**THE VALIDITY OF THE "EIGHT MONTH MOVEMENT ASSESSMENT
OF INFANTS" AS A PREDICTOR OF MOTOR OUTCOME
IN EXTREMELY LOW BIRTH WEIGHT INFANTS**

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Abstract

With improvments in neonatal intensive care, more extremely low birth weight (ELBW) infants are surviving and are followed in developmental clinics from birth to adulthood. Early research with this population describes increasing frequencies of motor handicaps with decreasing birth weight. Although identification of major and subtle motor disabilities in these ELBW infants remains complex and difficult, it is important so that therapeutic interventions can be initiated at an early stage of the infants' development.

In 1980, three therapists working with ELBW infants in a follow-up clinic designed the Movement Assessment of Infants (MAI), to be used for early identification of motor dysfunction in this population. The MAI has two profiles, a four month profile and an eight month profile. Since its publication, research evaluating the MAI has used the four month profile. Although this profile has been shown to be a reliable measure, it has not been found to be predictive of long term motor outcome in ELBW infants. There is little research reporting the predictive validity of the eight month profile.

The major purpose of this study is to determine whether the eight month MAI profile is predictive of motor outcome at four and a half years in ELBW infants. In addition, the predictive ability of another eight month measure, one which is based on clinicians' subjective ratings of neuromotor status (NMS), is investigated.

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The seventy-two infants included in this study were cared for in the Special Care Nursery at British Columbia's Children's Hospital and were followed in the Neonatal Follow-up Clinic. Assessment tools were administered at eight months corrected chronological age (corrected for prematurity) and again at four and a half years by the clinic occupational therapist. The eight month assessment included the MAI and the NMS. Outcome assessments administered at four and a half years included the Peabody Developmental Motor Scale-Fine Motor Subtest, Gross Motor Screening Items and another NMS rating. Finally, all infants were given a neurological assessment by the clinic paediatrician to diagnose cerebral palsy (CP) and identify any other medical problems.

The ability of the eight month MAI and NMS to correctly identify infants with CP was determined using sensitivity and specificity analyses. The ability of the eight month measures to predict fine motor outcome at four and a half years was determined using Spearman's rank correlations. Finally, using a multivariate approach, the eight month measures were correlated with all four and a half year outcome measures using canonical analysis.

Analyses revealed that the eight month NMS had both higher sensitivity and specificity than the MAI in identifying CP in ELBW infants. The eight Month MAI was not predictive of fine motor outcome at four and a half years, but was predictive of gross motor outcome. Finally, the eight month NMS rating was the best predictor of both fine and gross motor outcome at four years.

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CHAPTER ONE:

PROBLEM STATEMENT

The primary goal of paediatric physical and occupational therapists who evaluate the motor outcome of premature infants is early identification of motor disabilities. Early diagnosis of motor disabilities in this high risk population allows application of therapeutic interventions which may minimize the effects of the disability, thereby improving these children's overall function (Bobath and Bobath, 1956). However, changing motor signs with increasing age, particularly in extremely low birth weight infants (ELBW) (Drillien, Thomson and Burgoyne, 1983), effects of persisting perinatal illness and the lack of standardized, reliable predictive neuromotor tests have complicated accurate early diagnosis (Harris, Swanson, Andrews, Sells, Robinson, Bennett and Chandler, 1984b)

With recent advances in perinatal medicine, a greater number of extremely low birth weight infants ($\leq$1000 grams) are surviving. (See Appendix A for definitions of infant descriptors). Survival of ELBW infants between 1975 and 1980 increased 24 percent at two major perinatal units in the United States (Vohr and Hack, 1982). At the B.C.'s Children's Hospital in Vancouver, British Columbia, the survival rate for ELBW infants in 1985 was as high as 70 percent.

Nevertheless, this improved survival rate is accompanied by costs in the neurodevelopmental outcomes of the survivors of

neonatal intensive care. Low birth weight infants have a rate of major neurodevelopmental disabilities ranging from 10 to 40 percent (see Table 1) (Sweeney and Swanson, 1990).

Table 1. Incidence of major neurodevelopmental Handicaps* in low birth weight infants.

Infant birth weight	Neurodevelopmental Handicaps
1500-2500 grams	10%
1001-1500 grams	10%-20%
≤1000 grams	15%-40%

*Cerebral Palsy, mental retardation, hydrocephalus, visual impairment, sensorineural hearing loss

And these figures suggest that those infants of lowest birth weights (≤1000 grams) are at the highest risk for developing major disabilities. More importantly, follow-up studies of longer duration are reporting increased incidence of intellectual disabilities, and subtle motor and learning disabilities in ELBW infants compared to normal controls (Vohr and Hack, 1982).

Although therapists strive for early identification of motor disabilities in the ELBW population, providing accurate diagnosis and predicting which ELBW infants are at greatest risk for developing motor abnormalities remains complex for a number of reasons. Firstly, as more is written about the motor development of ELBW infants, it is becoming increasingly clear that their development is quite different from that of the normal full term infant. In fact, the early motor characteristics of ELBW infants may resemble that of an infant who has cerebral palsy (CP). For example, Richmond Paine (1961) described the motor signs which most

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clearly identify those infants who have motor abnormalities or cerebral palsy. These signs included delayed social responses such as smiling, early strong hand preference, increased muscle tone in the extremities with decreased muscle tone in the neck and trunk, delayed balance, movement that is influenced by neonatal and infant reflexes long after they should be integrated, and generalized delay in achievement of motor milestones.

Then in 1972, Drillien described a group of transient abnormal neurological signs seen in the premature infant during their first year of life (Drillien, 1972a). These signs, called "transient dystonia", were almost identical to those described by Paine, but were found to "disappear" within the first year of life in 60 percent of the premature infants. Of the remaining 40 percent, half were subsequently normal and the other half were subsequently diagnosed with CP. Drillien's description of transient dystonia was an important contribution to neonatal medicine and follow-up. The challenge to therapists involved in the follow-up of the ELBW infant is to identify, predict and differentiate which of these infants will show true, persisting abnormal motor signs from those who have transient dystonia.

A second factor which complicates early identification of motor abnormalities in ELBW infants is the effect that persistent perinatal illness has on the development of their motor skills. Premature infants with severe respiratory distress often demonstrate decreased muscle tone and delayed motor maturation which may persist as long as their pulmonary capacity is

compromised (Bennett, Robinson and Sells, 1982). When the pulmonary condition resolves, these infants can show an acceleration in their development so that they function within the normal range when evaluated at 12-18 months of age. Once again, therapists evaluating ELBW infants must predict and identify those infants who have motor development that will improve as their respiratory status improves and those who will show truly abnormal motor signs.

Thirdly, in addition to the complex motor development of the ELBW infant, the lack of standardized and predictive neuromotor tests have further complicated early diagnosis of motor disability in the ELBW infant (Harris et al. 1984b). In a comprehensive review, Harris and Brady (1986) described the reliability and validity of six infant neuromotor assessments currently being used to identify CP. They found that infant neuromotor assessments lacked both published norms and substantiated predictive validity.

Finally, as the ELBW infants grow older, long-term outcome studies are reporting new information about less obvious, but persisting motor disabilities which are revealed just prior to and at school age. Drillien (1972a) described both learning disabilities, and behavioral disturbances, in 60% of premature infants evaluated at school age. More recently, Kaye, Whitfield and Grunau (1989) reported that 4 1/2 year old children with birth weights $\leq$ 800 grams who were free of CP had an extremely high incidence (70%) of fine motor disability. The incidence of these more subtle motor disabilities appears to be even higher than that

of CP in the ELBW infant population. Therefore, it is important that therapists involved in high-risk infant follow-up use assessments that not only provide early identification of major motor disabilities, but that also can identify minor, but more prevalent disabilities.

Thus with the complexities of transient abnormal motor signs, persisting neonatal illness and the lack of predictive infant neuromotor tests, identification of permanent major and minor motor disabilities in ELBW infants continues to be a difficult challenge for clinicians and researchers.

CHAPTER TWO:

LITERATURE REVIEW

The "art" and "science" of developing infant and neonatal neuromotor assessments have been of interest to both medical and allied health professionals for many years. Current evaluation tools were based on infant neurological assessments developed in France by Andre-Thomas, Chesni and Saint-Anne Dargassies. The works of these physicians were supplemented by those of a British physician, Illingworth and then of an American physician, Richmond Paine, who published one of the first comprehensive neurologic examinations for infants and children (Harris and Brady, 1986). Milani-Comparetti and Gidoni (1967), Capute, Accardo and Vining, (1978) and Amiel-Tison and Grenier (1983), further refined the evaluation of infants' neuromotor status.

As more preterm infants survived, interest in neurological examination of this group of babies was intensified in an effort to be able to identify those with motor disabilities at as early an age as possible. Prechtl (1977), Brazelton (1983,1984) and Dubowitz and Dubowitz (1981) were instrumental in describing techniques and designing assessments specifically for the preterm infant. In more recent years, Als, Duffy and McAnulty (1982), and Chandler, Andrews and Swanson (1980) have designed specialized assessments which are used for the evaluation of the preterm infant. In this chapter, the works of the major authors of infant and preterm infant

neurological tests will be reviewed.

Clinical Judgment as a Measure of Infant and Preterm Neurological/Neuromotor Status

Prior to the advent of standardized infant and preterm assessments, the "art" of infant neuromotor evaluation allowed clinicians to base their findings on a variety of clinical procedures and subjective observations. These encouraged clinicians to use their judgment and experience to diagnose motor disabilities in infants. Although the attitude is not documented in the literature, regular use of standardized infant and preterm assessments was met with some resistance from the therapy community. Many experienced therapists felt that clinical judgment was an adequate measure of infants' neuromotor status and that, by administering standardized tests, they were subjecting the infants to long and unnecessary testing.

As therapists became more involved in the assessment and treatment of high risk infants, they were required to evaluate infants more scientifically - to demonstrate that their assessment and treatment methods were reliable, valid and effective. Thus, the importance of clinical judgment was diminished. This shift from the use of clinical judgment as the sole measure of infants' neuromotor status to the use of standardized measures remains an unexplored area of infant and preterm assessment research.

Infant Neurological/Neuromotor Assessment

Infant neurological assessment was first described in detail by three French physicians, Andre-Thomas, Chesni and Saint-Anne Dargassies (Harris and Brady, 1986). Their methods were based on adult neurological examination and focused on the examination of the infant's muscle tone, and on elicitation of certain primitive reflexes and reactions. A British physician, Illingworth (1966), was also a pioneer in describing methods for early diagnosis of cerebral palsy. Although he did not design a specific protocol for evaluation of the infant, he did describe early markers of cerebral palsy, such as increased muscle tone. Illingworth added to the neurological evaluation of the infant by not only assessing primitive reflexes and reactions, but also by observing how the infant performed in a variety of developmental positions, an important aspect used in infant neurological evaluation today.

Richmond Paine, an American physician, published the first comprehensive neurological examination of infants and children (Harris and Brady, 1986). His contribution to infant assessment included the evaluation of special senses such as vision, hearing, taste and smell and, in the older child, evaluation of speech, mental state, sensation and autonomic function. The invaluable contributions of these early scientists formed the basis upon which the more modern infant neurological assessments are based (Harris and Brady, 1986).

One of the first of these modern assessments was the Milani-Comparetti Developmental Examination (Milani-Comparetti and Gidoni, 1967). Its purpose was to evaluate infants' neurological and developmental status. It could be used with infants from birth to 24 months of age and focused on the gross motor development and the underlying postural reactions required to perform motor skills. The original form of this test did not provide any method of quantifying motor skills, but more recent versions have included numerical scoring systems with a total score achieved by summation (Sweeney and Swanson, 1990). It has been shown that, when this assessment was used on infants at three months, it was not predictive of later motor outcome. However, when used at six months, it was able to identify those infants with cerebral palsy, but not at an acceptable level needed for a screening tool (Sweeney and Swanson, 1990).

