University of Alberta

The Longitudinal Relationship of Peabody Balance Scores Obtained by Children at 21 Months and 4 Years of Age

By

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ABSTRACT

The purpose of this study was to explore the relationship between the 21-month and 4-year old balance scores obtained by typically developing children on the Peabody Developmental Gross Motor Scales (PDGMS) and the Peabody Developmental Gross Motor Scales – Second Edition (PDGMS-2). The relationship between the balance scores and physical measures was also explored. Secondary data of the same 78 children that participated in longitudinal infant and preschool studies was analyzed. The 21-month old PDGMS balance scores were not predictive of 4-year old PDGMS balance or PDGMS-2 stationary scores. The physical characteristics of the children at 4-years old did not influence balance performance in this sample. The findings suggest test factors and child characteristics need to be examined carefully in studies evaluating relationships across time. The PDGMS-2 stationary subscale score should be used in conjunction with clinical observations and the PDGMS-2 total gross motor score when assessing a child's balance abilities.

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Hugs for my daughter, Tatiana.

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LIST OF ABBREVIATIONS

PDGMS	Peabody Developmental Gross Motor Scales
PDGMS-2	Peabody Developmental Gross Motor Scales – Second Edition
PDMS	Peabody Developmental Motor Scales
PDMS-2	Peabody Developmental Motor Scales – Second Edition
21-DS	21-month old derived PDGMS-2 stationary subscale
21-OB	21-month old PDGMS balance subscale

CHAPTER I

INTRODUCTION

Functional balance develops as children explore their environment. Balance, stability and postural control are often used synonymously in the literature to describe the ability of a person to maintain his or her center of gravity within the base of support (Pollock, Durward, Rowe, & Paul, 2000). The development of balance involves maturation of multiple subsystems, in addition to the neurological system, within the child. The dynamic systems theory (DST) recognizes that balance abilities are shaped by the interaction among the child, the environment and the task.

Clinically, balance abilities are often assessed by using items on developmental scales of gross motor skills. One frequently used developmental assessment scale that includes balance items is the Peabody Developmental Gross Motor Scales, original edition (PDGMS) (Folio & Fewell, 1983) and revised edition (PDGMS-2) (Folio & Fewell, 2000). Therapists utilizing the PDGMS and PDGMS-2 often assume that balance scores at different ages are related. The assumption that a child with poor scores at one age would have poor scores later in life is derived from the neuromaturation theory. In contrast to the neuromaturational approach, the tenets of DST support a nonlinear development of balance abilities and the role factors other than maturation of the central nervous system have on balance development.

The main aim of this study was to explore the relationship between the balance subscale raw scores of the same children at 21 months and 4 years of age on the PDGMS and PDGMS-2. In addition, the influence of height, weight, head circumference (all measured at 4 years of age), and gender on balance scores at 4 years of age was examined. The results of the study have clinical implications because it is currently assumed that early motor skills are predictive of later motor skills (Darrah, Hodge, Magill-Evans & Kembhavi, 2003).

CHAPTER II

LITERATURE REVIEW

The literature review first describes two theories of motor development, neuromaturational and dynamic systems, and explains the development of balance under each theory. Then the development of balance in young children is reviewed. Finally the clinical assessment of balance is discussed.

Changing Theoretical Perspectives of Motor Development

Factors influencing the development of balance vary depending on the theoretical framework used to explain motor development. Traditionally the neuromaturational theory provided a guide to the development of motor abilities for physical therapists. More recently the dynamic systems theory has been used to explain motor development.

Neuromaturational Theory

Under the neuromaturational perspective, the development of motor skills occurs primarily because of maturation of the central nervous system (CNS) and concomitant inhibition of lower centers by higher centers of the CNS. The tenets of neuromaturational theory describe motor skills as changing from reflexive to voluntary movement, and progressing in cephalocaudal and proximal-distal directions (Gesell, 1971; Thelen & Adolph, 1992). The influence of the environment on motor abilities received very little recognition from a neuromaturational perspective of motor development (Newell, 1986).

Using the framework of the neuromaturational theory, the development of balance is explained by the maturation of the CNS. The hierarchy of reflexes and balance reactions progresses from the spinal cord to the brainstem, to the midbrain, and finally to the cortex. Postural reflexes are present at birth, changing the body posture when changes to the head position occur. The postural reflexes are replaced by righting reactions, resulting in orientation of the head and body in space to keep visual input horizontal. Finally, the equilibrium reactions emerge in the form of tilting reactions, postural fixation reactions and protective responses (Shumway-Cook & Woollacott, 2001). Equilibrium reactions occur in response to external perturbations such as being on an unstable surface or being displaced with a push. The equilibrium reaction involves a weight shift to bring the center of gravity back within the base of support by means of moving the trunk and extremities (Horak & Macpherson, 1996).

Under the neuromaturational perspective, balance is assessed primarily as a person's response to external perturbations. Mature balance is gauged by the presence of equilibrium reactions, which occur in response to the external perturbations. The neuromaturational model accounts for reactive balance responses, but does not account for anticipatory balance responses (Mathiowetz & Haugen, 1994). The response to external perturbations is only one use of balance abilities; more often balance is used to maintain posture and prepare for movement in an anticipatory manner. Although equilibrium reactions assist in maintaining balance, there are other factors intrinsic and extrinsic to the child that influence balance responses. Viewed from the neuromaturational perspective the development of balance is primarily dependent on the maturation of the CNS, with little regard to the influence of other factors within the child or the environment. Dynamic systems theory proposes a different framework for motor development and the emergence of balance abilities.

Dynamic Systems Theory (DST)

The main tenets of DST include self-organization, nonlinear dynamics, and constraints (Thelen, 1989; Ulrich, 1997). Self-organization implies that the interaction of the child's subsystems can lead to spontaneous organization of the child's movements in order to perform functional motor tasks in particular environments (Lewis, 2000; Thelen, 1989). The second tenet, nonlinear dynamics, describes how a small but critical change to one of the subsystems can cause a significant change in the motor output. The small changes to the subsystems within the child may create a period of instability in the child's motor development (Lewis, 2000; Thelen, 1995). This period of instability is often called a transitional phase, and it is hypothesized that children are more likely to try new motor skills during transitional phases (Thelen, 1995). The third tenet of constraints to movement indicates that constraints can influence the movement strategies children choose, suggesting that motor skills are not just preprogrammed in the genetic code (Mathiowetz & Haugen, 1994; Newell, 1986). There are three categories of constraints: organismic, environmental, and task constraints. Organismic constraints are within the child and may include musculoskeletal, neuromuscular, cognitive and psychological systems. Environmental constraints are external to the child such as gravity, temperature and light. Task constraints refer to the goal of the activity, the rules regarding the motor pattern, and the physical objects involved in the task (Newell, 1986).

Using the dynamic systems framework, the maturation of balance involves more than neuromaturation of the CNS and the presence of equilibrium reactions. The maturation of balance abilities involves other factors, such as changes to a child's musculoskeletal subsystems. Intrinsic variables within the child such as limb proportions, strength, range of motion, and tone may affect the balance strategy chosen. A collective variable, "a low-dimensional descriptor of a complex system's behavior", leads to the production of movement (Ulrich, 1997). The similarities in balance responses amongst same age peers can be partially attributed to the spontaneous organization of these similar collective variables (Ulrich, 1997). The influence that collective variables have on motor skill acquisition is further explored by ecological task analysis.

Ecological task analysis (ETA) applies the dynamic systems approach to movement assessment. ETA analyses movement by exploring the relationship between the child, the task, and the environment. ETA recognizes an optimal relationship between the child's characteristics and the task (Davis & Burton, 1991). For example, throwing a ball may involve a relationship between ball diameter and hand width. In intervention this control variable (ball size) could be scaled to the child to promote consistent achievement of a task goal or lead to the emergence of a new movement pattern (Burton, Greer, & Wiese-Bjornstal, 1993). The relationship among the child's physical characteristics may influence balance abilities more than any one physical parameter alone. Burton and Davis (1996) recognize that individual attributes such as height and weight are relevant to movement performance, but are often not included in the calculation of normative scores of development. These performer-scaled measures, which are intrinsic measures, use relevant task to performer ratios. The inclusion of an intrinsic measure could assist in linking the task goal to the child and/or the environment (Burton & Davis, 1996). A critical proportion between two variables may influence balance abilities. For example, height or head size alone may not influence balance abilities, but the ratio of head size to height may influence balance abilities. Both DST and ETA recognize the effect collective variables may have on motor development.

