental 5=mixed GA=gestational age at birth (wks) BW=birhtweight (grams)

# APPENDIX K

## AIMS Sub Scores and Total Scores

## Follow-up Cohort

## Raw Data

AIMS SCORES

Prone Cases-

| ID | AGE | PRONE | SUPINE | SIT | STAND | TOTAL |
|---|---|---|---|---|---|---|
| 672 | 9.00 | 13.00 | 9.00 | 10.00 | 8.00 | 40.00 |
| 852 | 8.00 | 10.00 | 9.00 | 10.00 | 4.00 | 33.00 |
| 871 | 8.00 | 11.00 | 9.00 | 9.00 | 3.00 | 32.00 |
| 897 | 8.00 | 11.00 | 9.00 | 10.00 | 3.00 | 33.00 |
| 1030 | 8.00 | 11.00 | 8.00 | 10.00 | 3.00 | 32.00 |
| 1039 | 9.00 | 14.00 | 9.00 | 10.00 | 7.00 | 40.00 |
| 1142 | 6.00 | 6.00 | 8.00 | 6.00 | 3.00 | 23.00 |
| 1152 | 6.00 | 7.00 | 7.00 | 9.00 | 3.00 | 26.00 |
| 1161 | 7.00 | 8.00 | 7.00 | 9.00 | 2.00 | 26.00 |
| 1180 | 7.00 | 8.00 | 8.00 | 9.00 | 3.00 | 28.00 |
| 1187 | 7.00 | 8.00 | 8.00 | 9.00 | 3.00 | 28.00 |
| 1188 | 8.00 | 11.00 | 8.00 | 10.00 | 3.00 | 32.00 |
| 1248 | 7.00 | 8.00 | 9.00 | 7.00 | 3.00 | 27.00 |
| 1272 | 8.00 | 11.00 | 9.00 | 9.00 | 3.00 | 32.00 |
| 1306 | 6.00 | 7.00 | 7.00 | 8.00 | 3.00 | 25.00 |
| 1359 | 7.00 | 8.00 | 7.00 | 8.00 | 3.00 | 26.00 |
| 1395 | 8.00 | 10.00 | 9.00 | 10.00 | 3.00 | 32.00 |
| 1545 | 5.00 | 6.00 | 7.00 | 5.00 | 3.00 | 21.00 |
| 1564 | 5.00 | 5.00 | 7.00 | 5.00 | 3.00 | 20.00 |

Prone Controls-

| ID | AGE | PRONE | SUPINE | SIT | STAND | TOTAL |
|---|---|---|---|---|---|---|
| 743 | 8.00 | 18.00 | 9.00 | 12.00 | 3.00 | 42.00 |
| 758 | 8.00 | 15.00 | 8.00 | 11.00 | 3.00 | 37.00 |
| 848 | 9.00 | 20.00 | 9.00 | 10.00 | 8.00 | 47.00 |
| 863 | 8.00 | 20.00 | 9.00 | 10.00 | 10.00 | 49.00 |
| 880 | 9.00 | 20.00 | 9.00 | 12.00 | 10.00 | 51.00 |
| 1090 | 7.00 | 16.00 | 8.00 | 9.00 | 5.00 | 38.00 |
| 1091 | 7.00 | 12.00 | 7.00 | 9.00 | 3.00 | 31.00 |
| 1108 | 7.00 | 11.00 | 8.00 | 10.00 | 3.00 | 32.00 |
| 1146 | 6.00 | 10.00 | 7.00 | 7.00 | 3.00 | 27.00 |
| 1196 | 7.00 | 19.00 | 9.00 | 10.00 | 7.00 | 45.00 |
| 1230 | 7.00 | 13.00 | 8.00 | 10.00 | 3.00 | 34.00 |
| 1252 | 8.00 | 21.00 | 9.00 | 12.00 | 11.00 | 53.00 |
| 1340 | 6.00 | 10.00 | 9.00 | 6.00 | 3.00 | 28.00 |
| 1350 | 8.00 | 21.00 | 9.00 | 10.00 | 9.00 | 49.00 |
| 1403 | 8.00 | 18.00 | 9.00 | 11.00 | 8.00 | 46.00 |
| 1447 | 8.00 | 12.00 | 9.00 | 10.00 | 3.00 | 34.00 |
| 1478 | 5.00 | 8.00 | 8.00 | 4.00 | 2.00 | 22.00 |
| 1503 | 5.00 | 7.00 | 7.00 | 4.00 | 3.00 | 21.00 |
| 1627 | 5.00 | 8.00 | 7.00 | 5.00 | 2.00 | 22.00 |