In 1978, Capute and colleagues published the Primitive Reflex Profile. This assessment was created to both identify and predict cerebral palsy in infants. The development of this assessment tool was extremely important because it taught clinicians the role that primitive reflex activity has on the development of normal and abnormal movement in infants. In addition, assessment of a group of normal infants was included in the test development. Although this assessment tool was the first to describe the normal appearance and integration of primitive reflexes in the infant, several limitations of its use have been identified since its publication. No statistical analysis of its reliability has been

conducted. Further, neither concurrent nor predictive validity data were compiled during the test development.

In 1983, the Neurologic Evaluation of the Newborn and Infant was published by Amiel-Tison and Grenier. This test could be used to evaluate infants up to one year of age, and its purpose was to identify neurological abnormalities. This assessment focused on muscle tone primarily, but did not include evaluation of developmental milestones. Although this assessment had a described procedure for administration, it was not standardized on a group of normal infants. Moreover, the use of this assessment for predictive purposes was limited because abnormal signs noted during infancy resolved at older ages.

Preterm Neurological/Neuromotor Assessment

As neonatal medicine progressed, more clinicians became involved in the development of neurological and neuromotor assessment tools which could be used specifically for the evaluation of the premature infant. These assessments were needed because of differences in motor development between preterm and full term infants. Two types of assessments were developed: assessments used to calculate the infant's gestational age (Dubowitz, Dubowitz and Goldberg, 1970, and Lubchenco, 1976) and assessments used to evaluate the integrity of the central nervous system and to describe newborn behaviour. The purpose of the following discussion is to review the development of this second group of

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assessment tools.

The first neonatal neurological assessment, the Neurological Examination of the Full-term Infant, was developed by Prechtl (1977). The purpose of this assessment tool was to identify abnormal neurological signs in the newborn period. This assessment tool was standardized on 1350 infants with gestational ages ranging from 38-42 weeks, but has been adapted to be used with the premature infant. Prechtl stated that if the assessment is used on the low birth weight infant, examiners should expect lower muscle tone than found in the full term infant. Based on his work with the full term infant, Prechtl described a group of abnormal findings which placed the premature infant at risk for later developmental handicap. These findings included asymmetries in tone, postures or reflexes, instability of behavioral states such as prolonged crying, increased muscle tone, or decreased muscle tone and low levels of arousal. Today this assessment is regularly used by clinicians working in intensive care nurseries to evaluate the neurological status of the low birth weight infant when they reach term corrected chronological age (this age is based on the expected date of birth of the infant, not on the actual delivery date) (Sweeney and Swanson, 1990). Although this assessment continues to be used regularly, no reliability or predictive validity data were provided when this test was introduced.

A second infant assessment used for the evaluation of the preterm infant was developed by Brazelton, a paediatrician who was very interested in infant behaviours as markers of normal and abnormal

neurological status. Portions of his assessment were based on Prechtl's earlier work. Brazelton designed an infant evaluation called the Neonatal Behavioral Assessment Scale (NBAS)(Brazelton, 1973). The test consisted of both items which require observation and items which involve eliciting infant behaviours and infant reflexes. Like Prechtl's work, this assessment was originally designed to be given to full-term infants, but more recently has had nine additional items included so that it can be given to the low birth weight infant (Brazelton, 1984). Clusters of behaviors which describe deviations in motor activity and organizational behaviour have been associated with increased risk for developmental handicaps (Sweeney and Swanson, 1990). In a study of 53 preterm neonates followed to 7 years, the NBAS was been shown to be more predictive of outcome than standard clinical neurological examination (Tronick and Brazelton, 1975). Although this assessment is also used regularly, no normative data were collected during the test's development.

In 1981, Dubowitz and Dubowitz published the Neurological Assessment of Preterm and Full-term Newborn Infant, the first neurological test designed specifically for use with the low birth weight infant. Including portions of previously designed tools, this test incorporated items from the NBAS as well as items that assessed tone, movement and infant reflexes taken from the works of many of the previously mentioned authors. Although this assessment has been used on infants of varying gestational ages, reliability and long term predictive validity data , that which includes

criterion measures after 3 years of age, are not yet published. And although initial reports have described the abnormal neonatal findings which best correlated with abnormal outcome at one year of age, these findings were based on case studies only.

The most recently published neonatal evaluation, the Assessment of Preterm Behaviour, was designed by Als and colleagues (1982). Als is an American psychologist who has worked closely with Brazelton. This tool provided a detailed evaluation of the low birth weight infant's autonomic, adaptive, and interactive responses to graded handling and environmental stimuli. This assessment was developed using traditional psychometric principles of test development; however, it requires extensive training to achieve acceptable reliability among examiners and is therefore not practical for many clinicians. Further, because it is newly developed, long term predictive validity data are not yet available.

Based on the early works of Milani-Comparetti, Capute and Amiel-Tison, and later of Prechtl, Brazelton and the Dubowitzes, more sophisticated and sensitive neurological assessments for the low birth weight infant are now available. These assessments utilize a variety of neuromotor and behavioral components, such as muscle tone, primitive reflexes, balance reactions and motor milestones. These remain the basis for infant and neonatal assessments for the ELBW population. It is not yet clear, however, how well evaluations given in the newborn period predict long term outcome in this high-risk group of children. A summary of the infant and preterm

neurological/neuromotor assessments is presented in Table 2.

Table 2. Summary of Infant and Preterm Neurological/Neuromotor Assessments

Test	Strengths	Weaknesses
Infant Neurological/Neuromotor Assessments		
1. Neurological Examination (Paine, 1966)	First neurological evaluation for infants	No traditional test development techniques used
2. Milani-Comparetti Developmental Examination (Milani-Comparetti and Gidoni, 1967)	Included motor milestones and balance reactions, used longitudinally, revised form includes reliability data	Test shown not to be predictive of later motor outcome
3. Primitive Reflex Profile (Capute et al, 1978)	Stressed importance of primitive reflexes, used control group for norming	No correlation coefficients of reliability, nor measures of concurrent validity in test manual
4. Neurologic Evaluation of the Newborn Infant (Amiel-Tison and Grenier, 1983)	Focused on muscle tone	Not normed and limited reliability and validity measures at test publication
Preterm Neurological/Neuromotor Assessments		
1. Neurological Examination of the Full-term Infant (Prechtl, 1977)	Adapted for preterm infants, systematic approach to examination	No reliability data in test manual, predictive validity not investigated through use of correlation coefficients by subsequent investigators
2. Neonatal Behavioral Assessment Scale (Brazelton, 1973/1984)	Included infant behaviors, provides reliability and validity data	No normative data provided
3. Neurologic Assessment of Preterm and Fullterm Newborn (Dubowitz and Dubowitz, 1981)	Specifically designed for use with preterm infants	No reliability or validity data available at publication
4. Assessment of Preterm Behaviour (Als et al, 1982)	Specifically designed for preterm infants	Requires extensive training, predictive studies only use early outcome measures (18 months)
5. The Movement Assessment of Infants (Chandler et al, 1980)	Provided systematic neuromotor evaluation, can be used for preterm infants	Small high risk sample used in test development, limited reliability and predictive validity data available at time of publication

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The Movement Assessment of Infants

a. Introduction

As previously described, the Milani-Comparetti Developmental Evaluation, Amiel-Tison and Grenier's Neurological Evaluation of the Newborn and Infant and Capute et al.'s Primitive Reflex Profile are all currently used for follow-up evaluation of premature infants. However, the use of these assessments for this population presented problems in diagnosis and prediction of motor disability because they were not designed specifically to assess the premature infant and thus did not take into account the complexities of transient neuromotor signs and persisting perinatal illness which made evaluation of the premature infant population so difficult. Further, these assessments were not created with the rigorous test development techniques needed to produce reliable, valid and generalizable results. Finally, many of the infant tools previously described relied heavily on the examiner's subjective ratings of the infant's neuromotor behaviors. At the time, subjective ratings of infants' neuromotor development were not considered reliable or valid measures of true motor performance although this belief has never been researched.

To address some of these difficulties, three therapists at the Child Development and Mental Retardation Centre (CDMRC) in Seattle, Washington developed an infant neuromotor assessment which provided both well defined assessment procedures for use in their neonatal follow-up clinic and allowed for clinicians' subjective impressions of the infants' neurodevelopment. In 1980 the Movement Assessment

of Infants (MAI) manual was published. The MAI (Chandler et al, 1980) is a systematic neuromotor evaluation which quantifies elements of motor functioning in infants up to twelve months of age and assists in the identification of motor normality or dysfunction. The authors state that the purposes of the MAI are

1. to identify motor dysfunction in infants up to the age of twelve months;

2. to establish the basis for an early intervention program;

3. to monitor the effects of physical therapy on infants and on children whose motor behaviour is at or below one year of age;

4. to aid in research on motor development by using a standard system of movement assessment; and

5. to teach skillful observation of movement and motor development through evaluation of normal and handicapped children. (Chandler et al, 1980)(page 3)

Two scales have been developed using limited normative data. The authors state in the test manual that the assessment was given to 35 infants who were tested at four months and again at one year of age. No other information describing these infants is presented in the manual, that is, it is not clear whether these were full term infants or high risk infants. However, based on these data, the authors published one scale which can be used as a "motor profile" at four months of age. A few years later a second profile was disseminated, although not formally published, for use at eight months of age. This eight month profile was normed on a sample of 50 full term infants, but this was a different group of infants from those used for the development of the four month profile.

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The assessment consists of 65 items which are divided into four
sections and which evaluate muscle tone, primitive
reflexes,automatic reactions (including balance and protective
responses) and volitional movement. Risk points are assigned for
certain items for which an abnormal responses can be elicited;
clear definitions of scoring criteria are provided in the test
manual. The risk points are totalled for each section and a
cumulative risk score is tallied for each complete assessment. The
higher the total score, the greater the risk of neuromotor
abnormality.For the four month profile, a total of 48 risk points
out of the 65 items is possible because incomplete responses on
some items are not abnormal, therefore not given risk points, at
four months. At eight months, a total of 64 risk points are
possible.

The four sections are scored on two different scales. The items
in the muscle tone section are scored on a six-point scale which
ranges from 1 representing very low muscle tone, 3 representing
normal muscle tone, 5 representing high muscle tone, the score of
6 being reserved for those infants whose tone fluctuates. The
primitive reflex items, on the other hand, are scored on a four
point ordinal scale with the score of 1 representing a reflex that
is completely integrated and 4 indicating a reflex that dominates
the infant's movement. The automatic reactions items are also
scored on a similar four point-scale with the most mature response
scored as 1 and the least mature or most abnormal response as 4.
Finally, the volitional movement items, like the primitive reflexes

and automatic reactions sections, are also scored on a four-point scale. The volitional movement section is a measure of motor milestone development. Those developmental skills which are present at an age-appropriate level are scored as 1 and those which are least mature or most abnormal are given 4. Additional scoring opportunities are provided to indicate asymmetrical responses in each of the sections. The muscle tone section provides a further opportunity for scoring distributions of tone; that is, scores can be given for differences in muscle tone between upper and lower extremities.

The authors of the MAI have tried to design a pure motor test which eliminates many of the shortcomings of previous tests, such as lack of standardization, quantification of results, reliability and validity (Harris et al. 1984). When the MAI was published, the authors cautioned that the assessment was not designed to predict long term neuromotor outcome, or to diagnose specific movement disorder. Drawing conclusions that reinforce this disclaimer, Deitz, Crowe and Harris (1987), in a longitudinal study of prematurely born children, could find no significant relationship between the four month MAI scores and gross motor outcome at four and one half years. However, Harris and colleagues (1984) demonstrated highly significant, albiet modest, correlations between the four month scale and one and two year motor outcomes. Kaye and Whitfield (1988) also reported statistically significant relationships between the eight month scale and eighteen month motor outcome in high-risk infants.