For the purposes of this study, some of the collective variables included are height, weight, head circumference and gender. The influence of a shorter height and a larger head size compared to adults can be observed in children because they have a higher center of mass located at the 12^{th} thoracic vertebral level, compared to the adult's center of mass at the fifth lumbar vertebral level and the first sacral vertebral level. An increased rate of body sway results from the higher center of mass and children require larger and quicker balance adjustments than adults to compensate (Forssberg & Nashner, 1982; Shumway-Cook & Woollacott, 2001). Children between 4 and 6 years of age often experience a period of disproportionate growth that coincides with a period of variability in balance responses. The critical dimension changes in the child's body may cause a transition in motor strategies used (Shumway-Cook & Woollacott, 2001). One study of infants also noted a significant association between head proportion and motor abilities at 6 weeks of age; infants with proportionately larger heads tended to have lower motor scores (Bartlett, 1998).

Research also suggests a relationship between balance responses and height. Young children (5 to 7 years of age) who were taller had better Functional Reach Test (FRT) (Duncan, Weiner, Chandler, & Studenski, 1990) and Timed Up and Go (TUG) (Podsiadlo & Richardson, 1991) scores than their same-aged peers (Habib & Westcott, 1998). Since height is highly correlated with base of support, it is postulated that taller children had better stability because of their larger base of support. The weight of the children did not show a statistically significant relationship to the FRT or TUG scores

(Habib & Westcott, 1998). Gender was not found to be a significant factor for balance performance on the Pediatric Clinical Test of Sensory Interaction for Balance (Deitz, Richardson, Atwater, Crowe, & Odiorne, 1991). However, a study of static balance of 6-, 8-, and 10-year old children, using a force platform, found gender differences. Girls at 6 and 8 years of age performed better than same age males on the tandem standing test, as indicated by lower mean radius values of the posturogram (Figura, Cama, Capranica, Guidetti, & Pulejo, 1991). In a different study of static balance, 4- and 5-year old girls ranked higher than boys when they stood on one foot (Sellers, 1988).

The work of Bernstein and Nashner both support the dynamic systems perspective of balance. Bernstein hypothesized that the organization of movement involves more than programming from the CNS because movement strategies are context, force, and time dependent (Bernstein, 1984). DST explains the changes in balance responses by considering the interactions between the child's subsystems, the environment, and the activity. Nashner (1979) used computerized posturography and electromyography to examine balance. He found that a person's muscles would contract in anticipation of an activity or factors in the environment to produce a balance response. He suggested that the balance responses are not simply reactions to external forces (Nashner, 1979). Anticipating the need to respond is suggestive that other systems, in addition to the neurological system, are needed to develop balance. It was Nashner's facilitation of these balance responses, by manipulating the environment, which provided the groundwork for describing the influence of the sensory systems on balance abilities.

In summary, how development of balance abilities is explained depends on the theoretical perspective used. The neuromaturational theory supports a linear progression of balance, in which improvement in balance abilities with age are dependent primarily on maturation of the CNS. This framework suggests that motor performance of a child at one age would predict that same child's performance later in life. The DST supports a nonlinear progression of development, whereby the balance abilities of a child at one age may not predict balance abilities later. Inter-individual variability in balance development may be a result of some children entering the transition phase or it may be related to the child's height, weight, head circumference, gender and/or a performer-scaled measure such as weight/height, head circumference/height, and weight/head circumference ratios. DST and ETA consider the influence of the environment, the task and the child's multiple subsystems on balance abilities. Changes to the sensory and motor systems of children contribute to balance development and performance.

Development of Balance in Children

Balance is dependent on information from three sensory systems: visual, somatosensory, and vestibular systems (Foudriat, Di Fabio, & Anderson, 1993; Shumway-Cook & Woollacott, 2001). Adults can use one or more of these systems to maintain their balance. The sensory systems develop in a stage-like progression throughout childhood starting with the visual, then somatosensory, and finally the vestibular system. The maturation of the sensory systems appears to influence the strategies that children use to maintain their balance and their subsequent balance responses.

Vision is the primary sensory system strategy that children use to maintain their balance from infancy to 3 years of age (Woollacott, Debû, & Shumway-Cook, 1987).

Vision continues to play a role in balance development throughout life. However, around 3 years of age, children start to incorporate information from their somatosensory system to maintain balance. Research on balance involving 3- to 6-year old children, revealed that 3-year old children were able to compensate for misleading visual information (sway referenced enclosure) and maintain standing on a fixed platform (Foudriat et al., 1993). If the children were relying only upon the visual information, the children would have swayed more or fallen. This research supports the idea of a shift at 3 years of age from visual control to somatosensory-vestibular control of balance responses (Foudriat et al., 1993). The somatosensory system provides children with information on their body's position and the force of their movements. As a child walks, runs, jumps, or rides a bicycle, muscles contract and joints move to provide input to the somatosensory system. Therefore, active exploration of one's environment facilitates the development of the somatosensory system (Huebner, 2001). The sense of body position or somatosensation is dependent on input from the slowly adapting skin receptors and muscle spindle afferents. Fatigue of the muscles could result in decreased input from the muscle spindles, and a corresponding decrease in the accuracy of the somatosensory information (Forestier, Teasdale, & Nougier, 2002).

Children between 4 and 6 years of age start to integrate the three sensory systems. The children rely more on the somatosensory and vestibular systems, with vision having a continued role (Woollacott & Shumway-Cook, 1987). At 4 years of age somatosensory input from the foot and ankle, in addition to visual input, facilitates a balance response (Foudriat et al., 1993). The somatosensory system is maturing, with maturation of somatosensation by 6 years of age (Hirabayashi & Iwasaki, 1995; Rine, Rubish, &

Feeney, 1998). The corresponding balance response muscle synergy would include activation of the neck, trunk, and leg muscles (Woollacott & Shumway-Cook, 1987). The leg muscles are activated in a distal to proximal sequence. The principal pattern of muscle activation remains similar as children become older, but the amplitude and duration of muscle response decreases (Deitz et al., 1991; Muller, Homberg, Coppenrath, & Lenard, 1990; Roncesvalles, Woollacott, & Jensen 2001; Sundermier, Woollacott, Roncesvalles, & Jensen, 2001). The balance strategies that may be observed clinically are ankle and hip strategies. The ankles move first to compensate for changes in the surface or to respond to external perturbations to maintain a child's balance. The hip strategy responds to larger or quicker forces exerted on the body (Shumway-Cook & Woollacott, 2001; Woollacott & Shumway-Cook, 1990). Therefore, balance responses involve integration of the available sensory information and activation of muscle synergies to maintain standing.

Balance improves with age, but between 4 and 6 years of age inter-individual and intra-individual variability in balance responses is apparent. When standing on a moving platform, 4- to 6-year old children have leg muscle responses that are more variable in comparison to 15- to 31-month old and 7- to 10-year old children. The variability in leg muscle responses can be attributed to the increased rate of body sway seen in young children (Forssberg & Nashner, 1982). The proximal leg muscles of 4- to 6-year old children activate later and the proximal and distal leg muscle synergies are suggested to be less tightly coupled (Woollacott & Shumway-Cook, 1987). At 4 years of age, the variability in balance responses can also be partially attributed to a shift in the sensory information that dominates the control of balance adjustments (Shumway-Cook &

Woollacott, 2001; Woollacott & Sveistrup, 1992). Some children make the shift to use somatosensory/vestibular information, in addition to visual cues, while their same aged peers continue to use predominantly visual strategies (Richardson, Atwater, Crowe, & Deitz, 1992). At 4 years of age some children are also developing the ability to discriminate between conflicting sensory information (Foudriat et al., 1993).

The development of balance continues beyond 6 years of age with the development of systematic selection of sensory information (Richardson et al., 1992). Greater reliance on the vestibular system also occurs around 7 years of age, allowing for an improvement in discrimination between conflicting sensory information and integration of sensory information (Kirshenbaum, Riach, & Starkes, 2001; Woollacott & Shumway-Cook, 1987). The sensory systems continue to develop, with the vestibular system continuing to develop past 15 years of age (Hirabayashi & Iwasaki, 1995). As new balance skills develop, children display an increase in muscle response latencies and variability in response to altered sensory conditions, followed by a shift to normal levels once the new balance abilities are attained (Woollacott & Sveitstrup, 1992). Variability in balance abilities between children at certain stages of development can be attributed to the transition to higher-level balance abilities by some children, while other children have not. This variability in balance abilities on developmental tests may vary within the same child if he or she is in a transitional phase at the time of testing.