## AIMS SCORES

Sit Cases-

| ID1 | AGE | PRONE | SUPINE | SIT | STAND | TOTAL |
|---|---|---|---|---|---|---|
| 1104 | 8.00 | 16.00 | 9.00 | 6.00 | 4.00 | 35.00 |
| 1127 | 7.00 | 12.00 | 9.00 | 5.00 | 3.00 | 29.00 |
| 1132 | 7.00 | 10.00 | 8.00 | 6.00 | 3.00 | 27.00 |
| 1136 | 7.00 | 12.00 | 9.00 | 5.00 | 3.00 | 29.00 |
| 1145 | 6.00 | 9.00 | 8.00 | 4.00 | 3.00 | 24.00 |
| 1178 | 7.00 | 10.00 | 8.00 | 6.00 | 3.00 | 27.00 |
| 1256 | 7.00 | 13.00 | 8.00 | 5.00 | 5.00 | 31.00 |
| 1267 | 6.00 | 10.00 | 7.00 | 4.00 | 3.00 | 24.00 |
| 1293 | 7.00 | 18.00 | 8.00 | 6.00 | 3.00 | 35.00 |
| 1307 | 6.00 | 17.00 | 8.00 | 4.00 | 3.00 | 32.00 |
| 1316 | 6.00 | 8.00 | 8.00 | 4.00 | 3.00 | 23.00 |
| 1328 | 7.00 | 10.00 | 9.00 | 5.00 | 3.00 | 27.00 |
| 1355 | 8.00 | 15.00 | 9.00 | 5.00 | 5.00 | 34.00 |
| 1365 | 7.00 | 11.00 | 9.00 | 5.00 | 2.00 | 27.00 |
| 1373 | 6.00 | 12.00 | 9.00 | 4.00 | 3.00 | 28.00 |
| 1376 | 7.00 | 11.00 | 8.00 | 6.00 | 2.00 | 27.00 |
| 1424 | 7.00 | 14.00 | 9.00 | 6.00 | 6.00 | 35.00 |
| 1459 | 6.00 | 16.00 | 9.00 | 4.00 | 3.00 | 32.00 |
| 1508 | 5.00 | 7.00 | 7.00 | 2.00 | 3.00 | 19.00 |
| 1855 | 5.00 | 8.00 | 7.00 | 3.00 | 3.00 | 21.00 |
| 1873 | 5.00 | 9.00 | 7.00 | 3.00 | 3.00 | 22.00 |