After the publication of the MAI manual, researchers began evaluating its psychometric properties. Because therapists were concerned with the early identification of motor disabilities, the majority of the studies have used the four-month profile for these analyses.

b. The Four Month MAI

In 1981, Campbell published a review of the MAI, describing its purpose and reporting preliminary data on the validity of the four-month scale as described in the MAI manual. These initial data reported the predictive relatioship of the assessment administered at four months with outcomes measured at one year in 35 infants. This study was very limited by the size of the sample chosen but given this sample, the authors suggested that a total risk score of seven should be used as the cut-off for normal infants. That is, those infants who score 0-7 risk points were to be considered falling within the normal range and those scoring 8 or more risk points would be "at risk" for neuromotor abnormality. Following Campbell's preliminary review, Harris, Haley, Tada and Swanson (1984a) published data describing the interobserver and test-retest reliability of the four month MAI. This study was completed on 27 full term and 26 preterm infants. This was the first report of the assessment being used on a normal group of infants (it is not clear in the test manual whether the infants used for development of the four month profile were normal term infants or high risk

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infants). Further, these were the first data published using a traditional statistical measure of reliability, the correlation coefficient. The authors reported fair interobserver (r=.72) and test-retest reliability (r=.76).

The first large sample study using the MAI was published by Harris and colleagues (1984b) later that same year. This study evaluated the predictive validity of the four month MAI using 246 high risk infants with outcome measures at one or two years. As with their previous work, this was the first MAI study that used conventional statistical measures, in this case Pearson product moment correlations, of predictive validity. The results showed that the majority of the correlations between the four month MAI risk scores and later outcome measures were significant. In reviewing the predictive power of the section risk scores, primitive reflexes were the least predictive, with volitional movement risk scores the most predictive of outcome at one or two years; this section exceeded the predictive power of the total risk scores for the overall test.

In 1986, Haley, Harris, Tada and Swanson provided the first item analysis on the MAI. They described the item reliability using two groups of infants, 27 full term controls and 26 high-risk infants. Because of the small sample size, the groups were combined for the item analysis. This group utilized two indices to estimate inter- observer and intra-observer reliabilities, the percentage of agreement index and the Kappa coefficient. The authors concluded that the items on the MAI have varying levels of reliability. A

summary of their results is presented in Table 3.

TABLE 3.   Item Reliability of the Four Month MAI (Percentage Agreement)

MAI sections	Inter-Observer Reliability	Intra-Observer Reliability
Muscle Tone	54%-87%	48%-100%
Primitive Reflexes	37%-98%	52%-100%
Automatic Reactions	41%-100%	38%-100%
Volitional Movement	52%-100%	24%-100%

Haley and colleagues then describe the Kappa score results in the following way:

In summarizing all the items from the sections in which the Kappa score could be calculated, 2% of the items had excellent inter-observer reliability, 58% fair to good and 40% had poor inter-observer reliability. Ten percent of the items had excellent intra-observer stability, 42% had fair to good and 48% had poor intra-observer stability. (Haley et al, (1986))(page 38)

A major flaw in this research is that the authors had a very small sample. Nevertheless, this was the first attempt at evaluating the reliability of the individual items on the four month MAI.

In 1987, Harris compared the sensitivity and specificity of the four month MAI to the Bayley Scales of Infant Development (Bayley, 1969)(an infant developmental assessment) and other infant neurological assessments. On a total of 228 infants, the MAI was shown to compare favourably with other infant neurological assessment tools in its ability to predict cerebral palsy, but the MAI was less specific than the Bayley Scales in correctly identifying normal infants (Harris, 1987a).

In 1987, Deitz and colleagues published the first analysis of

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long term predictive validity- that which included outcome measures of children just prior to school age. They studied the ability of the four month MAI to predict later gross and fine motor outcomes at four and 1/2 years in high-risk infants. This study was the first to use Spearman's rank correlation coefficients for their analysis. Previous predictive studies had used Pearson's r as an important element in analyses of the MAI. Frequency distributions of the scores obtained using the MAI produce a one-tailed distribution, thereby making the Spearman's rank the more appropriate statistic for these predictive studies (Deitz et al. 1987). In this longitudinal, retrospective study, Deitz and colleagues found that the four month MAI was not predictive of four year gross motor outcome. If a p value of 0.01 was used, the MAI was also not predictive of fine motor outcome,however, when the authors lowered the p valule to 0.05, two of the MAI category risk scores and the total risk score were moderately predictive (r=-.20 to -.25) of fine motor outcome as measured by the Frostig Eye-Motor Coordination Subtest. Although Dietz and her colleagues stated that their results differed from those reported by Harris et al (1984a), the authors were tentative in stating their conclusion too strongly because of limitations in their research such as using a retrospective study and not choosing a random sample.

A second MAI item analysis, looking at significant predictors of later cerebral palsy in high-risk infants, was published that same year (Harris, 1987b). Of a total sample of 229 high risk infants, 36 (16%) were diagnosed with CP. A total of 32 items of the

possible 48 were predictive of CP in this high risk sample.

In 1988, Schneider, Lee and Chasnoff published the first report reviewing the validity of the 4-month risk profile of the MAI. Based on the early work of the MAI authors, a cut-off of 7 risk points had been used to separate normal infants from those at higher risk for neuromotor handicaps. Schneider's group assessed 50 normal infants using the four month MAI. Their results showed that 30% of their normal infants scored total risk scores above 7 and recommended that a cut-off score of 10 and a range of 0-13 risk points should be used to classify normal infants. In a more recent study, Washington and Harris (1989) evaluated how low-birthweight infants with normal outcomes performed on the 4-month MAI. Their results were similar to those of Schneider's group in that 38% of the 118 high risk infants studied received total risk scores of greater than 7. Washington and Harris (1989) thus recommended that revision of the 4-month MAI should include raising the cut-off level.

Since the MAI was first published in 1980, research investigating such psychometric properties as reliability and validity have been limited to use of the four month risk profile. The four month profile has been shown to be a generally reliable and valid instrument for evaluating high risk infants and predicting later motor handicap (Harris, 1987b). Problems remain, however, with this scale. Firstly, it has not been normed on a large, well-distributed, randomly sampled population. Secondly, approximately half of its items have low reliability and some are not predictive

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of later outcome. Finally, all the studies describing outcome have been retrospective.

For researchers interested in early diagnosis of handicap in premature infants, the four month MAI profile appears to be a useful tool. Since its publication in 1980, however, a substantive body of literature evaluating its reliability and validity has shown that diagnosis and prognosis of motor handicaps in this high risk population is complex. The search for better neonatal and infant neuromotor assessments continues because clinicians remain unsatisfied with the properties of the tests currently in use with this population. Although there are studies reporting the ability of the four month MAI profile to predict outcome in premature infants, only two published abstracts have evaluated the predictability of the eight month scale.

c. The Eight Month MAI

Although the goal of therapists is to identify motor disability as early as possible, there is a small body of literature which supports evaluation of high risk infants at relatively older ages since diagnosis of handicap in early infancy seems fraught with problems. Andre-Thomas, 1952, was the first researcher to state the importance of the eight month assessment in the diagnosis of motor abnormalities in term infants. More specifically relating to the premature infant, Bennett, Chandler, Robinson and Sells (1981)

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studied the etiology of spastic diplegia, a type of cerebral palsy, in high risk infants. These authors found that they could not definitively diagnose spastic diplegia prior to eight months of age. Parmelee, in 1980, found that developmental assessment at 9 months of age was more strongly correlated with later outcome than either obstetrical or neonatal measures, and he recommends that this be the best age for routine examination of high risk infants. Finally, Saint-Anne Dargassies' (1977) long-term study of 246 premature infants also confirmed that evaluation at eight months of age provided critical diagnostic information. She described a phenomenon called the symptomatic gap where "the child passed through an interval of uncertainty before either a diagnosis or prognosis could be made." She noticed also that "...an extensive symptomatic gap occurred in every case of cerebral palsy". According to Saint-Anne Dargassies, this symptomatic gap exists from birth to eight months of age for cerebral palsy, thereby making earlier diagnosis of motor handicap very inaccurate. The small body of available literature supports the view that diagnostic evaluation of the high risk infant is more reliable at eight to nine months of age rather than earlier.

Initial reports on the predictive validity of the eight month MAI have been published in abstract form. Kaye and colleagues in 1988 reported significant relationships between the eight month MAI and eighteen month motor outcome in high risk infants. Swanson (1988) confirmed these findings. The correlations between the eight month categorical risk and total risk scores to outcome scores were

substantially higher than those reported by Harris et al, (1984b) who used the four month profile. The higher correlations found by Kaye and Whitfield (1988) and again by Swanson (1988) may have occurred because the time interval between initial assessment and outcome assessments were considerably smaller than those of Harris et al (1984) (10 months for the former two studies and 20 months for the latter study). Thus, although two published abstracts support that prediction of outcome by the MAI may be better at this later age, there are no full reports on long term predictive validity of the eight month profile.

Long Term Motor Outcome in ELBW Infants

As ELBW infants are followed to older ages not only are major motor disabilities being identified, but more subtle motor disabilities are being discovered in even higher proportions. For example, Drillien (1980) reviewed the outcome of 261 premature infants at the age of six years compared to a group of full-term control children. Those infants who had exhibited early transient neurological signs had significantly poorer scores than controls on all outcomes including motor scales. And even those infants who had appeared normal in the first year of life still performed less well than the controls. Nickel, Bennett, and Lamson (1982) evaluated 25 children with birthweights <1000 grams at 10 years of age. Sixty-four percent of these children required special education. This group excluded those children identified with

major disabilities.

In addition, Klein, Hack, Gallagher and Fanaraoff (1975) evaluated preschool performance of children with birthweights <1500 grams. They found that these children displayed significantly poorer scores in the areas of visual-motor skills and eye-hand coordination than did control children. Kaye and colleagues (1989) reported that in 4 1/2 year old children with birthweights $\leq$800 grams, 70% scored more than one standard deviation below the mean on fine motor testing when compared to normal controls.

Given this growing body of literature reporting long term outcomes of high risk infants, it is clear that a large proportion of those infants, although at risk for major motor disabilities such as cerebral palsy, are at even higher risk for developing more subtle motor disabilities. It is important then for infant assessments to be able to predict all types of neuromotor handicaps, including less obvious disabilities which may not be measurable until later ages in this high risk population. To date, there has been no infant test designed specifically to identify children who are at risk for developing these subtle disabilities, nor has there been any research to determine whether existing assessments such as the MAI are able to predict the presence of these disabilities at follow-up.

Purposes of the Study

Therefore, the purposes of this study will be

a. to determine if the eight month MAI identifies both major motor disabilities (CP) and more subtle motor disabilities in ELBW infants (<1000 grams) followed to 4 1/2 years; and

b. to determine whether clinicians' subjective ratings of neuromotor status in infancy can be as accurate as the MAI in identifying and predicting both major motor disabilities and long term motor outcome in ELBW infants followed to 4 1/2 years.

To these ends, six research questions will be addressed:

1. How sensitive is the eight month MAI in identifying major motor disabilities (CP) in ELBW infants?

2. How sensitive is the clinician's eight month neuromotor status rating (NMS) in identifying major motor disabilities (CP) in ELBW infants?

3. Does the eight month MAI total risk score signficantly predict fine motor outcome?

4. Are any of the eight month MAI categorical risk scores significantly predictive of fine motor outcome in ELBW infants?

5. In what order do the categorical risk scores best predict fine motor outcome?

6. Which of the 8 month measures--the eight month MAI (total risk scores, and all category risk scores) or the clinician's subjective neuromotor status rating--is a more significantly

predictive of motor outcome in ELBW infants?

CHAPTER 3

METHODOLOGY

Subjects and Setting

In 1985, there were 43,000 infants born in British Columbia. (Whitfield, 1985). Of the 43,000 babies born, approximately 800 infants/ year are admitted to the Special Care Nursery (SCN) at B.C.'s Children's Hospital (BCCH) because of perinatal adversity.