There are clinical implications for the variability in balance abilities between 4 and 6 years of age. The neuromaturational theory suggests early balance abilities predict later balance abilities. However, the DST proposes a nonlinear progression of balance development and inter-individual variability of balance responses in 3- and 4-year old children. The DST suggests that there may be a poor relationship between 4-year old balance scores and earlier balance scores. If a 4-year old child does not shift the focus on to somatosensory inputs, instead of vision, and the child continues to have variable muscle responses to body sway, the child may have poorer balance scores than other 4-year old children.

Clinical Assessment of Balance

Clinical vestibular system tests, neurological assessments, and some functional and developmental assessments are used to assess balance (Westcott, Lowes, & Richardson, 1997). The Functional Reach Test (FRT) is a tool used to measure a person's ability to reach outside of their base of support (Duncan et al., 1990). The FRT requires a child to reach forward with a straight arm elevated to 90 degrees without moving his or her feet. Although the FRT has good inter-rater reliability (intra-class correlation coefficient [ICC] = .98) and intra-rater reliability (ICC = .87 to .98), it has two limitations (Donahoe, Turner, & Worrell 1994; Niznik, Turner, & Worrel, 1995). First, the FRT has minimal normative data for people younger than 20 years of age (Donahoe et al., 1994). Second, the FRT does not assess children using their balance abilities in a functional context. Thus the results of an FRT test do not guide clinicians about a child's functional balance abilities.

Another clinical measure is the Pediatric Clinical Test for Sensory Interaction in Balance (P-CTSIB) (Shumway-Cook & Horak, 1986), also known as the foam and dome test. Children are required to maintain standing balance while experiencing different visual or somatosensory inputs. This test replicates the conditions often used in the laboratory to facilitate reactive balance responses. Having eyes open, or eyes closed, or wearing a dome that affects peripheral vision alters visual input. Changing the support surface from the floor to high-density foam alters somatosensory input (Deitz et al., 1991). However the application of this tool clinically is limited. The test may assist in diagnosing which sensory system is not functioning properly, but it does not provide information about a child's functional balance abilities. As a result, the P-CTSIB has not been adopted universally as a measure of balance in children.

Balance is most commonly assessed in pediatrics using developmental tests that have subscales or particular items that are reported to target balance abilities. Developmental tests are often used to screen for gross motor delays and track changes in motor abilities. One of the most frequently used outcome measures for children under 6 years of age is the second edition of the Peabody Developmental Motor Scales (PDMS-2) (Folio & Fewell, 2000). The PDMS-2 recently replaced the Peabody Developmental Motor Scales (PDMS) (Folio & Fewell, 1983). The PDMS-2 has gross motor (PDGMS-2) and fine motor (PDFMS-2) scales. The movements tested are similar to play activities for children (Folio & Fewell, 2000). The PDGMS-2 includes 151 items that are divided into four subscales: reflexes, stationary, locomotor, and object manipulation. The stationary subscale aims to measure balance abilities such as kneeling, standing on one foot, and standing on tiptoes.

Although the PDGMS and PDGMS-2 offer comprehensive assessments of gross motor activities that are familiar to children, the tests do not consider the influence of physical characteristics on balance performance. Therapists assessing balance do not often consider the influence of height, weight, head circumference, gender and the interactions of these variables upon balance abilities.

Summary

The assessment of balance abilities of children has ranged from assessing equilibrium reactions to observing children in their daily activities and analyzing the influence of factors within the person, task and environment. Clinically, a direct relationship between a child's early balance scores and later ones is assumed, implying that children who are more proficient in balance abilities at young ages will continue to be more proficient as they get older. The neuromaturational theory supports this linear progression of abilities. The DST and research supports a nonlinear development of balance abilities, which is dependent on the interaction of many different factors within the child. Some 4-year old children move to more mature balance responses to body sway, incorporating visual and somatosensory cues, while their peers continue to rely on visual information. The balance performance of children at 4 years of age is often measured using the PDGMS-2. The 4-year old children may have balance scores on the PDGMS-2 that are more closely linked to specific performer attributes, such as height, weight, gender and head circumference, than balance performance earlier in life. The theory and research supporting predictors of balance performance at 4 years of age needs to be evaluated. The study aims to evaluate a theoretical perspective and offer information for clinicians to use in the interpretation of PDGMS-2 balance scores.

CHAPTER III

OBJECTIVES

The main aim of this study was to explore the relationship between the balance subscale raw scores obtained by the same children at 21-months old on the PDGMS and at 4-years old on both the PDGMS and PDGMS-2. In addition, the influence of height at 4 years, weight at 4 years, head circumference at 4 years, and gender on balance scores at 4 years of age was examined. The results will assist therapists to identify the importance of these factors in the assessment of children's balance abilities.

Specific Objectives

1) To examine the relationship between the 21-month old derived PDGMS-2 stationary subscale (21-DS) raw scores and 4-year old PDGMS-2 stationary subscale raw scores. The 21-DS included PDGMS test items that corresponded to the same or similar items in the PDGMS-2 stationary subscale tested at 21-months old. The relationship was also examined between the 21-month old PDGMS balance subscale (21-OB) raw scores and the 4-year old PDGMS-2 stationary subscale raw scores. Finally, the relationship between the 21-OB raw scores and the 4-year old PDGMS balance subscale raw scores was explored. Raw scores were used to maintain consistency across objectives and to allow for comparison to the PDGMS-2.
2) To evaluate the relationship among PDGMS-2 stationary subscale raw scores of 4-year old children and five factors that may have influenced the scores: 21-DS, height at 4 years, weight at 4 years, head circumference at 4 years, and gender.

3) To evaluate the predictive validity of the 21-OB. The 16th percentile was used as the cut-off to classify suspicious/delayed versus normal balance abilities because 1 standard deviation below the mean was recommended as a cut-off point by the PDGMS manual (Folio & Fewell, 1983). The PDGMS-2 manual also stated the 16th percentile was below average (Folio & Fewell, 2000). The 4-year old PDGMS-2 stationary subscale percentile ranks of the children (above or below the 16th percentile) were used as the gold standard to calculate sensitivity, specificity, and positive and negative predictive values. The calculations were repeated using the 4-year old PDGMS balance subscale as the gold standard. The use of both the PDGMS and PDGMS-2 as gold standards allowed for a comparison between the two tests, with differences noted in the ranking of the balance abilities of children.
4) To examine the relationship between raw scores on all subscales in the PDGMS (balance, nonlocomotor, locomotor, receipt and propulsion) at 21 months and 4 years of age. This analysis determined if the relationship between raw scores was similar or different across the subscales.

A summary of the objectives of this study can be found in Table 3.1.

Table 3.1.

Summary of Objectives

OBJECTIVES	4-YEAR MEASURE	21-MONTH MEASURE
1. Relationship between Peabody balance scores	(a) PDGMS-2 stationary subscale (4-years old) (b) PDGMS-2 stationary subscale (4-years old) (c) PDGMS balance subscale (4-years old)	(a) 21-DS (b) 21-OB (c) 21-OB
2. Relationship among scores at 4 years and five child factors	(a) PDGMS-2 stationary subscale (4-years old) (b) Height (4-years old) (cm) (c) Weight (4-years old) (kg) (d) Head size (4-years old) (cm) (e) Gender (male/female)	(a) 21-DS
3. Predictive Validity of PDGMS balance subscale to PDGMS-2 stationary and PDGMS balance subscales	Gold Standard (4-years old) - 16th percentile cut-off (a) PDGMS-2 percentile ranks on stationary subscale (b) PDGMS percentile ranks on balance subscale	21-OB percentile ranks - 16th percentile cut-off
4. Relationship of scores on all subscales	PDGMS raw scores (4-years old) (a) Balance subscale (b) Locomotor subscale (c) Nonlocomotor subscale (d) Receipt and Propulsion subscale	PDGMS raw scores (21-months old) (a) Balance subscale (b) Locomotor subscale (c) Nonlocomotor subscale (d) Receipt and Propulsion subscale

CHAPTER IV

METHODS AND PRODEDURES

Sample and Study Design

This was a secondary analysis of data from two longitudinal studies of motor development conducted at the Faculty of Rehabilitation Medicine at the University of Alberta, Edmonton. The infant and preschool studies included the same typically developing children and retrospective charting of 21-DS raw scores.