Sit Controls-

| ID1 | AGE | PRONE | SUPINE | SIT | STAND | TOTAL |
|---|---|---|---|---|---|---|
| 710 | 8.00 | 17.00 | 9.00 | 10.00 | 3.00 | 39.00 |
| 714 | 8.00 | 20.00 | 9.00 | 11.00 | 8.00 | 48.00 |
| 866 | 8.00 | 20.00 | 9.00 | 10.00 | 9.00 | 48.00 |
| 1139 | 7.00 | 13.00 | 9.00 | 10.00 | 3.00 | 35.00 |
| 1153 | 8.00 | 19.00 | 8.00 | 10.00 | 6.00 | 43.00 |
| 1168 | 6.00 | 14.00 | 9.00 | 10.00 | 3.00 | 36.00 |
| 1223 | 6.00 | 12.00 | 8.00 | 7.00 | 3.00 | 30.00 |
| 1228 | 7.00 | 17.00 | 9.00 | 12.00 | 3.00 | 41.00 |
| 1232 | 7.00 | 18.00 | 9.00 | 10.00 | 3.00 | 40.00 |
| 1279 | 7.00 | 9.00 | 7.00 | 8.00 | 2.00 | 26.00 |
| 1303 | 6.00 | 13.00 | 9.00 | 10.00 | 3.00 | 35.00 |
| 1324 | 7.00 | 11.00 | 8.00 | 8.00 | 3.00 | 30.00 |
| 1361 | 7.00 | 11.00 | 7.00 | 10.00 | 3.00 | 31.00 |
| 1379 | 7.00 | 13.00 | 8.00 | 10.00 | 3.00 | 34.00 |
| 1439 | 7.00 | 9.00 | 7.00 | 9.00 | 3.00 | 28.00 |
| 1442 | 7.00 | 11.00 | 8.00 | 10.00 | 3.00 | 32.00 |
| 1443 | 7.00 | 12.00 | 8.00 | 11.00 | 3.00 | 34.00 |
| 1456 | 7.00 | 21.00 | 9.00 | 10.00 | 9.00 | 49.00 |
| 1460 | 7.00 | 14.00 | 9.00 | 7.00 | 3.00 | 33.00 |
| 1532 | 5.00 | 8.00 | 8.00 | 6.00 | 3.00 | 25.00 |
| 1540 | 5.00 | 10.00 | 8.00 | 5.00 | 2.00 | 25.00 |
| 1556 | 5.00 | 11.00 | 9.00 | 7.00 | 3.00 | 30.00 |

# APPENDIX L

## Calculation of Adjusted Alpha Levels

## Ordered Bonferroni Procedure

# Ordered Bonferroni Calculation

(adapted from - Ottenbacher, 1991)

Step 1: Assign order of priority to each of the contrasts according to their importance to the research question. Weight contrasts according to their order.

| | | |
|---|---|---|
| Walk Age | = | weight of 9 |
| P Raw GM | = | weight of 8 |
| P Age GM | = | weight of 7 |
| M Raw GM | = | weight of 6 |

Step 2: Calculate individual p values for top 4 contrasts using formula below.

$\alpha j = \alpha Wj/\Sigma W$ $\Sigma W = H(C - L) + L$

$\alpha$ (Walk Age) = 05 (9)/18 = .025 $\Sigma W = 9(9 - 8) + 9 = 18$

$\alpha$ (P Raw GM) = 05 (8)/23 = .017 $\Sigma W = 8(9 - 7) + 7 = 23$

$\alpha$ (P Age GM) = 05 (7)/27 = .013 $\Sigma W = 7(9 - 6) + 6 = 27$

$\alpha$ (M Raw GM) = 05 (6)/29 = .01 $\Sigma W = 6(9 - 5) + 5 = 29$

---

$\alpha j$ = $\alpha$ level for jth contrast

$\alpha$ = overall $\alpha$ level for all contrasts (.05)

$Wj$ = weight of jth contrast

$\Sigma W$ = sum of weights over all contrasts

H = weight assigned to j contrast

C = total number of contrasts

L = number of lower priority contrasts

# APPENDIX M

## Power Calculation

## Power Calculation

(adapted from - Pocock, 1983)

Sample size was determined using the following formula:

$$n = \frac{2\sigma^2}{(\mu 2 - \mu 1)^2} \times f(\alpha,\beta)$$

$$n = \frac{2(9.5)^2}{(161 - 151.5)^2} \times 7.9$$

$$n = 15.8$$

---

| | | |
|---|---|---|
| n | = | number of subjects |
| $\alpha$ | = | .05 |
| $\beta$ | = | .2 |
| $\sigma$ | = | 9.5 |
| $\mu 2 - \mu 1$ | = | 9.5 (effect size) |
| f | = | $(\alpha,\beta)$ (value from table) |