Patients eligible for inclusion in this study were born in British Columbia, cared for in the Special Care Nursery at B.C.'s Children's Hospital, and subsequently recruited for longitudinal follow-up by the Neonatal Follow-up Programme. The Neonatal Follow-up Programme follows the growth and development of infants at high risk of developing neurodevelopmental handicap because of perinatal adversity. The objectives of the clinic are as follows:

1. To evaluate short and long-term results of perinatal/neonatal intensive care in the Provincial Tertiary Perinatal Unit (Special Care Nursery) by sequential clinical and neurodevelopmental assessment during infancy and early childhood of surviving infants graduating from this unit.

2. To ascertain handicap early in this high-risk population of infants in order to promote early application of interventional techniques to minimize the functional effects of perinatally acquired handicap.

3. To provide an educational experience in neonatal follow-up techniques and in the long-term effects of perinatal/neonatal intensive care for members of perinatal/neonatal training programmes.

4. To promote and carry out research to further knowledge of the long-term effects of selected aspects of perinatal and neonatal

management.

5. To cooperate with Perinatal Follow-up Programmes across Canada and the U.S. in assessing patients belonging to those programs who move to our area. (Whitfield, 1985)

Infants are recruited while still in the Special Care Nursery and are followed to the age of 17 years. They receive sequential, multidisciplinary developmental assessments from a team of health care professionals including a paediatrician/neonatologist, registered psychologist, physiotherapist, occupational therapist, speech/language pathologist, audiologist, paediatric ophthalmologist, nurse dietician and social worker.

Between January, 1983 and December, 1986, 407 ELBW infants (≤1000 grams) were admitted to the SCN. Of these, 251 survived to discharge. Four other infants died after discharge. Of the remaining 247 patients, 52 (21%) were not recruited because they lived outside the geographical area for inclusion, and 195 (79%) were recruited to the Neonatal Follow-up Programme according to the criteria listed in Appendix B. One other child died after recruitment and two assessments. Of the remaining 194 patients recruited for follow-up, all have been seen for at least one follow-up visit. This is a net follow-up rate of 79 percent of those infants who survived.

One hundred and twenty-two patients (63%) did not have completed assessments at one or the other age (8 months, 4 1/2 years corrected chronological age) or were not seen during the correct age windows required for inclusion (8 months ± 2 weeks, 4 1/2 years ± 6 months. The remaining 72 (37%) patients will constitute the

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sample used for analysis. It is important to note that random sampling is not employed in this study and that a large proportion of the patients seen in the Neonatal Follow-up Clinic were not included in this study because of incomplete, missing data or attended the clinic outside the age window specified by the MAI. Although a large proportion of patients seen in the clinic could not be included in this study, comparative analyses were done of birth weights, gestational ages and maternal education to determine whether those not included in this study differed significantly from the study patients. These data will be discussed in Chapter IV.

All patients included in this study were evaluated during regular 8-month and 4 1/2 year clinic visits to the hospital and were tested by the author. The author is a registered occupational therapist who has worked in neonatology and follow-up for the past six years. She is fully trained and certified to administer the standardized assessments used in this study. In addition, each subject was given a neurological assessment by a paediatrician. The study patients attended the clinic at eight months corrected chronological age (corrected for prematurity) at the age window required to record a profile score on the eight month MAI (7 months, 15 days to 8 months, 14 days) and were seen again at 4 1/2 years corrected chronological age at which time the Peabody Developmental Motor Scale-Fine Motor Subtest and gross motor screening items were given. The measures in this study are part of the regular protocol used in the Neonatal Follow-up Programme. The

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complete listing of the motor assessments done at these two ages are listed in Table 4.

Table 4. Motor Assessments at 8 months and 4 1/2 Years.

Time	Test
8 Month Visit	The Bayley Scales of Infant Development Mental Scale Motor Scale The Movement Assessment of Infants* Neuromotor Status Rating Scale*
4 1/2 Year Visit	The Peabody Developmental Motor Scales Fine Motor Subtest* Gross motor screening items* Neuromotor Status Rating Scale*

*Those assessments included in this study.

Motor Measures at Eight Months

a. <u>The Movement Assessment of Infants (Chandler et al. 1980)</u>

The Movement Assessment of Infants is administered at eight months of age plus or minus two weeks corrected chronological age. The eight month profile is scored similarly to the four month profile and a copy of the eight month profile is included in Appendix C. The higher the total score, the greater the risk of neuromotor abnormality. A score of 10 or more risk points is suggestive of significant movement problems (M.W. Swanson, personal communication, 1989).

b. Neuromotor Status Rating

When the patients are evaluated in the Neonatal Follow-up Programme, the therapist, in addition to scoring the MAI, also rates the subject's neuromotor status (NMS) on a four point scale. The rating was given, in some cases, after scoring the MAI or the other tests given during the assessments, but this was not always the case. No accurate records of the exact order in which the NMS rating is scored in relation to the other measures has been kept.

This neuromotor status rating represents the clinician's clinical judgement as to the neuromotor integrity of the infant or child. The scale was adapted from Knobloch's scale (Knobloch, Steven and Malone, 1980). At the eight-month visit, one rating is given to describe the overall neuromotor status of the patient. The definition of this rating is as follows:

1. Indistinguishable from normal

2. Suspect (minor motor signs or mild developmental delay)

3. Definite motor abnormalities which could be classified as cerebral palsy or significant motor delay

4. Severe motor abnormality.

Motor Measures at Four and One Half Years

At the four and one half year visit, the patients' prior assessment results were reviewed during an in-take meeting at which all members of the clinic team are present. Since these results

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are reviewed, the examiner was not blinded to previous assessment information.

a. The Peabody Developmental Motor Scale-Fine Motor Subtest (Folio and Fewell, 1983)

This standardized test is divided into Gross Motor and Fine Motor Subtests. Each subtest can be used individually to document the motor performance of children from birth to 83 months of age. The Fine Motor Subtest is divided into four skill areas: Grasping, Hand-Use, Eye-Hand Coordination and Manual Dexterity (a copy of the test sheet is placed in Appendix C). The Grasping skill area assesses the maturity of pencil grasp and the Hand-Use skill area measures the development of hand preference. The Eye-Hand Coordination skill area assesses the child's ability to perform increasingly difficult activities which combine both visual motor tasks such as pencil copying, three dimensional block design production and more adaptive tasks such as bead threading and manipulation of buttons and paper clips. The Manual Dexterity skill area assesses the child's ability to perform timed tasks with either hand and their dominant hand.

For each test item administered, the child is given a score of 0 for a failed item, 1 for partial completion, and 2 for a correctly completed item. These scores are added in each skill area to give a total raw score. This raw score is then converted to a standardized score called the Developmental Motor Quotient (DMQ). As reported in the test manual, the mean for the DMQ is 100

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with a standard deviation of 15. Scores falling below 85, or more than one standard deviation below the mean, indicate a delay in fine motor skills.

Normative data for the Peabody Developmental Motor Scales were collected during test development and include a stratified sample of 617 children ranging in age from 1-83 months . As reported in the test manual, interrater and test-retest reliability are high $(0. \geq .80)$ and the correlation coefficient for concurrent validity of the Peabody Fine Motor Scale with the Bayley Mental Scale was $r=.78$, $p=02$ (Harris, and Heriza, 1987c). Palisano (1986) examined the concurrent and predictive validities of the Bayley Motor Scales and the Peabody Developmental Motor Scales. He reported that the predictive abilities of 12-month scores to 18-months scores were generally poor $(r = \leq 0.60)$ with the exception for the premature infant group $(r=.75)$.

b. <u>Gross motor screening items</u>.

In addition to the standardized fine motor measure given at four and a half years, gross motor outcome is assessed using items from two normed and standardized tests including the Bruininks Test of Motor Proficiency (Bruininks, 1978) and the Peabody Developmental Motor Scale-Gross Motor Subtest. The purpose of these items is to screen for gross motor abnormalities. The child's performance on each item is then rated, again from 1 to 4, according to set, described criteria. (See Appendix D for these criteria). The gross

motor items assess the following skills:

1. Gait pattern

2. Muscle strength

3. Agility and Speed

4. Static Balance skills

5. Dynamic Balance skills

6. Symmetry of motor development

7. Motor planning

8. The ability to rise from supine to standing

c. Neuromotor Status Rating

When the children are evaluated at 4 1/2 years, their neuromotor status is also rated according to the 4 point scale used at the eight month visit. Again, as with the eight month assessment, the rating of NMS was generally given after scoring the Peabody Fine Motor Subtest and rating the gross motor screening items, however, this was not always the case (strict documentation of when the rating was to be given was not part of the clinic protocol).

Data Analysis

Preliminary Analysis

Because of the high exclusion rate in this study, Student's t tests were used to compare the demographic characteristics of the children included in the study with those who were dropped because of insufficient data or they were not seen in the specified age windows. This was performed so that the conclusions from the

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analyses could better be generalized to the ELBW population.

In order to address the research questions posed in this study, a number of statistical analyses were used.

Analysis for Research Questions 1 and 2.

1. How sensitive is the eight month MAI in identifying major motor disabilities (CP) in ELBW infants?
2. How sensitive is the clinician's eight month neuromotor status rating (NMS) in identifying major motor disabilities (CP) in ELBW infants?

Sensitivity and specificity analyses of both the 8 Month MAI and the 8 Month Neuromotor Status Rating scale were used to determine how accurate they were in identifying cerebral palsy in the study group. Sensitivity was measured by dividing the number of correctly identified abnormal subjects into the total number of abnormal subjects (subjects with cerebral palsy). This fraction was then multiplied by 100 to calculate a percentage score. Specificity was derived in a similar way. However, specificity represents the percentage of normal infants classified correctly as normal (Harris, 1987a). It is desirable to have a test that is both highly sensivitive and highly specific (over 80%) thus identifying those infants who need early intervention and not over-referring potentially normal infants. Usually there is some trade-off between sensitivity and specificity when the clinical data are represented by a range of values. In this situation, the cut-off point between abnormal and normal is arbitrary (Fletcher, Fletcher, and Wagner, 1982). When a test is sensitive, but not specific, a larger number of infants will be referred to treatment

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services. These potentially normal infants both increase the costs of providing health care and, when included in studies evaluating the efficacy of treatment, confound the results.

Analysis for Research Questions 3-5.

3. Does the eight month MAI total risk score signficantly predict fine motor outcome?
4. Are any of the eight month MAI categorical risk scores significantly predictive of fine motor outcome in ELBW infants?
5. In what order do the categorical risk scores best predict fine motor outcome?

To determine the predictive validity of the 8 month MAI and its subtests, Spearman's rank correlation coefficients were calculated relative to fine motor outcome. Spearman's rank correlation was the most appropriate statistical test because the assumptions for the use of parametric statistics were not met. The distribution of MAI total risk scores is not normal, but skewed (see Appendix E). The Statistical Package for the Social Sciences (SPSS)(Nie, Hull, Jenkins, Steinbrenner and Bent, 1975 and SPSS Inc. 1986) was utilized for this analysis. Because multiple comparisons were made, an alpha level of 0.01 was set for the analysis.

Analysis for Research Question 6.

6. Which of the 8 month measures--the eight month MAI (total risk scores, and all category risk scores) or the clinician's subjective neuromotor status rating--is a more significantly predictive of motor outcome in ELBW infants?

To determine which 8 month variables were most predictive of 4 1/2 year motor outcome, canonical analysis was conducted using BMDP

2P Statistical Software (Dixon, 1985). Canonical analysis was chosen so that variables could be entered into the canonical predictive equation simultaneously (rather than one at a time as with multiple regression) so that effects of the variables on each other could be taken into account. Prior to analysis, a review of the distributions of all the variables was completed. Those variables which were not severely skewed (values $\pm$ 1.01) were then excluded from the analysis.