Description of Infant Longitudinal Study

The original infant longitudinal study evaluated the gross motor abilities of children at 9, 11, 13, 16 and 21 months of age in their homes using the PDGMS. A volunteer sample of 120 children was recruited in 1998. The children included in the study had a gestational age of 37 weeks or greater. No parents were concerned about the development of their infant. The purpose of the original study was to examine the stability of gross motor, fine motor, and communication scores of typically developing infants. The PDGMS was used to monitor gross motor abilities. The children were determined to be typically developing at 23-months of age by using the Diagnostic Inventory for Screening Children Preschool Screen (DISC Preschool Screen) (Parker, Mainland, & Amdur, 1998) or the Diagnostic Inventory for Screening Children (DISC) (Amdur, Mainland, & Parker, 1988).

Motor therapists (occupational and physical therapists) assessed the children. The inter-rater reliability for the first study was measured on average at every 10th assessment, with a therapist's score being compared to that of another therapist by observing the same child, with correlation coefficients of .99 obtained (Darrah et al., 2003).

Description of Preschool Longitudinal Study

The families of the same children that were assessed at 21-months old were invited to participate in a preschool longitudinal study that included an assessment at 4 years of age. The purpose of the second study was to see if the scores of the children became more stable with age, and to identify scoring patterns that suggested difficulty with motor skills. The motor assessments at 4 years of age included both the PDGMS and PDGMS-2, with items from the PDGMS and PDGMS-2 combined for the assessments. The inter-rater reliability for the motor assessments (PDGMS and PDGMS-2 combined) for the second study was measured on average at every 20th assessment, with an intra-class correlation coefficient of .86. The item-by-item agreement for the motor therapist was 69% to 85%. The variability in item-by-item agreement may be due to the items from both tests being combined before administration to the 4-year old children.

Of the 84 children recruited for the preschool study, who had also completed the infant study, one dropped out, three did not complete the 4-year old motor assessment, and two had incomplete 4-year old physical measure data. Therefore, the number of preschool children that completed both the 21-month and 4-year old assessments was 78. Boys accounted for 58% of the sample, and all but 15% were White (1% Chinese, 2.6% South Asian, and 7.7% mixed ethnicity). Sixty four percent of fathers and 68% of mothers had completed college or university. The family yearly median income was $70,000 to $79,999.

A two-tailed alpha table was used to calculate effect size because the direction of the balance scores for the children was not known. With a correlation coefficient of .30 ($\alpha_2 = .05$) and a sample size of 78, 78% power could be attained (Appendix A) (Portney & Watkins, 2000). Given a sample size of 78, 5 variables, and 80% power, a R^2 of .15 ($\alpha = .05$) would be statistically significant (Appendix A) (Portney & Watkins, 2000).

Consent from the Health Research Ethics Board: Panel B, University of Alberta was obtained for the secondary data analysis (Appendix B). Confidentiality of the information was respected.

Data Collection: Measures

Peabody Developmental Gross Motor Scales (PDGMS)

The PDGMS was used to assess the gross motor development of children at 21 months and 4 years of age. The PDGMS includes 170 items that are divided into five subscales: reflexes, balance, nonlocomotor, locomotor, and receipt and propulsion (Appendix C). The reflex section evaluates the primitive reflexes that are normally integrated within the first year of life. The balance section assesses a child's ability to maintain or attain a position. Items include standing on one foot, walking on tiptoes, and walking on a balance beam. For example, one item determines if a child can stand on one foot for 3 seconds with hands on his or her hips. The nonlocomotor section looks at upper body and trunk muscle strength on the spot. The locomotor section assesses the ability of children to move throughout their environment. The receipt and propulsion section evaluates ball skills (Folio & Fewell, 1983). The items were scored on a three point ordinal scale from 0 to 2. Children scored a 2 if the item was completed successfully, a 1 if the motor skill was emerging, and a 0 if the child was unsuccessful. Basal and ceiling levels were identified, with scoring criteria further explained in the manual but not on the record form. The gross motor score can be converted into a percentile, an age-equivalent, or a standardized score (Folio & Fewell, 1983).

The reliability of the PDGMS to accurately measure the motor development of children included two evaluations. First, the test/retest reliability of the PDGMS was greater than .99 when children were tested no greater than one week apart and basal items were included. Secondly, the inter-rater reliability was .97 for the PDGMS, which indicated tests administered by different assessors resulted in consistent results (Folio & Fewell, 1983). A study that evaluated the inter-rater reliability of the PDGMS included 4- and 5-year old children with and without identified delays. The high intraclass correlation coefficients (.84 to .94) suggested that the therapists achieved high levels of inter-rater reliability (Schmidt, Westcott, & Crowe, 1993).

Content, construct, concurrent, and predictive validity of the PDGMS have been evaluated. The content of the PDGMS was created from review of items on other motor development scales and the creation of new items based on motor development. The items chosen for inclusion in the PDGMS were movement strategies that develop in a predictable and orderly sequence throughout early childhood (Folio & Fewell, 1983). To evaluate the construct validity of the PDGMS, the relationship between total score and age was examined; a correlation coefficient of .99 was reported in the manual. Also the PDGMS was able to identify children with motor development problems when their scores were compared to the normative population. The construct validity of the individual items was based upon the assumptions from the neuromaturational perspective, including sequential and hierarchical development of motor skills (Burton & Miller, 1998; Palisano & Lydic, 1984). The subscales for the PDGMS were not determined by factor analysis but only by the developers' clinical judgement of which items belonged on the subscales.

The concurrent validity of the PDGMS had been reported in relation to the Bayley Scales of Infant Development Motor Scale (BSID Motor Scale) (Bayley, 1969) and the Bayley Scales of Infant Development II Motor Scale (BSID II Motor Scale) (Bayley, 1993). The age equivalent scores for the BSID Motor Scale had good to high correlation (r = .78 to .96) with the PDGMS for both full-term and healthy premature infants at 12, 15 and 18 months of age (Palisano, 1986). The concurrent validity of the PDGMS and the BSID II was studied on typically developing children 2 years of age. The relationship between the age equivalent scores of the BSID II and the PDGMS was good, with a correlation coefficient of .83. However, the relationship between standard scores of the BSID II and the PDGMS was unacceptable (r = .49) because only 66% of the children were classified the same on the BSID II Motor Scale and the PDGMS (Provost, Crowe, & McClain, 2000).

The predictive validity of the PDGMS has been evaluated for infants. Palisano (1986) evaluated full-term and healthy premature infants at 12, 15, and 18 months of age. It was reported that the PDGMS 12-month age equivalent scores did not effectively predict 18-month old scores with a correlation coefficient of .60 for full-term infants and .54 for healthy premature infants (Palisano, 1986). The predictive validity of the PDGMS over 3 months ranged from correlation coefficients of .58 to .85 (Palisano, 1986). In a study of infants (ranging in age from 2- to 33-months old) with a diagnosis of cerebral palsy, Down syndrome, hydrocephalus, pre-term with developmental delay, and full term with developmental delay receiving early intervention, the mean PDGMS raw score increased over a 6-month interval. However, the individual raw score improvements were compared and it was determined that for 38% of the changes in raw scores, measurement error or random variation could not be ruled out. It was concluded that the PDGMS was not responsive to change over a 6-month period (Palisano, Kolobe, Haley, Lowes, & Jones, 1995).

A second edition of the Peabody Developmental Gross Motor Scales (PDGMS-2) recently replaced the PDGMS (Folio & Fewell, 2000).

Peabody Developmental Gross Motor Scales – Second Edition (PDGMS-2)

The PDGMS-2 contains a total of 151 items in four subscales: reflexes, stationary, locomotion, and object manipulation. A comparison between the stationary subscale of the PDGMS-2 (Appendix D) and the balance subscale of the PDGMS revealed that some items were kept under the stationary subscale, while others were moved to the locomotor subscale or eliminated (Appendix E) (Folio & Fewell, 1983; Folio & Fewell, 2000). From birth to 72 months of age the PDGMS-2 stationary subscale had 30 items (Appendix D), 10 of which were typically tested on children between 12 and 60 months of age. There were an additional 18 items that children typically received credit for because items 1-18 usually occurred before 10 months of age (Folio & Fewell, 2000). There was a significant decrease in items measuring balance for children 12 to 60 months of age using the PDGMS-2 instead of the PDGMS balance subscale; there were 10, instead of 20 balance items (Appendix F). However, some of the PDGMS balance items were moved to the locomotor section of the PDGMS-2 (Folio & Fewell, 1983; Folio & Fewell, 2000).