# APPENDIX N

## Gross Motor and Prelocomotor Status Outcomes

## Follow-up Cohort

## Raw Data

GROSS MOTOR AND PRELOCOMOTOR STATUS OUTCOMES

Prone Cases-

| ID | AGE | PRAWGM | PAGEGM | MRAWGM | MAGEGM | WALK | CRAWL |
|---|---|---|---|---|---|---|---|
| 672 | 19 | 172.00 | 19.00 | 23.00 | 22.00 | 12.00 | 2.00 |
| 852 | 19 | 162.00 | 17.00 | 21.00 | 19.00 | 12.00 | 2.00 |
| 871 | 18 | 162.00 | 17.00 | 23.00 | 22.00 | 13.00 | 1.00 |
| 897 | 20 | 171.00 | 18.50 | 22.00 | 20.00 | 13.00 | 1.00 |
| 1030 | 21 | 158.00 | 16.00 | 20.00 | 18.00 | 17.00 | 1.00 |
| 1039 | 18 | 166.00 | 17.50 | 22.00 | 20.00 | 10.50 | 1.00 |
| 1142 | 16 | 157.00 | 16.00 | 18.00 | 15.00 | 13.00 | 1.00 |
| 1152 | 15 | 145.00 | 14.00 | 15.00 | 12.50 | 11.00 | 2.00 |
| 1161 | 15 | 151.00 | 15.00 | 17.00 | 14.00 | 15.00 | 1.00 |
| 1180 | 16 | 151.00 | 15.00 | 19.00 | 17.00 | 13.50 | 1.00 |
| 1187 | 16 | 155.00 | 15.50 | 16.00 | 13.00 | 14.00 | 1.00 |
| 1188 | 17 | 151.00 | 15.00 | 17.00 | 14.00 | 13.00 | 1.00 |
| 1248 | 15 | 150.00 | 15.00 | 18.00 | 15.00 | 12.00 | 1.00 |
| 1272 | 16 | 156.00 | 16.00 | 17.00 | 14.00 | 13.00 | 1.00 |
| 1306 | 16 | 164.00 | 17.00 | 20.00 | 18.00 | 12.00 | 1.00 |
| 1359 | 17 | 155.00 | 15.50 | 17.00 | 14.00 | 15.00 | 1.00 |
| 1395 | 16 | 165.00 | 17.00 | 23.00 | 22.00 | 11.00 | 1.00 |
| 1545 | 15 | 156.00 | 16.00 | 19.00 | 17.00 | 12.00 | 1.00 |
| 1564 | 15 | 161.00 | 16.50 | 21.00 | 19.00 | 9.00 | 2.00 |

Prone Controls-

| ID | AGE | PRAWGM | PAGEGM | MRAWGM | MAGEGM | WALK | CRAWL |
|---|---|---|---|---|---|---|---|
| 743 | 21 | 188.00 | 22.00 | 24.00 | 24.00 | 11.00 | 1.00 |
| 758 | 18 | 162.00 | 17.00 | 20.00 | 18.00 | 11.50 | 1.00 |
| 848 | 18 | 163.00 | 17.00 | 19.00 | 17.00 | 11.00 | 1.00 |
| 863 | 20 | 176.00 | 19.50 | 20.00 | 18.00 | 9.00 | 1.00 |
| 880 | 16 | 179.00 | 20.00 | 25.00 | 27.00 | 12.50 | 1.00 |
| 1090 | 16 | 161.00 | 16.50 | 25.00 | 27.00 | 10.50 | 1.00 |
| 1091 | 16 | 159.00 | 16.00 | 20.00 | 18.00 | 12.00 | 1.00 |
| 1108 | 18 | 165.00 | 17.00 | 25.00 | 25.50 | 12.00 | 1.00 |
| 1146 | 16 | 154.00 | 15.00 | 20.00 | 18.00 | 13.00 | 2.00 |
| 1196 | 16 | 158.00 | 16.00 | 19.00 | 17.00 | 11.00 | 1.00 |
| 1230 | 16 | 168.00 | 18.00 | 18.00 | 15.00 | 10.00 | 2.00 |
| 1252 | 16 | 157.00 | 16.00 | 22.00 | 20.00 | 8.50 | 1.00 |
| 1340 | 16 | 163.00 | 17.00 | 19.00 | 17.00 | 11.00 | 1.00 |
| 1350 | 18 | 164.00 | 17.00 | 24.00 | 24.00 | 12.00 | 1.00 |
| 1403 | 17 | 156.00 | 16.00 | 20.00 | 18.00 | 11.50 | 2.00 |
| 1447 | 17 | 155.00 | 15.50 | 20.00 | 18.00 | 13.00 | 1.00 |
| 1478 | 15 | 152.00 | 15.00 | 20.00 | 18.00 | 11.00 | 1.00 |
| 1503 | 15 | 144.00 | 14.00 | 16.00 | 13.00 | 14.00 | 1.00 |
| 1627 | 15 | 153.00 | 15.00 | 18.00 | 15.00 | 13.00 | 1.00 |