CHAPTER FOUR: RESULTS

Study Group Characteristics

a. Demographics

The primary purpose of this study was to determine whether the eight month MAI is predictive of motor outcome at 4 1/2 years in ELBW children.   The study sample consists of 72 children recruited for the Neonatal Follow-up Programme at B.C.'s Children's Hospital and who were assessed at both eight months and 4 1/2 years corrected chronological age by the clinic occupational therapist. The study group consists of 31 males and 41 females.   Sixty two of the children were Caucasian, 6 were East Indian and 4 were of other ethnic   backgrounds.   Table   5   compares   the   demographic characteristics for those children who were included in this study with those who were recruited and followed, but who were not included.

Table 5. Comparison of Demographic Data for Study Patients (n=72) and Infants Excluded from the Study (n=122).

	Characteristic	Included	Excluded	t	p
1.	Mean Birth Weight (grams)	865.9	817.4	1.08	NS
	Standard Deviation	112.1	116.5		
	Range	570-1000	540-1000		
2.	Mean Gestational Age (weeks)	26.1	26.32	0.66	NS
	Standard Deviation	1.85	1.84		
	Range	23-31	24-33		
3.	Mean Maternal Educ. (years)	12.8	11.90	0.89	NS
	Standard Deviation	2.73	2.64		
	Range	4-20	3-20		

The Student's t test revealed no statistically significant differences between the demographic characteristics of the children included in this study and those excluded.

b. Motor Outcome

i. Major Motor Disabilities:

Of the total sample of 72 children, the clinic paediatrician diagnosed 9 with cerebral palsy at 18 months corrected chronological age. This represents a major motor handicap rate of 12.5% and is consistent with other reported rates in the literature.

ii. Eight Month Outcome:

Of the children followed in this study, 43 (60%) scored within the normal range on the Eight Month MAI (Total risk scores ≤ 10) and were also rated by the therapist as being either neurologically normal or suspect. Table 6 displays the eight MAI scores and the therapist's neuromotor status ratings for the study group.

TABLE 6. Distributions of the Eight Month MAI Scores and Eight Month Neuromotor Status Ratings of the Study Group

	Patients		
Total MAI Score	N	Percent	
0-10	43	60	
11-20	21	29	
>20	8	11	
Mean Total Score			10.02
Standard Deviation			± 8.33
Range			0-36
Neuromotor Status Rating			
1 Normal	45	63	
2 Suspect	10	14	
3 Abnormal	15	21	
4 Severely abnormal	2	3	

iii. Four Year Outcome:

At the four and one half year visit, 35 (49%) children scored more than one standard deviation below the mean on the Peabody Developmental Motor Scales-Fine Motor Subtest. On gross motor testing, more than 80% of the children (58 or more) were rated as being either normal (1) or suspect (2) on five of the eight gross motor tasks. The two tasks on which the children were given the most abnormal ratings (score of 3 or 4) was on balance where 47% were rated abnormal and on symmetry where 36% of the children were

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rated as being abnormal or were showing asymmetries in their performance of motor skills. Table 7 displays these results in more detail.

TABLE 7. Four and One Half Year Peabody Fine Motor Scores (DMQ) and Gross Motor Screening Item Ratings.

| 4 1/2 Year Motor Outcome | Gross Motor Neuromotor Status Ratings | | | |
| | Score 1-2 | | Score 3-4 | |
	N	%	N	%
Fine Motor				
Peabody Mean DMQ*	76.78			
Standard Deviation	21.67			
Gross Motor				
Supine to Standing	58	81	14	19
Agility and Speed	64	89	8	11
Motor Planning	62	86	10	14
Static Balance	38	53	34	47
Dynamic Balance	49	68	23	32
Muscle Strength	59	82	13	18
Gait	64	89	8	11
Symmetry	46	64	26	36
Neuromotor Status	62	86	10	14

*Test mean score for the DMQ is 100 ± 15.

iv. Shifts in Motor Status Between 8 months and 4 1/2 Years:

Between the 8 month and 4 year visit, the frequency of the abnormal ratings given by the therapist decreased. Of the 17 children who were given a NMS rating of 3 or 4 at 8 months by the therapist, only 10 continued to have an abnormal rating at school age on gross motor tasks. Four infants rated as a 2 at eight months were given an abnormal ratings of 3 (none were rated as a 4) at 4 and 1/2 years.

Research Question Results

Results for Research Question 1 and 2.

1. How sensitive is the eight month MAI in identifying major motor abnormalities (CP) in ELBW infants?
2. How sensitive is the clinician's eight month neuromotor status rating (NMS) in identifying major motor abnormalities (CP) in ELBW infants?

The sensitivity and specificity of the 8 Month MAI and the 8 month Neuromotor Status (NMS) ratings are shown in Tables 8 and 9. This analysis revealed that the MAI and the 8 month NMS ratings were highly and equally sensitive (100%) in correctly identifying those infants who were later diagnosed with cerebral palsy. However, the specificity of the MAI was lower than the 8 Month NMS rating (68.2% vs 86%). The level of specificity of the 8 Month MAI was (68.2%), somewhat higher than the 62.7% reported by Harris (1987a) for the 4 Month MAI. These values may be different because Harris (1987a) used a cutoff score of 7 risk points for the normal range, whereas a cutoff score of 10 total risk points was used in this study. By reducing the cutoff score to 7 risk points, the specificity of the 8 month scale would drop to 59%. Further, because the scoring of NMS was not always done prior to the scoring of the MAI there may be an order effect which artificially raises the specificity of the NMS.

Table 8. Sensitivity and Specificity of the 8 Month Movement Assessment of Infants (MAI).

MAI Total Risk Score	Outcome Classification	
	Normal	Abnormal (CP)
Normal (0-10)	n=43* (68.2%)	n=0 (0%)
Abnormal (>10)	n=20 (31.8%)	n=9 (100%)+
Total	n=63	n=9

*specificity
+sensitivity

Table 9. Sensitivity and Specificity of the 8 Month Neuromotor Status Rating (NMS) Scale.

Neuromotor Status Rating	Outcome Classification	
	Normal	Abnormal (CP)
Normal/Suspect (1-2)	n=54* (86%)	n=0 (0%)
Abnormal (3-4)	n= 9 (14%)	n=9 (100%)+
Total	n=63	n=9

*specificity
+sensitivity

Results for Research Questions 3-5.

3. Does the eight month MAI total risk score signficantly predict fine motor outcome?
4. Are any of the eight month MAI categorical risk scores significantly predictive of fine motor outcome in ELBW infants?
5. In what order do the categorical risk scores best predict fine motor outcome?

The relationships between the 8 month MAI category scores and

total score to the Peabody Developmental Motor Scales-Fine Motor Subtest (PFS) developmental motor quotient (DMQ) at 4 1/2 years were analyzed using Spearman's rank correlation. The results are presented in Table 10.

TABLE 10. Spearman's Correlation Coefficients Between 8 Month Measures and Fine Motor Performance at 4 1/2 years.

Eight Month Measures	Four Year Fine Motor Measure
1. 8 M MAI Scores	Peabody Fine Motor Subtest
Muscle Tone	-.08
Primitive Reflexes	-.07
Automatic Reactions	-.05
Volitional Movement	-.09
Total Risk Score	-.11
2. Neuromotor Status Rating	-.30*

*p<0.001
Note that a higher scores on the MAI and neuromotor status rating indicate abnormal performance whereas a low score on the PFS indicates an abnormal performance.

Neither the MAI category scores nor the total 8 month MAI score were significantly predictive of 4 1/2 year fine motor performance. However, the clinicians' rating of the 8 month neuromotor status was significantly predictive of fine motor performance, although the correlation is low.

Results for Research Question 6.

6. Which of the 8 month measures--the eight month MAI (total risk
    scores, and all category risk scores) or the clinician's
    subjective neuromotor status rating--is a more significantly
    predictive of motor outcome in ELBW infants?

For this part of the analysis, canonical correlation was
performed between the 8 month MAI scores, 8 month Neuromotor status
rating and the 4 1/2 year motor outcome variables.   All the
variables were examined for violations of the assumptions required
for canonical analysis. Two of the variables, the primitive reflex
category on the 8 month MAI and the Strength neuromotor status
rating at 4 1/2 years, were excluded from subsequent analysis
because their score distributions were seriously skewed with values
greater than $\pm$ 1.01. Multicollinearity was not an influence on the
data analysis as the squared multiple correlations of each variable
with all the other variables in each set ranged from 0.20 to 0.84
(that is, none of the squared correlations exceeded 0.99). There
were no missing cases which would influence the data analysis.
Finally, the largest and smallest standard scores of the variables
was examined for serious outliers.   Having excluded the two
previously mentioned variables (primitive reflexes and strength) no
further variables needed to be excluded.

Only the first eigenvalue was statistically significant with the
canonical correlation of 0.78 (62% shared variance). With all five
canonical correlations included, χ^2 (45)=97.55,p <0.0001).   With
the other correlations removed, χ^2 values were not statistically

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significant. The second canonical correlation by itself was not significant (p<0.125). The first canonical variate, therefore, accounted for the significant relationships between the two sets of variables and will be interpreted. The data on the first canonical variate are shown in Table 11. This table shows the correlations between the variables and the canonical variate, standardized canonical variate coefficients, within-set variance accounted for by the canonical variates (percent of variance), redundancies, and canonical correlations. Total percentage variance and total redundancy indicate that the canonical variate was moderately related.

TABLE 11. Canonical Analysis for the First Canonical Pair

	First Canonical Pair			
	Structure Coefficients	Standardized Coefficients	Percentage of Variance	Redundancy
Eight Month Measures (X)			0.56	0.35
1. Neuromotor Status	0.88	0.68		
2. MAI				
Automatic Reactions	0.73	0.24		
Volitional Movement	0.72	0.35		
Total Score	0.72	-0.22		
Muscle Tone	0.67	0.20		
4 1/2 Year Measures (Y)			0.41	0.25
1. Gross motor screening				
Supine to Stand	0.84	0.62		
Agility and Speed	0.70	0.31		
Motor Planning	0.66	0.20		
Static Balance	0.62	-0.01		
Dynamic Balance	0.61	0.03		
Gait	0.60	-0.15		
Symmetry	0.59	0.32		
2. Neuromotor Status	0.61	0.09		
3. Peabody Fine Motor Test	-0.45	0.08		
Canonical Correlation 0.78				

Using a cutoff correlation of r=0.30, all the variables in both sets correlated with the canonical variate. In general, higher or more abnormal scores on all the Eight month measures tended to predict abnormal Gross motor ratings at 4 1/2 years. However, abnormal scores at eight months have a much weaker relationship (-0.45) with poor fine motor outcome (PFS) at 4 1/2 years. Of particular interest is that the correlation between the Eight Month Neuromotor Status rating and the canonical variate is higher (0.88) than all the other variables.

CHAPTER FIVE

DISCUSSION

Conclusions

Conclusion 1. The 8 month MAI as a Screening Tool for Cerebral Palsy

The 8 Month MAI is a very effective tool for correctly identifying infants having cerebral palsy. In this study, 100 % of those infants diagnosed by the paediatrician also had total MAI scores of >10 risk points. This level of sensitivity substantially exceeds that of the 4 month MAI . However, because of the small number of subjects diagnosed as having CP (n=9), these results should be viewed with cautious optimism.   The 8 month MAI also has a higher level of specificity (68%) than does the 4 month scale (62%); however, this increase is only produced if the cutoff score for the total risk points is 10 rather than 7.

Conclusion 2. Relationship between 8 month MAI and 4 1/2 Year Fine Motor Outcome

The correlations between the Eight Month MAI and the Peabody Fine Motor Subtest were not statistically significant; thus, the MAI is a poor predictor of fine motor outcome in the ELBW infant at school age.   Although the relationship between the eight month MAI and Peabody Fine Motor Subtest is not strong, a large proportion of the children (49%) scored poorly (more than one standard deviation

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below the mean) on the fine motor testing at school age. It would therefore seem important to include a better measure of fine motor skills in the 8 month assessment as a regular part of the follow-up evaluation of ELBW children.