The items included in the PDGMS-2 were scored on a three point ordinal scale from 0 to 2, but unlike the PDGMS, the criteria for scoring 2, 1, or 0 were clearly described in the examiner record booklets. The test-retest reliability of the PDGMS-2 was .89 and the inter-rater reliability was .97. The construct validity of the PDGMS-2 was tested primarily with confirmatory factor analyses. For the children aged 12 through 71 months of age, the goodness-of-fit indexes indicated that the PDGMS-2 model had an excellent fit to the data (Folio & Fewell, 2000).

The PDGMS was used for the first study on 21-month olds. The second study on 4-year olds used both the PDGMS and PDGMS-2. In order for the results to be clinically relevant, the 21-month old scores were compared to the 4-year old scores on both the PDGMS and PDGMS-2. The items on the PDGMS similar to the PDGMS-2 stationary subscale were identified and used to calculate the 21-month old derived PDGMS-2 stationary subscale (21-DS) raw scores (Appendix F). This allowed for a comparison of 4-year old balance performance to earlier balance performance of the same children at 21 months of age.

Physical Growth Parameters

The preschool study assistant measured the height, weight, and head circumference for each child at 4 years of age. Height was measured in centimeters from the floor to the top of the child's head. Weight was measured in kilograms using a calibrated medical weight scale. Head circumference was measured in centimeters by using a tape measure wrapped around the largest portion of the child's head. Three measures were taken and averaged.

Data Collection: Procedures

The PDGMS was administered as specified for each item by motor therapists who were familiar with the test and participated in training and reliability sessions before the study began. The total time to administer the PDGMS was between 40 and 60 minutes. The assessments were administered within 2 weeks of the children reaching 21 months of age (average age 21.13 months old; *SD* = 0.16) and 4 years of age (average age 48.17 months old; *SD* = 0.34). Children were assessed at 21 months of age in their homes and at 4 years of age at Corbett Hall at the University of Alberta. At 4 years of age the children were each assessed using the PDGMS and the PDGMS-2. Some of the therapists that assessed at 21-months of age assessed the children at 4-years of age. However, the therapists were not matched up with the same children they previously assessed in the infant study. The assessing therapist scored the items on the PDGMS and the project coordinator calculated the percentile ranks and standard scores for each child. Since the PDGMS-2 was not available during the 21-month assessments, this study required additional tabulation of the total stationary raw score for the children at 21-months of age to allow for a comparison to the 4-year old scores on the PDGMS-2. The items on the PDGMS similar to the PDGMS-2 stationary subscale were identified and used to calculate the 21-DS raw scores (Appendix F).

Data Analyses

Descriptive statistics were calculated. Age, height, weight, head circumference, and gender described the group of children.

Objective 1

To examine the relationship between the 21-DS raw scores and the 4-year old PDGMS-2 stationary subscale raw scores. Also, the relationship between the PDGMS balance subscale raw scores was explored using the 21-OB raw scores and 4-year old data.

Pearson correlation coefficients were calculated to determine the association between 21-DS and 4-year old PDGMS-2 stationary subscale raw scores, 21-OB and 4-year old PDGMS-2 stationary subscale raw scores, and 21-OB and 4-year old PDGMS balance subscale raw scores.

Objective 2

To evaluate the relationship among PDGMS-2 stationary subscale raw scores of 4-year old children and five factors that may have influenced the scores: 21-DS raw scores, height at 4 years, weight at 4 years, head circumference at 4 years, and gender.

First a correlation matrix among all variables, except gender, was done. Then stepwise regression was used to evaluate the relationship of 4-year old PDGMS-2 stationary subscale raw scores to all five factors that may have influenced balance abilities. The analysis evaluated the proportion of variance in 4-year old scores accounted for by each variable. Each variable was entered individually and then physical measure ratios were explored. The physical measure ratios included head circumference/height, weight/head circumference and weight/height.

Objective 3

To evaluate the predictive validity of the 21-OB percentile ranks. The 16^{th} percentile rank was used as the cut-off to classify suspicious/delayed versus normal balance abilities at 21-months and 4-years old. The 4-year old PDGMS-2 stationary subscale percentile ranks of the children (above or below the 16th percentile) were used as the gold standard to calculate sensitivity, specificity, and positive and negative predictive values. The calculations were repeated using the 4-year old PDGMS balance subscale as the gold standard.

Objective 4

To examine the relationship of 21-month and 4-year old PDGMS subscale raw scores for all subscales (balance, nonlocomotor, locomotor, receipt and propulsion). This analysis determined if the relationship of scores at the two ages was similar or different across the subscales.

For this objective, Pearson correlation coefficients were calculated for the association between 21-OB and 4-year old PDGMS balance subscale. Pearson correlation coefficients were also calculated for the relationships between 21-month and 4-year old scores on each PDGMS subscale. The balance subscale was compared to the other subscales with an evaluation of the significance of difference between the independent correlation coefficients (Cohen & Cohen, 1983). If there was a significant difference between the correlation coefficient of the balance subscale and the other subscales, one explanation could be the variability in the development of balance abilities at 4 years of age.

CHAPTER V

RESULTS

Descriptive Statistics

Seventy-eight children had complete data sets at the 4-year assessments. There were 45 boys, accounting for 58% of the sample. The average age of the children was 48.17 months (*SD* = 0.34). Table 5.1 provides descriptive statistics on physical measures of the children at the 4-year old assessment.

Table 5.1.

Descriptive Statistics on Physical Measures of the Children at 4-Years Old (N = 78)

	Mean	Standard Deviation	Range
Height (cm)	101.85	4.26	92 – 112
Weight (kg)	16.80	2.29	11 – 22
Head circumference (cm)	51.33	1.39	47 - 55
Weight/height ratio	0.16	0.02	0.11 – 0.20
Head circumference/ height ratio	0.50	0.02	0.47 - 0.56
Weight/ head circumference ratio	0.33	0.04	0.22 - 0.43

Objective 1

Three relationships between 21-month and 4-year old Peabody data were examined: 1) 21-DS and 4-year old PDGMS-2 stationary subscale raw scores, 2) 21-OB and 4-year old PDGMS-2 stationary subscale raw scores, and 3) 21-OB and 4-year old PDGMS balance subscale raw scores. The relationship between 4-year old PDGMS-2 stationary subscale and the 21-DS raw scores was not significant ($r = .10$). The range of scores for the 21-DS appeared small and a histogram confirmed this suspicion (Figure 5.1). Sixty-nine children received the same score on the 21-DS. The scores of all children ranged only 3 points. This attenuated range of scores affected the correlation coefficient. The range and variability of scores was improved with the 21-OB, 4-year old PDGMS balance subscale, and 4-year old PDGMS-2 stationary subscale raw scores (Figure 5.2, 5.3, & 5.4). The relationship between 4-year old PDGMS-2 stationary subscale raw scores and 21-OB raw scores revealed a significant correlation coefficient of .25 ($p = .03$). There was a larger spread of raw scores on the 21-OB (range 27 – 36) compared to the 21-DS raw scores (range 34 – 37). The relationship between the 4-year old PDGMS balance subscale and 21-OB raw scores was slightly higher with a correlation coefficient of .31 ($p = .01$) (Table 5.2). Table 5.3 shows the range of raw scores for the children at 21-months and 4-years old on both the PDGMS and the PDGMS-2. The absolute values of all three correlation coefficients were low.