Notes PRAWGM=PDMS raw gross motor score PAGEGM=PDMS age equivalent score (mos) MRAWGM=MCDI raw gross motor score MAGEGM=MCDI age equivalent score (mos) WALK= walking age (mos) CRAWL= prelocomotor strategy (1=crawl,2=no crawl)

GROSS MOTOR AND PRELOCOMOTOR STATUS OUTCOMES

Sit Cases-

| ID | AGE | PRAWGM | PAGEGM | MRAWGM | MAGEGM | WALK | CRAWL |
|---|---|---|---|---|---|---|---|
| 1104 | 16 | 155.00 | 16.00 | 20.00 | 18.00 | 11.50 | 1.00 |
| 1127 | 15 | 160.00 | 16.00 | 21.00 | 19.00 | 10.00 | 1.00 |
| 1132 | 17 | 163.00 | 17.00 | 21.00 | 19.00 | 12.00 | 1.00 |
| 1136 | 17 | 160.00 | 16.00 | 21.00 | 19.00 | 14.00 | 1.00 |
| 1145 | 15 | 143.00 | 14.00 | 16.00 | 13.00 | 15.00 | 2.00 |
| 1178 | 15 | 150.00 | 15.00 | 20.00 | 18.00 | 12.00 | 1.00 |
| 1256 | 16 | 153.00 | 15.50 | 17.00 | 14.00 | 10.50 | 1.00 |
| 1267 | 16 | 162.00 | 17.00 | 22.00 | 20.00 | 12.50 | 1.00 |
| 1293 | 17 | 153.00 | 15.00 | 18.00 | 15.00 | 10.50 | 1.00 |
| 1307 | 16 | 158.00 | 16.00 | 16.00 | 13.00 | 12.50 | 1.00 |
| 1316 | 16 | 157.00 | 16.00 | 19.00 | 17.00 | 11.00 | 1.00 |
| 1328 | 15 | 151.00 | 15.00 | 18.00 | 15.00 | 14.00 | 1.00 |
| 1355 | 18 | 168.00 | 18.00 | 20.00 | 18.00 | 12.00 | 1.00 |
| 1365 | 16 | 155.00 | 16.00 | 18.00 | 15.00 | 12.00 | 1.00 |
| 1373 | 17 | 157.00 | 16.00 | 19.00 | 17.00 | 13.00 | 1.00 |
| 1376 | 16 | 156.00 | 16.00 | 22.00 | 20.00 | 12.00 | 1.00 |
| 1424 | 15 | 163.00 | 17.00 | 21.00 | 19.00 | 10.00 | 1.00 |
| 1459 | 15 | 155.00 | 15.00 | 17.00 | 14.00 | 10.00 | 1.00 |
| 1508 | 15 | 148.00 | 14.00 | 21.00 | 19.00 | 11.00 | 1.00 |
| 1855 | 15 | 147.00 | 14.00 | 19.00 | 17.00 | 12.00 | 1.00 |
| 1873 | 15 | 156.00 | 16.00 | 20.00 | 18.00 | 11.50 | 1.00 |