Conclusion 3: Relationship between 8 month MAI and 4 1/2 Year Gross Motor Outcome

Although not strongly predictive (-.30) of fine motor outcome at 4 1/2 years, the 8 month MAI is predictive of later gross motor outcome in the ELBW children. The canonical analysis reveals that the Eight month MAI Total score and two of the categories, Automatic Reactions and Volitional Movement, are predictive of the Gross Motor outcome measures at four and a half with structure coefficients above 0.70. The canonical analysis reveals that a "gross motor" dimension underlies the two sets of variables. That this dimension is present can be concluded for two reasons. First, the 8 month MAI has a low correlation with the Peabody Fine Motor Subtest at 4 1/2 years, and second, the MAI is related to and more predictive of the gross motor measures given at four and one half years in the ELBW subjects. This is probably the case because the items on the MAI are more heavily weighted to gross motor function.

Unlike Deitz et al (1987), who found that the four month MAI did not predict four year gross motor outcome, this study shows that the MAI administered at eight months _is_ predictive of long term gross motor outcome. Evaluation at this later age may be more accurate because the effects of transient dystonia which appear as

52

early abnormal motor signs may be disappearing at this later age. Further, the effects of chronic illness which also influence these infants' motor development may be diminishing and therefore be less of a confounding factor. Finally, evaluation of these infants avoids the "symptomatic gap" occurring prior to eight months of age where the signs of motor abnormality are not apparent.

Conclusion 4: Relationship between Clinicians Impressions at Eight months and 4 1/2 year Motor Outcome

Of all the measures used at eight months of age, the clinician's rating of neuromotor status was the best predictor of both fine and gross motor outcome at 4 1/2 years. The relationship between 8 month neuromotor status rating and the Peabody Fine Motor Subtest, although statistically significant, was weak (that is the correlation coefficient was 0.30) and therefore is probably not clinically significant. The relationship to gross motor outcome was much stronger, however. Further, the clinician's neuromotor status rating was as sensitive as the MAI; that is, it identified those infants as being abnormal who were later diagnosed with cerebral palsy, and showed superior specificity over the 8 month MAI (86% vs 68.2%). These results suggest that clinician's subjective measures of neuromotor status may be a valuable tool in identifying major and minor motor disabilities in ELBW infants.

One might conclude that these results show that a skilled therapist can evaluate ELBW infants accurately without the use of the standardized test. This conclusion would be mistaken for it is unclear from these results whether the use of the infant test

itself allows a clinician to form a more accurate impression of the infant or whether knowledge of previous test scores derived at earlier assessments may influence the neuromotor status rating. In this study the clinician's rating of neuromotor status is not wholly an independent measure because in some cases the rating was made after the standardized tests were scored although there was no documentation of the exact timing of the ratings included in the clinical protocol. It is more likely that the therapist uses the standardized protocol to influence his/her judgment, but also takes into consideration other factors relating to the infant's motor skills which are not measured by the test. These factors may include behavioral characteristics such as hyper- or hypoactivity, parent interactions and whether the signs appearing as abnormal may be those which look transient or influenced by illness. That is, the child may score within the normal range at 8 months, but behave in an abnormal way, or may score abnormally, but still be delayed because of chronic lung disease. The therapist, on evaluation of the infant, can take these factors into consideration when giving the child a neuromotor status rating. A summary of the statistical and clinical relationships between the 8 month measures and 4 1/2 year measures is displayed in Table 12.

Table 12. Summary of the Relationship Between 8 Month Measures and
4 1/2 Year Motor Outcome

| | Four Year Motor Measures | |
Eight Month Measures	Peabody Fine Motor Subtest	Gross Motor Screening Items
8 Month MAI	weak* statistical, little clinically useful relationship	moderate* statistical and clinical relationship
Neuromotor Status Ratings	weak-moderate* statistical relationship, no clinical relationship	strong* statistical and clinical relationship

*See Appendix F for definitions of terms

Conclusion 5. Portions of the Assessment Which Did Not Contribute
to the Predictive Evaluation

Two of the variables were dropped from the canonical analysis
because they were negatively skewed. These variables were the
Primitive Reflex category on the 8 month MAI and the muscle
strength gross motor screening tasks at 4 1/2 years. In all the
previous studies evaluating the predictive validity of the MAI, the
Primitive Reflex category has been shown to be the least
predictive. It may be that the influence of primitive reflexes on
long term motor performance is less important than was once thought
and so even children who tend to have more abnormal ratings in this
area are not at any greater risk for later handicap. When
reviewing the MAI for possible changes in the test format, dropping

this section of the test may produce a shorter evaluation that is equally as accurate a predictor. The muscle strength rating at 4 1/2 years is also negatively skewed. Although this item was dropped for this analysis, instead of excluding it from future evaluations, the criteria for scoring should be reviewed.

Limitations of the Study

Although this study contributes information regarding the value of the 8 month MAI and Neuromotor status ratings in predicting 4 1/2 year motor outcome in ELBW infants, the results should be interpreted with caution because of a number of study limitations.

First, although 72 patients were included in the analysis, 122 patients were excluded. Although comparisons between the two groups revealed no statistically significant differences in birth weights, gestational age, years of maternal education, there still may be some question as to the generalizability of the results of this study to ELBW infants as a whole. Second, because this is a field study several sources of bias are present which may have affected the results. First, the evaluator was neither blind to the previous evaluations of the infants nor to their perinatal history. The clinic members regularly review the previous assessment results and the child's perinatal history at an in-take meeting. This knowledge may, therefore, influenced scores and ratings given at the assessments. Ashton, Piper, Warren, Stewin and Byrne (1991) have shown that therapists' knowledge of medical

history influenced the scores on the 4 month MAI. Low-risk infants labelled with high-risk histories tended to score higher risk points. This may explain why the MAI scores correlated with the Gross Motor Dimension so highly. Based on the child's medical history, the therapist was expecting a good or poor performance and therefore rated the skills accordingly.

A second potential source of bias is that in some cases,the therapist scored the neuromotor status ratings after the MAI and other standardized tests were scored. Thus, caution should be used when assuming this was an independent measure. Furthermore, only one therapist provided these ratings. This raises a question as to the accuracy and predictability of the ratings when applied to other therapists. A third possible source of bias influencing the results in this study was the effect of therapeutic intervention on the infants' development. Many of these high risk infants are referred to Infant Development programmes and/or to physical therapy upon discharge from the Special Care Nursery. Although it has been shown that physical therapy does not "cure" neuromotor disabilities, modest changes in motor performance have been achieved (Harris, 1988). Also, high risk infants given early intervention programmes like the Infant Development Programme in British Columbia have been shown to have less developmental delay, to achieve improved mental scores on the Bayley Scales of Infant Development and also to get better quality of caregiver-infant interactions (Resnick, Eyler, Nelson, Eitzman, Bucciarelli, 1987: Resnick, Armstrong, Carter, 1988). Thus intervention may have

resulted in fewer children identified as being abnormal at 4 1/2 years following these types of intervention programmes.

Implications for Clinical Practice

The eight month MAI provides therapists with a sensitive assessment tool which identifies major motor disabilities and predicts long-term gross motor outcome in ELBW infants and is therefore a valuable tool in the follow-up of these high risk infants. Caution should be exercised, however, in over-diagnosing cerebral palsy in the ELBW infant if the cut-off score is set at 7 risk points since a more accurate level of specificity is achieved when the cut-off score is raised to 10 risk points. In this study, the sensitivity was 100 % when the cut-off score was kept at 10 total risk points. Moreover, therapists should not rely on the eight month MAI to provide predictive information on fine motor outcome in this population. They should be prepared instead to administer additional measures which may more accurately identify those infants at risk for fine motor disabilities. Finally, using a measure of therapists' clinical impressions of neuromotor status should be encouraged in the motor evaluation of ELBW infants; this single measure provided equal sensitivity and higher specificity than the MAI and was the best predictor of motor outcome of the measures investigated in this study. Although this study provides strong support for the use of clinicians' subjective ratings, it does not imply that clinicians' ratings should be used to the

exclusion of standardized infant assessments. Rather, it is likely that administration of the standardized assessments provides important information which therapists then use in assigning subjective ratings.

Directions for Further Study

It can be concluded from this study that the 8 month MAI is predictive of 4 1/2 year gross motor outcome and is able to identify those infants who have cerebral palsy. However, the gross motor outcome measures used in this study were not normed. It would be important for future researchers to determine whether the eight month MAI was predictive of later gross motor outcomes using a properly normed outcome measure of gross motor skills.

The eight month MAI was not able to identify those infants who were at risk for later fine motor difficulties. Since a large proportion of the study infants went on to score poorly on the Peabody Fine Motor subtest, it would be important to determine whether another infant test could predict these fine motor problems. For example, the Bayley Scales of Infant Development were also administered at the 8 month visit; however, the predictive validity of these measures were not analysed in this study. The Mental Scale, in particular, includes many fine motor items and therefore may be a better predictor of the fine motor development in ELBW infants. And as Palisano (1986) described, the Peabody Fine Motor Subtest was predictive of fine motor performance

at 18 months in premature infants. Thus, future studies should evaluate the predictive validity of the Bayley Mental Scale in ELBW infants to determine if this scale can better identify those infants at risk for fine motor disabilities.

The clinician's rating of neuromotor status at 8 months was the strongest predictor of later gross motor outcome in ELBW infants and was able to identify those infants at risk for cerebral palsy with equal accuracy as the MAI. It is unclear whether the NMS rating was an independent measure in this study. Future research should evaluate if the sensitivity, specificity and predictive validity of this rating changes if the rating is made prior to scoring of any standardized measures. In addition, research should explore what factors therapists focused on to make the NMS rating a more accurate predictor than the 8 month MAI. Presumably, a standardized assessment built around these factors would exceed the predictive properties of both the NMS and MAI.

In addition, research should be undertaken to explain why some infants given abnormal ratings at 8 months were no longer exhibiting these abnormal signs at 4 1/2 years. Did factors such as higher parental education, therapeutic interventions administered in infancy or neonatal illness influence this trend? If therapeutic interventions explain this trend, then additional research comparing ELBW infants who receive intervention versus those who do not should be undertaken. The efficacy of various treatment alternatives should also be explored.

As has been recommended in other studies evaluating the 4 month

MAI, standardization of the scales on a large, normative sample should be completed for the 8 month MAI so that issues such as choosing the most appropriate cutoff score for identification of infants at risk, interrater and item reliability could be addressed.

Finally, given the moderate rate of cerebral palsy and high rate of subtle motor difficulties found in the ELBW infants in this study, further research describing the ongoing motor development of these new survivors is important. How do these children participate in functional activities given their motor disabilities? What kinds of occupations do they chose and do their disabilities influence these occupations? Do the subtle motor disabilities continue to "disappear" so that by the time they reach adulthood they are indistinguishable from the normal population?

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APPENDICES

APPENDIX A:
INFANT DESCRIPTIVE TERMS

1.   High risk infant- Includes all infants, both full term and preterm, at risk for neurodevelopmental handicaps due to perinatal/neonatal adversity.

2.   Premature infant- Any infant born prior to 37 weeks gestational age.

3.   Extremely low birth weight infant- Any premature infant born weighing $\leq$1000 grams.

APPENDIX B:

RECRUITMENT CRITERIA FOR B.C'S CHILDREN'S HOSPITAL'S NEONATAL
FOLLOW-UP CLINIC*

A. Anywhere in British Columbia

1.   Birth weight 800 grams or less
2.   Retinopathy of prematurity, Grade IV
3.   Hydrops fetalis
4.   Patients recruited to a funded study which pays travel costs
5.   Grade IV intraventricular hemorrhage, periventricular
        leukomalacia

B. Greater Vancouver Regional District, Lower Fraser Valley as far
as Hope, Lower Eastern Vancouver Island

1.   Birth weight 1000 grams or less
2.   Grade III intraventricular hemorrhage
3.   Post-hemorrhagic hydrocephalus
4.   Hypoxic ischemic encephalopathy with seizures or an Apgar
        of 0
5.   Ventilator management needing Tolazoline or Dopamine
6.   Bronchopulmonary dysplasia requiring oxygen past term
7.   Necrotising enterocolitis with perforation or strictures
        needing surgery
8.   Exchange transfusion for jaundice
9.   Bacterial meningitis in the neonatal period
10.   Blood culture proven Group B Streptococcal septicemia
11.   Other significant proven neurological abnormality in the
        neonatal period
12.   Patient on a funded study

* Patients need only to fit one of the above criteria to be
recuited for follow-up.