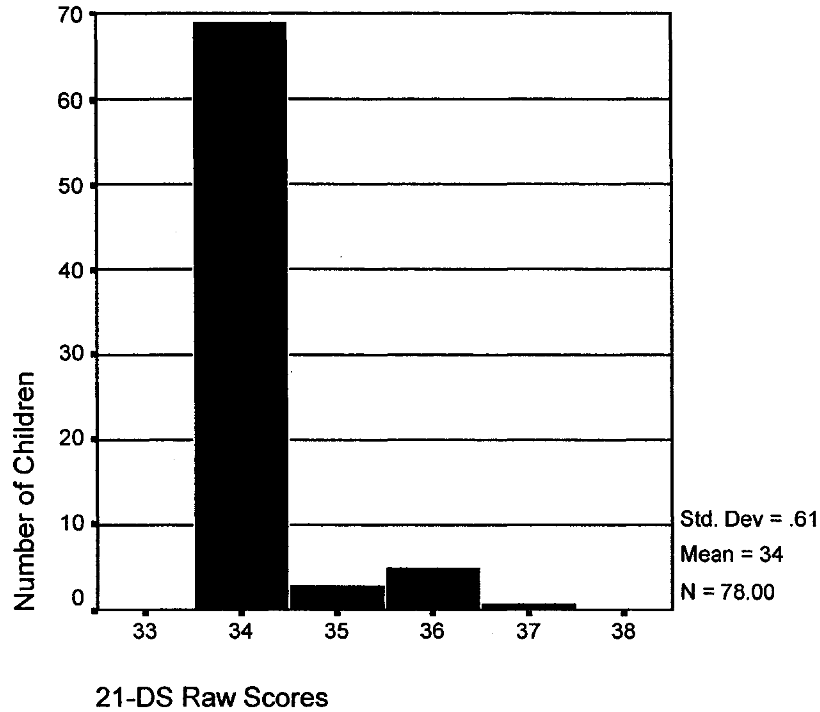

Figure 5.1. Histogram of 21-DS raw scores. Note: 21-DS = 21-month old derived PDGMS-2 stationary subscale.

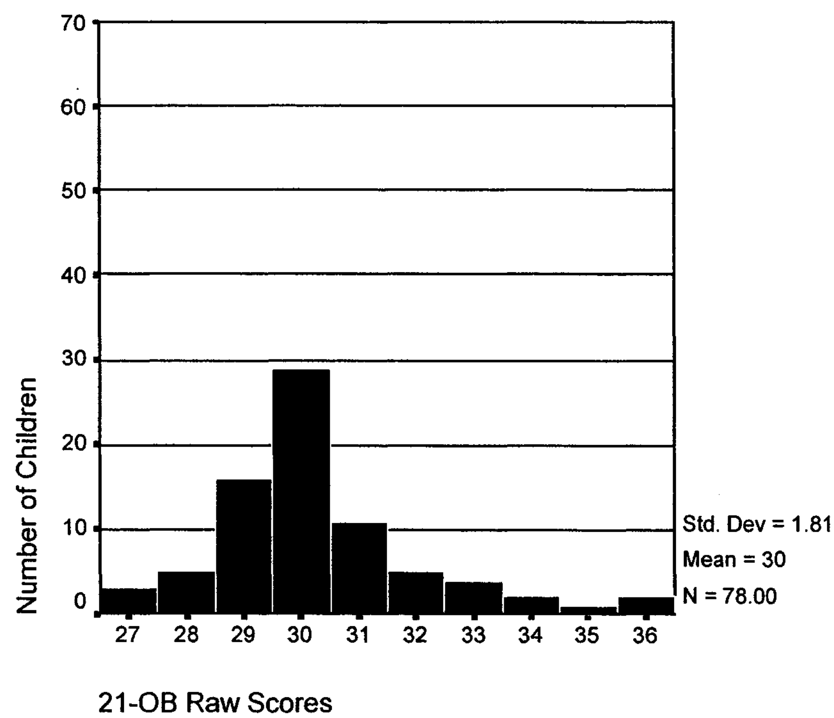

Figure 5.2. Histogram of 21-OB raw scores. Note: 21-OB = 21-month old PDGMS balance subscale.

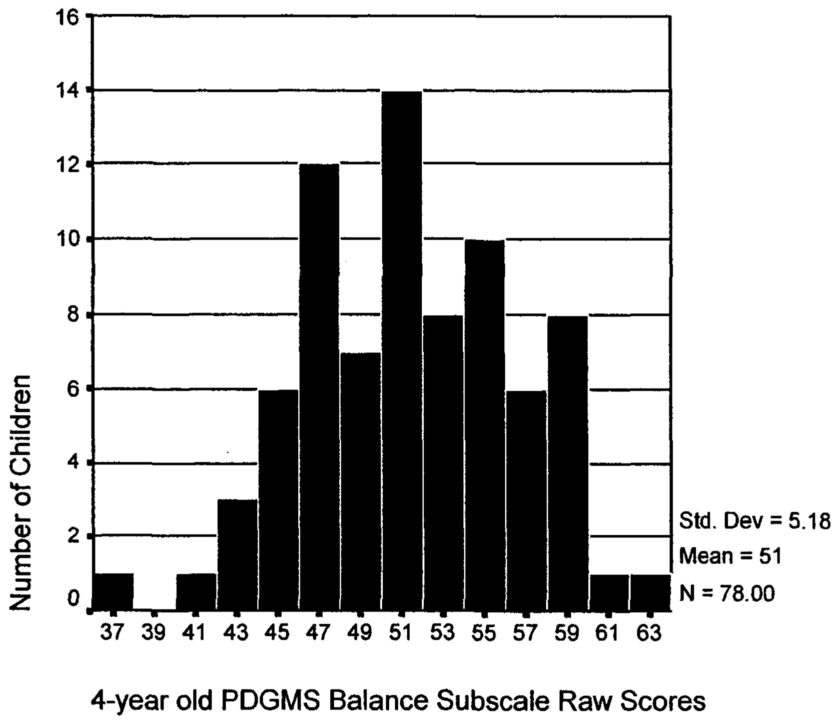

Figure 5.3. Histogram of 4-year old PDGMS balance subscale raw scores.

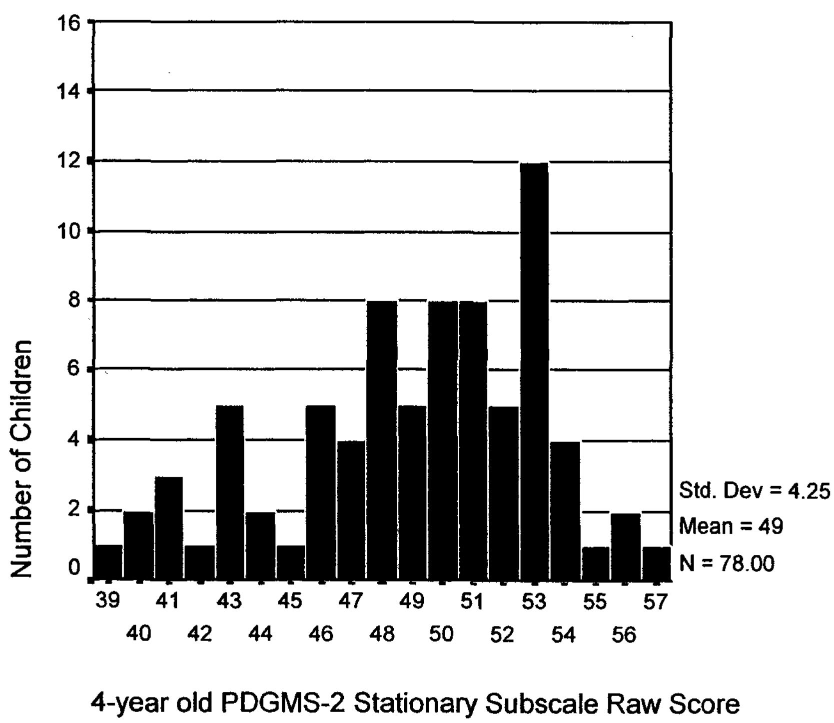

Figure 5.4. Histogram of 4-year old PDGMS-2 stationary subscale raw scores.

Table 5.2.

Correlation between 21-Month and 4-Year Old PDGMS Balance and PDGMS-2 Stationary Subscale Raw Scores

	4-year old PDGMS balance subscale	4-year old PDGMS-2 stationary subscale
21-OB	.31**	.25*
21-DS	.20	.10

Note. 21-DS = 21-month old derived PDGMS-2 stationary subscale; 21-OB = 21-month old PDGMS balance subscale.

*p ≤ .05, two-tailed. **p ≤ .01, two-tailed.

Table 5.3.