Sit Controls-

| ID | AGE | PRAWGM | PAGEGM | MRAWGM | MAGEGM | WALK | CRAWL |
|---|---|---|---|---|---|---|---|
| 710 | 18 | 165.00 | 17.00 | 19.00 | 17.00 | 14.50 | 1.00 |
| 714 | 18 | 164.00 | 17.00 | 19.00 | 17.00 | 10.00 | 1.00 |
| 866 | 17 | 172.00 | 19.00 | 23.00 | 22.00 | 11.00 | 1.00 |
| 1139 | 16 | 160.00 | 16.00 | 18.00 | 15.00 | 11.00 | 1.00 |
| 1153 | 16 | 157.00 | 16.00 | 21.00 | 19.00 | 11.00 | 1.00 |
| 1168 | 16 | 160.00 | 16.00 | 25.00 | 25.50 | 9.00 | 1.00 |
| 1223 | 15 | 148.00 | 14.00 | 18.00 | 15.00 | 12.00 | 1.00 |
| 1228 | 16 | 158.00 | 16.00 | 20.00 | 18.00 | 12.50 | 1.00 |
| 1232 | 16 | 149.00 | 14.50 | 18.00 | 15.00 | 12.50 | 1.00 |
| 1279 | 16 | 159.00 | 16.00 | 19.00 | 17.00 | 13.00 | 1.00 |
| 1303 | 15 | 159.00 | 16.00 | 20.00 | 18.00 | 9.00 | 2.00 |
| 1324 | 15 | 150.00 | 15.00 | 20.00 | 18.00 | 12.00 | 1.00 |
| 1361 | 15 | 151.00 | 15.00 | 21.00 | 19.00 | 12.00 | 1.00 |
| 1379 | 16 | 158.00 | 16.00 | 20.00 | 18.00 | 10.00 | 1.00 |
| 1439 | 17 | 160.00 | 16.00 | 21.00 | 19.00 | 11.50 | 1.00 |
| 1442 | 16 | 169.00 | 18.00 | 23.00 | 22.00 | 12.00 | 1.00 |
| 1443 | 16 | 166.00 | 18.00 | 21.00 | 19.00 | 10.50 | 1.00 |
| 1456 | 17 | 168.00 | 18.00 | 22.00 | 20.00 | 9.00 | 1.00 |
| 1460 | 17 | 159.00 | 16.00 | 19.00 | 17.00 | 13.00 | 1.00 |
| 1532 | 15 | 144.00 | 14.00 | 16.00 | 13.00 | 12.00 | 1.00 |
| 1540 | 15 | 156.00 | 16.00 | 21.00 | 19.00 | 13.00 | 1.00 |
| 1556 | 15 | 165.00 | 17.00 | 23.00 | 22.00 | 10.00 | 1.00 |

Notes PRAWGM=PDMS raw gross motor score PAGEGM=PDMS age equivalent score (mos) MRAWGM=MCDI raw gross motor score MAGEGM=MCDI age equivalent score (mos) WALK= walking age (mos) CRAWL= prelocomotor strategy (1=crawl,2=no crawl)

# APPENDIX O

## Fine Motor and General Development Outcomes

## Follow-up Cohort

## Raw Data

FINE MOTOR AND GENERAL DEVELOPMENT OUTCOMES

Prone Cases-

| ID1 | AGE | PRAWFM | PAGEFM | MRAWFM | MAGEFM | HAPPY |
|---|---|---|---|---|---|---|
| 672 | 19.00 | 138.00 | 20.00 | 30.00 | 30.00 | 1.00 |
| 852 | 19.00 | 138.00 | 20.00 | 29.00 | 30.00 | 1.00 |
| 871 | 18.00 | 129.00 | 17.50 | 29.00 | 27.00 | 1.00 |
| 897 | 20.00 | 138.00 | 20.00 | 20.00 | 12.00 | 1.00 |
| 1030 | 21.00 | 138.00 | 20.00 | 33.00 | 33.00 | 1.00 |
| 1039 | 18.00 | 136.00 | 19.00 | 27.00 | 22.00 | 1.00 |
| 1142 | 16.00 | 131.00 | 18.00 | 22.00 | 13.00 | 1.00 |
| 1152 | 15.00 | 125.00 | 16.50 | 23.00 | 14.50 | 1.00 |
| 1161 | 15.00 | 131.00 | 18.00 | 27.00 | 22.00 | 1.00 |
| 1180 | 16.00 | 122.00 | 16.00 | 25.00 | 18.00 | 1.00 |
| 1187 | 16.00 | 120.00 | 15.50 | 27.00 | 22.00 | 1.00 |
| 1188 | 17.00 | 117.00 | 15.00 | 23.00 | 14.50 | 1.00 |
| 1248 | 15.00 | 120.00 | 15.50 | 26.00 | 20.00 | 1.00 |
| 1272 | 16.00 | 124.00 | 16.00 | 22.00 | 13.00 | 1.00 |
| 1306 | 16.00 | 133.00 | 18.50 | 24.00 | 15.00 | 1.00 |
| 1359 | 17.00 | 141.00 | 20.50 | 29.00 | 27.00 | 1.00 |
| 1395 | 16.00 | 131.00 | 18.00 | 27.00 | 22.00 | 1.00 |
| 1545 | 15.00 | 126.00 | 17.00 | 20.00 | 12.00 | 1.00 |
| 1564 | 15.00 | 127.00 | 17.00 | 27.00 | 22.00 | 1.00 |