APPENDIX C

I. THE MOVEMENT ASSESSMENT OF INFANTS:EIGHT MONTH SCORE SHEET

II. THE PEABODY DEVELOPMENTAL MOTOR SCALE-FINE MOTOR SUBTEST

SCORE SHEET

Scoring Sheet for
MOVEMENT ASSESSMENT OF INFANTS
with Eight-Month Profile

Name _____ Date of exam _____

Birth date _____

Case number _____ Chronological age _____

Gestational age _____

Examiner _____ Corrected age _____

Total risk score [   ]

MUSCLE TONE

Items 1-6, 9 and 10 should be coded by the scale below.
Code items 7 and 8 as explained in the instructions for these items in the manual.

0 – Item omitted
1 – Hypotonic
2 – Greater than hypotonic but less than normal
3 – Normal
4 – Greater than normal but less than hypertonic
5 – Hypertonic
6 – Fluctuating, variable

| | | | Distribution Variations | | Asymmetries | |
			Upper	Lower	Left	Right
1 2 4 5 6 _____	1. Consistency		_____	_____	_____	_____ 1.
1 2 4 5 6 _____	2. Extensibility		_____	_____	_____	_____ 2.
1 2 4 5 6 _____	3. Passivity		_____	_____	_____	_____ 3.
1 2 4 5 6 _____	4. Posture in Supine		_____	_____	_____	_____ 4.
1 2 4 5 6 _____	5. Posture in Prone		_____	_____	_____	_____ 5.
1 2 4 5 6 _____	6. Posture in Prone Suspended		_____	_____	_____	_____ 6.
3 4 _____	7. Asymmetry					
3 4 _____	8. Distribution Variation					
1 2 4 5 6 _____	9. Summary of Tone - Extremities		_____	_____	_____	_____ 9.
1 2 4 5 6 _____	10. Summary of Tone - Trunk		_____	_____	_____	_____ 10.

[   ]

PRIMITIVE REFLEXES

Items 1-12 should be coded by the scale below.
Code items 13 and 14 as explained in the instructions for these items in the manual.

0 – Items omitted
1 – Integrated or not elicited
2 – Incomplete response
3 – Complete response
4 – Dominant

| | | | Asymmetries | |
			Left	Right
2 3 4 _____	1. Tonic Labyrinthine Reflex in Supine		_____	_____ 1.
2 3 4 _____	2. Tonic Labyrinthine Reflex in Prone		_____	_____ 2.
2 3 4 _____	3. Asymmetrical Tonic Neck Reflex - Evoked		_____	_____ 3.
2 3 4 _____	4. Asymmetrical Tonic Neck Reflex - Spontaneous		_____	_____ 4.
2 3 4 _____	5. Moro		_____	_____ 5.
2 3 4 _____	6. Tremulousness		_____	_____ 6.
2 3 4 _____	7. Palmar Grasp		_____	_____ 7.
4 _____	8. Plantar Grasp		_____	_____ 8.
2 3 4 _____	9. Ankle Clonus		_____	_____ 9.
2 3 4 _____	10. Neonatal Positive Support		_____	_____ 10.
2 3 4 _____	11. Walking Reflex		_____	_____ 11.
2 3 4 _____	12. Trunk Incurvation (Galant)		_____	_____ 12.
3 4 _____	13. Asymmetry			
2 3 4 _____	14. Summary of Primitive Reflexes			

[   ]

Peabody Developmental Motor Scales
Score Sheet*

Name _____

UH# _____

Examiner _____

	Year	Month	Day
Date of Testing	_____	_____	_____
Date of Birth	_____	_____	_____
Chronological Age	_____	_____	_____
Age in Months	_____		

GROSS MOTOR

		Raw Score	%tile	Z-Score
Skill A -	Reflexes			
Skill B -	Balance			
Skill C -	Non-Locomotor			
Skill D -	Locomotor			
Skill E -	Receipt and Propulsion			
Total Score				

FINE MOTOR

		Raw Score	%tile	Z-Score
Skill A -	Grasping			
Skill B -	Hand Use			
Skill C -	Eye-Hand Coordination			
Skill D -	Manual Dexterity			
Total Score				

Basal Score _____ Ceiling _____ Age Equivalent _____ Scaled Score _____

Basal Score _____ Ceiling _____ Age Equivalent _____ Scaled Score _____

Administration Codes

SU	Supine	H	Hopping
P	Prone	JF	Jumping Forward
SI	Sitting	JD	Jumping Down
ST	Standing	JU	Jumping Up
W	Walking	TT	Tiptoes
S	Stairs	SK	Skip/Gallop
RB	Regular (8") Ball	SS	Somersault
TB	Tennis Ball	BB	Balance Beam
B	Standing Balance		

Administration Codes

R	Rattle	PB	Pop Beads
C	Cubes	FB	Formboard
CP	Cup	SC	Scissors
PG	Pegboard	BU	Buttons
PT	Pellet	P	Paper and Marker
BK	Book	BO	Bottle
B	Beads	PI	Item can be passed by
RS	Ringstand		parent inquiry

8-9 MONTHS (For all items except 38, sitting in lap at table)
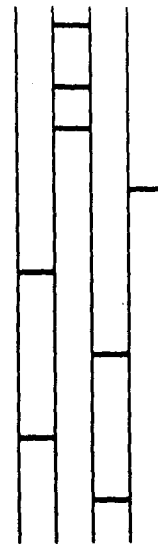
A B C D

PG 31. 3 pegs in pegboard, say "Get the peg" -- **removes one peg**

C 32. Grasping; thumb-finger, one cube on table, say "Get the block" -- **grasps cube using thumb and 1st and 2nd fingers.** If uses superior forefinger grasp, thumb on one side and index & 2nd finger in opposition with wrist elevated off table. score 2 on 32 and 51

C 33. Combining: cube in left hand, 2nd cube near right hand, say "Get this one too" -- **combines 2 at midline**

C 34. Retaining: cube in each hand, 3 seconds, place 3rd cube on table, say "Get this one, too" -- **retains 2 cubes in 1 hand, reaches for 3rd**

PT 35. Grasping: raking radial, 4 pellets on table, say "Get the candy" -- **secure at least 2 pellets, raking motion, radial side, predom. thumb and 1st & 2nd fingers.** If at least 1 pellet w/thumb opposed to inside of 2nd finger, score 2 on 35 & 36

PT 36. Grasping, inferior pincer: 4 pellets on table say "Get the candy" **grasps at least one pellet, thumb opposed to inside of 2nd finger.** If uses thumb & 1st or 2nd fingertip w/wrist & hand off table score 2 on 36 & 42

P 37. Manipulating: 8 1/2" x 11" paper on table, say "Get the papr" -- **crumples paper in palms of 1 or 2 hands**

38. Sitting, facing examiner, demonstrate clapping hands, say "Clap your hands" -- **claps hands at midline 2x (PI)**

34 + 24 + 18 + 0   = 76 CUMULATIVE MAXIMUM

10-11 MONTHS (For all items, sitting in lap at table)

A B C D

RS 39. 2 rings on stand, demonstrate removing 1 ring, replace it, say "You take it off" -- **removes 1 ring**

PG 40. Demonstrate poking finger in peg hole, say "You do it" -- **pokes 1st finger in or near hole**

BO 41. 4 pellets in bottle, shake, waving motion, place on table, say "Shake the bottle" -- **shakes using waving motion**

PT 42. Grasping, superior pincer: pellets on table, say "Get the candy" **grasps one using thumb & 1st or 2nd fingertip, neat pincer grasp, wrist and hand off table**

C 43. Releasing: cube in child's hand, say "Give me the block" -- **deliberate release of cube (1/2)**

C 44. Releasing: 4 cubes and cup on table, say "Put the cubes in the cup" -- **places 3 cubes into cup**

CP 45. Demonstrate stirring spoon in cup, say "Stir with the spoon" -- **stirs spoon in cup 2x**

CP 46. Demonstrate hitting outside of cup w/spoon (horiz), say "You do it" -- **hits cup 2x w/spoon (horiz. motion)**

36 + 30 + 24 + 2   = 92 CUMULATIVE MAXIMUM

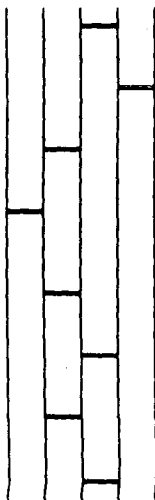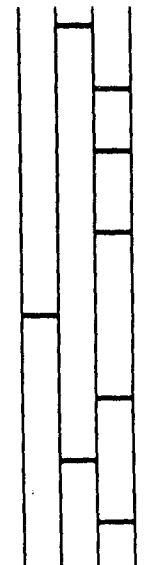**12-14 MONTHS** (For all items sitting in lap at table)

A B C D

PG 47. Demonstrates removing 1 of 3 pegs from pegboard, replace it, say "Pull out all the pegs", repeat once -- **removes 3 pegs**

PT 48. 4 pellets in box, say "Get the candy" -- **opens box**

BO 49. 4 pellets in uncapped bottle, say "Get the candy" -- **removes at least 1 by dumping**

BK 50. Thick paged book before child, say "Open the book" -- **turns more than 1 page at a time.** If turned singly, score 2 on 50 and 65

C 51. Grasping, overhand: cube before child, say "Get the block" -- **grasps cube w/superior forefinger grasp, thumb & index and 2nd fingers opposed, wrist off table**

C 52. Demonstrate building a tower w/4 cubes, put 4 other cubes on table, say "Build a tower like mine" -- **builds a tower of 2 cubes.** If 3 or 4 cubes, score 2 on 52 & 57

C 53. Grasping: 2 cubes side-by-side, say "Get both of the blocks" -- **secure both with 1 hand**

FB 54. Formboard and shapes separately on table, say "Put the shapes in the board" -- **puts 1 shape in board.** If 2 shapes, score 2 on 54 & 62; if 3 shapes, score 2 on 54, 62 & 66

40 + 36 + 28 + 4   = 108 CUMULATIVE MAXIMUM

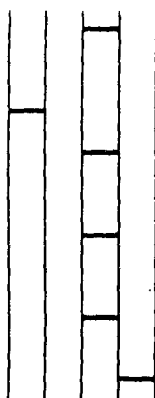**15-17 MONTHS** (For all items, sitting in lap at table)

A B C D

C 55. Bang cube on table, 3 x, wrap in tissue, say "Get the block" -- **secures by unwrapping**

C 56. Cup & 7 cubes on table, say "Put the blocks in the cup" -- **puts all cubes in cup**

C 57. Demonstrate building a 4 cube tower, put 8 cubes on table, say "Build a tower like mine" -- **builds tower w/3-4 cubes.** If 6-8 cubes, score 2 on 57 & 67

P 58. Demonstrate marking lines on paper, give clean sheet to child, say "Do what I did" -- **scribbles on paper.** Observe grasp of marker for item 59.