Descriptive Statistics of 21-Month and 4-Year Old PDGMS Balance and PDGMS-2 Stationary Subscale Raw Scores

	Mean	Standard Deviation	Range	Minimum	Maximum
21-OB	30.29	1.81	9	27	36
21-DS	34.21	.61	3	34	37
4-year old PDGMS balance subscale	50.90	5.18	26	37	63
4-year old PDGMS-2 stationary subscale	49.01	4.25	18	39	57

Note: 21-DS = 21-month old derived PDGMS-2 stationary subscale; 21-OB = 21-month old PDGMS balance subscale.

Objective 2

The relationship between PDGMS-2 stationary subscale raw scores of 4-year old children and five factors was evaluated: 1) 21-DS raw scores, 2) height at 4 years, 3) weight at 4 years, 4) head circumference at 4 years, and 5) gender. The correlation matrix is in Table 5.4. All four factors included in the correlation matrix had low correlation coefficients (r = .02 to .10) with 4-year old PDGMS-2 stationary subscale raw scores.

A stepwise regression predicting 4-year old PDGMS-2 stationary subscale raw scores from the five factors was not possible because the model would not enter any of the predictor variables due to each variable's low correlation with 4-year old PDGMS-2 stationary subscale raw scores. A multiple regression analysis was completed entering all the variables simultaneously (Table 5.5). Less than 3% of the variance in 4-year old PDGMS-2 stationary subscale raw scores was accounted for using these predictor variables. Another regression was completed adding the 4-year old physical measure ratios (weight/height, head circumference/height, and weight/head circumference) to the regression model (Table 5.5), and the variance accounted for increased to 3.7%.

Table 5.4.

Correlation Matrix of 4-Year Old PDGMS-2 Stationary Subscale Raw Scores and Four Variables

	4-year old PDGMS-2 stationary subscale raw scores	21-DS raw scores	Height (cm)	Weight (kg)	Head circumference (cm)
4-year old PDGMS-2 stationary subscale raw scores	—	.10	.05	.05	.02
21-DS raw scores		—	-.13	.14	-.11
Height (cm)			—	.75[τ]	.37[τ]
Weight (kg)				—	.47[τ]
Head circumference (cm)					—

Note: 21-DS = 21-month old derived PDGMS-2 stationary subscale.

[τ] $p \leq .001$, one-tailed.

Table 5.5.

Summary of Multiple Regression Analysis for Variables Predicting 4-Year Old PDGMS-2 Stationary Subscale Raw Scores

Variable	*B*	*SE B*	β
Model 1			
21-DS raw scores	.71	.90	.10
4-year old height	.06	.19	.06
4-year old weight	-.04	.38	-.02
4-year old head circumference	.13	.42	.04
Gender	-1.01	1.02	-.12
Model 2			
21-DS raw scores	.59	.96	.09
4-year old height	1.87	4.34	1.87
4-year old weight	6.13	9.22	3.30
4-year old head circumference	-5.41	9.08	-1.77
Gender	-1.29	1.10	-.15
4-year old weight/ height ratio	-4.29	971.44	-.02
4-year old head circumference/ height ratio	365.13	672.78	1.78
4-year old weight/ head circumference ratio	-313.31	629.32	-3.05

Note: 21-DS = 21-month old derived PDGMS-2 stationary subscale.

$R^2 = .03$ for Model 1 and $R^2 = .04$ for Model 2.

Objective 3

The 4-year old PDGMS-2 stationary subscale percentile ranks and the 4-year old PDGMS balance subscale percentile ranks were used as gold standards to evaluate the predictive ability of the PDGMS using the 21-OB percentile ranks (Table 5.6). The 16th percentile had been the cut-off level identified a priori to classify children's scores as suspicious or normal at 21-months old. However, no child scored below the 16th percentile rank on the 21-OB. For this reason, both the 16th and 25th percentile ranks were used as cut-off points at 21-months old. The 16th percentile cut-off point continued to be used as the gold standard at 4-years old on both versions of the Peabody (Figures 5.5, 5.6, 5.7, & 5.8) because the 16th percentile cut-off is used clinically to identify children considered suspicious in their motor development.

The ratios used to calculate the predictive values from the percentile ranks of the children were sensitivity [a/(a+c)], specificity [d/(d+b)], positive predictive value [a/(a+b)], and negative predictive value [d/(d+c)] (Figure 5.5). Sensitivity refers to the proportion of children that fell below the balance subscale cut-off at 4-years old that were identified below the cut-off at 21-months old. Specificity refers to the proportion of children classified in the normal category at 4-years old that were identified in the normal category at 21-months old. Positive predictive value refers to the proportion of children that scored below the cut-off at 21-months old whose scores remained below the cut-off at 4-years old. Negative predictive value represents the proportion of children with scores in the normal category at 21-months old who also had scores in the normal category at 4 years of age (Portney & Watkins, 2000).

The prevalence rate of children below the cut-off used at 4-years old differed depending on the test used. The different versions of the Peabody, PDGMS and PDGMS-2, identified different proportions of children that fell below the 16^{th} percentile cut-off. The PDGMS balance subscale identified 41 children (53%) and the PDGMS-2 stationary subscale identified 20 children (26%).

The negative predictive values were better with the PDGMS-2 stationary subscale (77%) than the PDGMS balance subscale (49%) (25^{th} percentile cut-off at 21-months old and 16^{th} percentile cut-off at 4-years old). The sensitivity of the PDGMS balance subscale (7%) and the PDGMS-2 stationary subscale (15%) were both very low when the 16^{th} percentile cut-off was used at 4-years of age. The specificity was 100% for both the PDGMS and the PDGMS-2 because the same three children that were identified as scoring below the 25^{th} percentile at 21-months old on the PDGMS balance subscale scored below the 16^{th} percentile at 4-years old on both tests. The specificity was not computable when the 16^{th} percentile cut-off point at 21-months old was used because no children were identified.

	4-year old Stationary ≤ 16th Percentile Rank (PDGMS-2)	4-year old Stationary >16th Percentile Rank (PDGMS-2)
21-month old Balance ≤ 16th Percentile Rank (PDGMS)	0 (a)	0 (b)
21-month old Balance > 16th Percentile Rank (PDGMS)	20 (c)	58 (d)

Figure 5.5. Classification of preschool children with the 4-year old PDGMS-2 stationary subscale as the gold standard, using the 16th percentile cut-off at both 21-months and 4-years old.

	4-year old Balance ≤ 16th Percentile Rank (PDGMS)	4-year old Balance >16th Percentile Rank (PDGMS)
21-month old Balance ≤ 16th Percentile Rank (PDGMS)	0 (a)	0 (b)
21-month old Balance > 16th Percentile Rank (PDGMS)	41 (c)	37 (d)

Figure 5.6. Classification of preschool children with the 4-year old PDGMS balance subscale as the gold standard, using the 16th percentile cut-off at both 21-months and 4-years old.

	4-year old Stationary ≤ 16^{th} Percentile Rank (PDGMS-2)	4-year old Stationary >16^{th} Percentile Rank (PDGMS-2)
21-month old Balance ≤ 25^{th} Percentile Rank (PDGMS)	3 a	0 b
21-month old Balance >25^{th} Percentile Rank (PDGMS)	c 17	d 58

Figure 5.7. Classification of preschool children with the 4-year old PDGMS-2 stationary subscale as the gold standard, using the 25^{th} percentile cut-off at 21-months old and 16^{th} percentile cut-off at 4-years old.

	4-year old Balance ≤ 16th Percentile Rank (PDGMS)	4-year old Balance > 16th Percentile Rank (PDGMS)
21-month old Balance ≤ 25th Percentile Rank (PDGMS)	3 (a)	0 (b)
21-month old Balance >25th Percentile Rank (PDGMS)	38 (c)	37 (d)

Figure 5.8. Classification of preschool children with the 4-year old PDGMS balance subscale as the gold standard, using the 25th percentile cut-off at 21-months old and 16th percentile cut-off at 4-years old.

Table 5.6.