Prone Controls-

| ID1 | AGE | PRAWFM | PAGEFM | MRAWFM | MAGEFM | HAPPY |
|---|---|---|---|---|---|---|
| 743 | 21.00 | 147.00 | 22.50 | 24.00 | 15.00 | 1.00 |
| 758 | 18.00 | 131.00 | 18.00 | 25.00 | 18.00 | 1.00 |
| 848 | 18.00 | 138.00 | 20.00 | 25.00 | 18.00 | 1.00 |
| 863 | 20.00 | 141.00 | 20.50 | 28.00 | 24.00 | 1.00 |
| 880 | 20.00 | 140.00 | 20.00 | 24.00 | 15.00 | 1.00 |
| 1090 | 16.00 | 136.00 | 19.00 | 29.00 | 30.00 | 1.00 |
| 1091 | 16.00 | 131.00 | 18.00 | 24.00 | 15.00 | 1.00 |
| 1108 | 18.00 | 138.00 | 20.00 | 30.00 | 30.00 | 1.00 |
| 1146 | 16.00 | 124.00 | 16.00 | 26.00 | 20.00 | 1.00 |
| 1196 | 16.00 | 134.00 | 19.00 | 26.00 | 20.00 | 1.00 |
| 1230 | 16.00 | 128.00 | 17.00 | 26.00 | 20.00 | 1.00 |
| 1252 | 16.00 | 122.00 | 16.00 | 26.00 | 20.00 | 1.00 |
| 1340 | 16.00 | 134.00 | 19.00 | 25.00 | 18.00 | 1.00 |
| 1350 | 18.00 | 120.00 | 15.50 | 26.00 | 20.00 | 1.00 |
| 1403 | 17.00 | 135.00 | 19.00 | 30.00 | 31.50 | 1.00 |
| 1447 | 17.00 | 129.00 | 17.50 | 26.00 | 20.00 | 1.00 |
| 1478 | 15.00 | 119.00 | 15.00 | 27.00 | 22.00 | 1.00 |
| 1503 | 15.00 | 126.00 | 17.00 | 26.00 | 20.00 | 1.00 |
| 1627 | 15.00 | 126.00 | 17.00 | 30.00 | 31.50 | 1.00 |

Notes PRAWFM=PDMS raw fine motor score PAGEFM=PDMS age equivalent fine motor score (mos) MRAWFM=MCDI raw fine motor score MAGEFM=MCDI age equivalent fine motor score (mos) HAPPY= parental response to question: "Are you happy with your child's development?" 1=yes 2=no