P 59. Grasping, pronation: while scribbling (#58), --- **uses pronation grasp (thumb & first finger toward paper, 3 fingers around end of marker**

PG 60. Pegboard on table, 3 pegs on table, say "Put the pegs in the board" -- **puts 3 pegs in board**

61. Remove child's shoes, say, "Take off your socks" -- **removes both socks (PI)**

FB 62. Formboard and shapes separately on table, say "Put the shapes in the board" -- **places 2 shapes in board.** If all 3 shapes, score 2 on 62 & 66

42 + 40 + 38 + 4   = 124 CUMULATIVE MAXIMUM

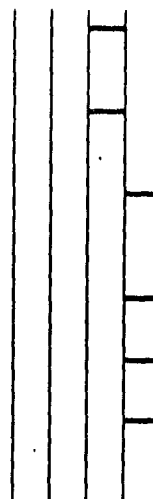**42-47 MONTHS** (For all items, sitting w/examiner at table)

A   B   C   D

P   89.   Give child marker & paper w/6" x 1/4" line in horizontal position, say "Draw on this line" -- traces on line w/<2 deviations. Observe grasp of marker for item 90.

P   90.   Observe grasp in #89 -- holds marker w/fingers in tripod

P   91.   Show card w/cross, give child paper & marker, say "Draw this" -- draws w/straight lines intersecting w/in 20 degrees of perpendicular near middle of horizontal line (1/2)

P   92.   Show card w/square, give child paper & marker, say "Draw this" -- draws w/straight lines w/in 15 degrees of vertical & horizontal w/closed corners

SC 93.   Give child scissors & paper w/circle, say "Cut the circle along the line" -- cuts ≥ 3/4 circle w/in 1/4" of line in 45 seconds

94.   Demonstrating lacing a lacing shoe, say "Lace like I did" -- laces 2/3 holes (do not need to cross from side to side) (PI)

44 + 52 + 72 + 20   = 188 CUMULATIVE MAXIMUM

48-59 MONTHS (For all items, sitting w/examiner at table)

A   B   C   D

BO 95.   Uncapped bottle & 10 pellets on table, say "Put the candles in the bottle as fast as you can. Put only 1 in at a time" -- puts in 10 pellets w/in 30 seconds (both hands can be used)

BU 96.   Button strip (1/2" buttons) on table, center & the end button buttoned, say "Button & unbutton this" -- buttons and unbuttons 1 button in 20 seconds

C   97.   Demonstrate building 5 cube gate, give child 5 cubes, say "Build one like mine" -- builds as demonstrated

P   98.   Give 8 1/2" x 11" paper, say "Fold the paper in half" -- folds paper in half w/edges w/in 1/8" of each other

SC 99.   Give child scissors & paper w/square, say "Cut the square along the lines" -- cuts square w/in 1/4" of lines w/in 45 seconds

100.   Give child 3 paper clips & 8 1/2" x 11" paper, say "Put the clips on the paper" -- clips 2/3 onto paper w/in 1/2 of long side of clip

44 + 52 + 80 + 24   = 200 CUMULATIVE MAXIMUM

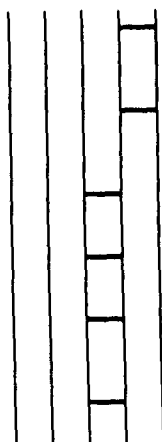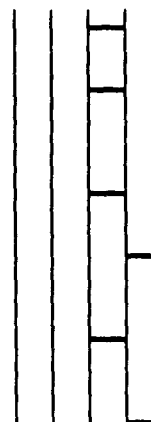**60-71 MONTHS** (For all items, sitting w/examiner at table)

A   B   C   D

P   101.   Give child marker & paper w/2 dots, say "Draw a line from one dot to the other" -- connects dots w/straight line with 1/4" or less deviation, in 10 seconds

C   102.   12 cubes on table, demonstrate 6 cube pyramid, give 6 cubes to child, say "Build one like mine" -- builds pyramid as demonstrated

103.   Demonstrate rapidly touching each finger to thumb, begin w/1st finger, say "Touch like I did" -- touches as demonstrated in 8 seconds. If w/in 5 seconds, score 2 on 103 & 110

104.   Give child spool w/unwound string, say "When I say 'go,' wind the string on the spool" -- winds string w/in 25 seconds

P   105.   Give marker & paper w/2 lines, say "Color between the lines" -- colors 3/4 w/in lines, crossing lines ≤ 2x

106.   Tape paper w/square on table, 20 pennies (2 rows of 10) on table, say "When I say 'go,' pick up the pennies one at a time and put them in the square as fast as you can using one hand" -- places all pennies (may overlap) in square in 35 seconds.   If w/in 25 seconds, score 2 on 106 & 112

44 + 52 + 84 + 32   +   = 212 CUMULATIVE MAXIMUM

72-83 MONTHS (For all items, sitting w/examiner at table)

A   B   C   D

P   107.   Show card w/"STOP" on it, give child paper & marker, say "Write this word" -- prints all letters correctly

P   108.   Give paper & marker, say "Draw a picture of someone" -- draws at least 6 body parts (i.e. torso, facial features, neck, and hands separate from arms, feet separate from legs, pairs as one part)

P   109.   Show card w/diamond, give paper & marker, say "Draw this" -- draws diamond w/straight connected lines

110.   Demonstrate rapidly touching each finger to thumb, beginning w/1st finger, say "Touch like I did" -- touches as demonstrated w/in 5 seconds

C   111.   10 cubes on table, demonstrate building steps, disassemble, push cubes to child, say "Build one like I did" -- builds steps as demonstrated.

112.   Same as 106, except w/in 25 seconds

44 + 52 + 92 + 36   = 224 CUMULATIVE MAXIMUM

APPENDIX D

DEFINITIONS FOR SCORING GROSS MOTOR

SCREENING ITEMS

GUIDE FOR SCORING GROSS MOTOR SCREENING ITEMS

Gait:
1. Heel-toe pattern, arms down, even cadence, symmetrical
2. Poorly defined heel-strike, feet pronated or malaligned
3. Toe strike before heel strike and/or mild asymmetry
4. Abnormal gait

Strength:

1. Dynamic movements age appropriate using the following gross motor screening items:
   -stepping up onto 20" high table and jumping off
   -throwing ball at a target
   -hopping on one foot
   -reaching down to pick up stick on test of running speed

2. Mild immaturity in performance of above items
3. Moderate immaturity in performance of above items because of lack of strength i.e. pressure of hand on knee, using hands to get up from reaching down to pick up object, tires before hopping several feet
4. Unable to perform above items without assistance

Agility and Speed:

Evaluate using the following items:
   -running speed and agility
   -stepping up onto 20" table and jumping off
   -hopping on one foot
   -running and kicking the ball

Use standard score from running speed and agility subtest from the Bruininks Oseretsky Test of Motor Proficiency to help determine if appropriate for age.

1. Normal brisk movement patterns. Able to stop, change directions, climb and jump off. Coordinated, smooth running (Standard score not <10)
2. Normal movement patterns but tends to be slow (Standard score (<10)
3. Immature movement patterns. Falls if speeded up
4. Abnormal, very slow or distinctly clumsy movement patterns

Balance:
   Static
   1.   Static balance age appropriate-able to stand on either foot easily for 8-10 seconds with hands on hips, minimal postural adjustments
   2.   Slight immaturity in performance-stands on either foot with hands on hips for < 8 seconds or only able to stand on prefered leg for 8-10 seconds without hands on hips
   3.   Immature-stands on either foot for less than 5 seconds and must use arms for help to balance
   4.   Unable to do skill-can only balance with support due to marked immaturity or motor deficit affecting balance

   Dynamic (hopping on one foot, climbing onto table and jumping off, walking balance beam, kicking ball, walk line heel-toe, skip alternately)

   1.   No difficulty adjusting posture
   2.   Accomplishees skills with some immaturities
   3.   Accomplishes some skills, but with significant difficulty and unable to perform one or more tasks
   4.   Unable to do skills requires support to walk beam, line. Has motor deficit

Symmetry:

   1.   All gross motor movements symmetrical. No asymmetrical associated reactions
   2.   Occasional evidence of unilateral asssociated reaction
   3.   Consistent mild asymmetry
   4.   Distinct asymmetry with impaired motor skills

Motor Planning:

   1.   Able to imitate mirror image of all 3 postures within 3 seconds
   2.   Able to imitate mirror image of 1 or 2 postures in more than 3 seconds
   3.   Able to imitate 3 postures with reversals within 3 seconds
   4.   Able to complete 1 or 2 postures with reversals or not able to complete postures
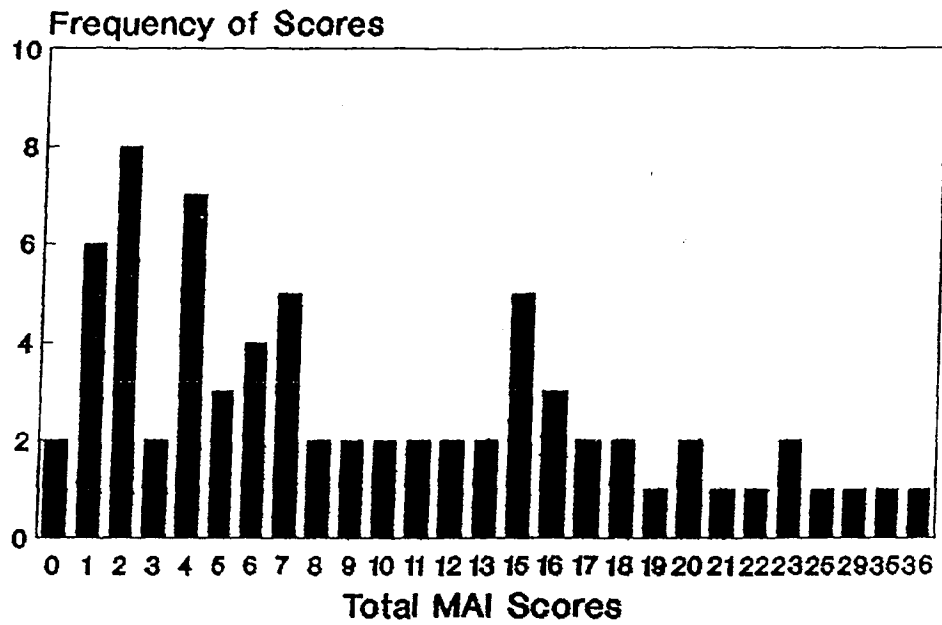
Supine to Stand:

1. Moves from supine to standing with sit up. Agile movement or rolls slightly to one side and stands up through squat or half kneeling
2. Rolls to sidelying then rises to half kneeling or squat
3. Rolls to prone: unable to stand through half kneeling or requires support to stand
4. No independent ability to complete task or marked abnormal patterning

APPENDIX E

DISTRIBUTION OF EIGHT MONTH MAI TOTAL SCORES

Distribution of 8 Month
Total MAI Scores

Frequency of Scores

Total MAI Scores

APPENDIX F

DEFINITIONS OF TERMS USED IN TABLE 12

Statistical Relationships:

1.   Weak statistical relationships include those variables with
        correlation coefficients ranging from 0.01-0.40.

2.   Moderate statistical relationships include those variables
        with correlation coefficients ranging from 0.41-0.70.

3.   Strong statistical relationships include those variables
        with correlation coefficients ranging from 0.71-1.00.

Clinical Relationships:

    These relationships are based on the values of the correlation
    coefficients derived in the statistical analysis. That is the
    higher the correlation coefficient, the better the clinical
    utility.

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PUBLICATIONS (if necessary, use a second sheet):

KAYE, L., WHITFIELD, M.F., (1988) THE EIGHT MONTH MOVEMENT ASSESSMENT
OF INFANTS AS A PREDICTOR OF CEREBRAL PALSY IN HIGH-RISK INFANTS.
ABSTRACT. DEVELOPMENTAL MEDICINE AND CHILD NEUROLOGY, 30, 23.

KAYE, L., WHITFIELD, M.F., GRUNAU, R. (1989) FINE MOTOR COORDINATION AT FOUR
AND ONE HALF YEARS IN CHILDREN WITH BIRTH WEIGHTS ≤ 800 GRAMS.
ABSTRACT. DEVELOPMENTAL MEDICINE AND CHILD NEUROLOGY, 31, 4.

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