Sit Cases-

| ID1 | AGE | PRAWFM | PAGEFM | MRAWFM | MAGEFM | HAPPY |
|---|---|---|---|---|---|---|
| 1104 | 16.00 | 120.00 | 16.00 | 20.00 | 12.00 | 1.00 |
| 1127 | 15.00 | 128.00 | 17.00 | 25.00 | 18.00 | 1.00 |
| 1132 | 17.00 | 130.00 | 18.00 | 26.00 | 20.00 | 1.00 |
| 1136 | 17.00 | 116.00 | 15.00 | 28.00 | 27.00 | 1.00 |
| 1145 | 15.00 | 123.00 | 16.00 | 24.00 | 15.00 | 1.00 |
| 1178 | 15.00 | 110.00 | 13.50 | 24.00 | 15.00 | 1.00 |
| 1256 | 16.00 | 124.00 | 16.00 | 25.00 | 18.00 | 1.00 |
| 1267 | 16.00 | 140.00 | 20.00 | 27.00 | 22.00 | 1.00 |
| 1293 | 17.00 | 124.00 | 16.00 | 25.00 | 18.00 | 1.00 |
| 1307 | 16.00 | 130.00 | 18.00 | 21.00 | 12.50 | 1.00 |
| 1316 | 16.00 | 138.00 | 20.00 | 27.00 | 22.00 | 1.00 |
| 1328 | 15.00 | 117.00 | 15.00 | 21.00 | 12.50 | 1.00 |
| 1355 | 18.00 | 139.00 | 20.00 | 26.00 | 20.00 | 1.00 |
| 1365 | 16.00 | 136.00 | 19.00 | 23.00 | 14.50 | 1.00 |
| 1373 | 17.00 | 128.00 | 17.00 | 27.00 | 22.00 | 1.00 |
| 1376 | 16.00 | 120.00 | 15.50 | 24.00 | 15.00 | 1.00 |
| 1424 | 15.00 | 111.00 | 14.00 | 22.00 | 13.00 | 1.00 |
| 1459 | 15.00 | 124.00 | 16.00 | 25.00 | 18.00 | 1.00 |
| 1508 | 15.00 | 122.00 | 16.00 | 29.00 | 27.00 | 1.00 |
| 1855 | 15.00 | 116.00 | 15.00 | 25.00 | 18.00 | 1.00 |
| 1873 | 15.00 | 136.00 | 19.00 | 27.00 | 22.00 | 1.00 |

Sit Cases-

| ID1 | AGE | PRAWFM | PAGEFM | MRAWFM | MAGEFM | HAPPY |
|---|---|---|---|---|---|---|
| 710 | 18.00 | 137.00 | 19.50 | 26.00 | 20.00 | 1.00 |
| 714 | 18.00 | 132.00 | 18.00 | 21.00 | 12.50 | 1.00 |
| 866 | 17.00 | 136.00 | 19.00 | 26.00 | 20.00 | 1.00 |
| 1139 | 16.00 | 126.00 | 17.00 | 23.00 | 14.50 | 1.00 |
| 1153 | 16.00 | 113.00 | 14.00 | 25.00 | 18.00 | 1.00 |
| 1168 | 16.00 | 133.00 | 18.50 | 25.00 | 18.00 | 1.00 |
| 1223 | 15.00 | 106.00 | 13.00 | 25.00 | 18.00 | 1.00 |
| 1228 | 16.00 | 128.00 | 17.00 | 23.00 | 14.50 | 1.00 |
| 1232 | 16.00 | 122.00 | 16.00 | 28.00 | 24.00 | 1.00 |
| 1279 | 16.00 | 125.00 | 16.50 | 28.00 | 24.00 | 1.00 |
| 1303 | 15.00 | 127.00 | 17.00 | 22.00 | 13.00 | 1.00 |
| 1324 | 15.00 | 126.00 | 17.00 | 26.00 | 20.00 | 1.00 |
| 1361 | 15.00 | 116.00 | 15.00 | 24.00 | 15.00 | 1.00 |
| 1379 | 16.00 | 133.00 | 18.00 | 22.00 | 13.00 | 1.00 |
| 1439 | 17.00 | 132.00 | 18.00 | 27.00 | 22.00 | 1.00 |
| 1442 | 16.00 | 135.00 | 19.00 | 27.00 | 22.00 | 1.00 |
| 1443 | 16.00 | 130.00 | 18.00 | 25.00 | 18.00 | 1.00 |
| 1456 | 17.00 | 133.00 | 18.50 | 28.00 | 27.00 | 1.00 |
| 1460 | 17.00 | 135.00 | 19.00 | 25.00 | 18.00 | 1.00 |
| 1532 | 15.00 | 110.00 | 13.50 | 23.00 | 14.50 | 1.00 |
| 1540 | 15.00 | 127.00 | 17.00 | 27.00 | 22.00 | 1.00 |
| 1556 | 15.00 | 136.00 | 19.00 | 27.00 | 22.00 | 1.00 |

Notes PRAWFM=PDMS raw fine motor score PAGEFM=PDMS age equivalent fine motor score (mos) MRAWFM=MCDI raw fine motor score MAGEFM=MCDI age equivalent fine motor score (mos) HAPPY= parental response to question: "Are you happy with your child's development?" 1=yes 2=no