Sensitivity, Specificity, Positive Predictive Values and Negative Predictive Values for the PDGMS and PDGMS-2

Test	Cut-off	Sensitivity	Specificity	+PV	-PV
PDGMS-2 stationary subscale	≤ 16th %ile at 21-months ≤ 16th %ile at 4-years	0% (0/20)	100% (58/58)	Error (0/0)	74% (58/78)
PDGMS balance subscale	≤ 16th %ile at 21-months ≤ 16th %ile at 4-years	0% (0/41)	100% (37/37)	Error (0/0)	47% (37/78)
PDGMS-2 stationary subscale	≤ 25th %ile at 21-months ≤ 16th %ile at 4-years	15% (3/20)	100% (58/58)	100% (3/3)	77% (58/75)
PDGMS balance subscale	≤ 25th %ile at 21-months ≤ 16th %ile at 4-years	7% (3/41)	100% (37/37)	100% (3/3)	49% (37/75)

<u>Objective 4</u>

The associations among 21-month and 4-year old raw scores for all subscales of the PDGMS (balance, nonlocomotor, locomotor, receipt and propulsion) were explored. The associations were calculated using Pearson correlation coefficients (Table 5.7) to determine if the balance subscale scores had lower correlation coefficients than the other subscales. Significant differences between pairs of subscale correlation coefficients were evaluated using Fisher's *z'* transformation of *r* (Cohen & Cohen, 1983). The relationship between 21-month and 4-year old balance subscale raw scores was not significantly different from all three of the other subscales. Therefore, there is not enough evidence to conclude that children's balance subscale scores are more variable than the other gross motor subscale scores at 4-years old.

Table 5.7.

Correlation between PDGMS Subscale Raw Scores at 21-Months and 4-Years Old

	Balance (4 years)	Nonlocomotor (4 years)	Locomotor (4 years)	Receipt/Propulsion (4 years)
Balance (21 months)	.31**			
Nonlocomotor (21 months)		.05		
Locomotor (21 months)			.37***	
Receipt/ Propulsion (21 months)				.37***

**$p \leq .01$, two-tailed. ***$p \leq .001$, two-tailed.

CHAPTER VI

DISCUSSION

Relationship between Peabody Balance Scores

The purpose of this study was to explore the relationship between the 21-month and 4-year old balance scores obtained by the same typically developing children on the PDGMS and PDGMS-2. The expectation of an association between earlier and later balance scores is dependent on the theory used to explain motor development. Neuromaturation theory suggests that a relationship between earlier and later balance scores would occur because development is linear. DST suggests motor development is nonlinear, and a relationship between earlier and later balance scores would not be expected. The balance scores of the children were assessed using two versions of a frequently used clinical assessment tool, the original and revised PDGMS. The predictive abilities of the balance subscale were explored to determine the long-term implication of a child receiving a low score on the balance subscale at 21 months of age. The relationships between physical measures and balance scores of children at 4-years old were also explored.

At first glance, it would appear that the results of this study support DST. The results of this study suggest that both the balance scores obtained by children at 21-months old and the physical measures of the children at 4-years old have poor relationships with 4-year old balance scores. The association between 21-month and 4-year old balance scores was low using both versions of the 21-month assessments (21-OB, 21-DS) and 4-year assessments (4-year old PDGMS balance subscale, 4-year old PDGMS-2 stationary subscale). The highest correlation coefficient (r = .31) was obtained for the relationship between 21-OB and 4-year old PDGMS balance subscale raw scores. These two subscale scores demonstrated the greatest range of scores at each assessment age of the four scores evaluated, but the ranges were still small. The findings also suggest that 21-OB raw scores do not predict 4-year old PDGMS balance or 4-year old PDGMS-2 stationary subscale raw scores.

The results of this study can be attributed to two factors; measurement, developmental theory, or both. Characteristics of the PDGMS and PDGMS-2, their administration, and characteristics of the sample all contribute to measurement issues that could have influenced the results. Alternatively, the nature of development of balance skills could be truly nonlinear, which could have produced the observed results. The results could also represent an interaction of both measurement and developmental issues. Unfortunately, the characteristics of the instrument and the sample preclude any conclusions regarding the influence of development on balance scores, or the interaction of the instrument with development. The restricted range of scores across all balance and stationary subscales can be attributed to testing and child factors. Testing factors include the number of balance/stationary items administered for each age category, the reliability of the raters, and the time period between testing. The child factors include the restricted age range of the participants and the fact that all children were typically developing. Test factors and child factors are discussed in this chapter.

Testing Factors

Test raw scores for both the PDGMS and PDGMS-2 required the calculation of basal and ceiling levels. The basal level for the PDGMS is "the first level at which the child scores 2 on all items or the level below the first level at which the child scores 0 or

1 on only one item and 2 on the remaining items" (Folio & Fewell, 1983, p.18). The ceiling level for the PDGMS is "the level at which the child scores 0 or 1 on all items or scores 2 on only one item and 0 or 1 on the remaining items" (Folio & Fewell, 1983, p.19). The basal level using the PDGMS-2 is the level at which the child obtains a score of 2 on three items in a row. The ceiling level is the level at which the child scores 0 on three items in a row (Folio & Fewell, 2000).

On the 21-DS, all children received full credit for the first 17 items of the stationary subscale contributing 34 points to each child's raw score. The children's scores varied on only 2 items on the 21-DS; standing on one foot for 1 second (item 96) and standing on one foot for 3 seconds (item 107). One child scored 3 on these items (total raw score = 37), five children scored 2 (total raw score = 36), and three children scored 1 (total raw score = 35). The rest of the children received a 0 on both of these items resulting in a total raw score of 34. Therefore the majority of children (n = 69) had a total raw score of 34 on the 21-DS, and the range of scores for the 21-DS was constrained to three points (range = 34-37).

All children received full credit for the first 12 items on the 21-OB, contributing 24 points to each child's raw score. The children's scores varied on five items: standing with one foot on the line and attempts to position the other foot (item 79), walking 10 steps on a balance beam with one foot on and one foot off (item 86), standing on one foot for 1 second (item 96), walking on tiptoes for five steps with hands on hips (item 97), and walking three steps forward on a balance beam (item 99). One child scored 10 in total on these five items, one child scored 9, three children scored 8, three children scored 7, five children scored 6, twelve children scored 5, twenty-nine children scored 4, sixteen children scored 3, five children scored 2, and three children scored 1. All children received credit for stooping and returning to standing (item 82). Only one child received credit for standing on one foot for 3 seconds (item 107). None of the children received credit for walking eight feet on a line on tiptoes (item 108). The range of scores for the 21-OB was greater than the range of scores for the 21-DS with a range of nine points (range = 27-36).

Both the 4-year old PDGMS balance subscale (range = 26) and PDGMS-2 stationary subscale (range = 18) had greater ranges of raw scores then either the 21-OB or 21-DS. The greater range and variability of scores at 4-years old was a result of more items administered and credited to the children. The relationship between scores at 21-months and 4-years old was highest ($r = .31$) when the subscales with the greatest variability at each assessment age were used (21-OB and 4-year old PDGMS balance subscale). The restricted range of scores, especially at 21-months old, adversely affected the absolute value of the correlation coefficients obtained.

The restricted range of scores could be attributed to the insufficient number of items at the 21-month old skill level. The PDGMS balance subscale has only two items at the 18- to 23-month old level. One of the items is easily achieved by 21-month old children, as evidenced by a score of 2 on stooping (item 82) for all children in our study. The other item in this age category, walking on a balance beam (item 86), demands a higher level of skill. Only 53 children received a score of 2 on item 86. The balance subscale doesn't include an adequate range of skills to facilitate discrimination of balance abilities among children. The addition of other items at this age category could assist in discriminating in this age group. Some examples of items include: half-kneeling for 3-5 seconds, tandem standing for 1-2 seconds, standing sideways on a balance beam for 3-5 seconds, and standing on one foot for 1 second with hands out to the side. The PDGMS-2 stationary subscale does not have any items for the 21-month old skill level; it has an item at the 13-month old level (item 19) and then an item at the 31- to 32-month old skill level (item 20). This lack of items between the 13-month and 31-month old skill levels, not only at the 21-month old skill level, would make detecting differences between children or tracking change over time difficult. The PDGMS balance subscale has two items at the 48-month old skill level. Again, one of the items (item 131), which required walking on a balance beam, was easily achieved by the children, with 71 of the children credited with a score of 2. Item 136, which required standing on tiptoes, was fully credited to only 16 children, 22 children received a score of 1, and 40 children did not receive any credit. The PDGMS-2 stationary subscale does not have any items at the 48-month old skill level, it has one item at the 45-46 month old skill level (item 23) and one item at the 51-52 month old skill level (item 24). The tests could be strengthened by the addition of items at the 21-month and 4-year old skills level. Users of the test should be aware of the paucity of items at 21 months of age.

It could be argued that the poor inter-rater reliability among therapists at both assessment ages contributed to the low correlation coefficients obtained. However, consistency among therapists' scoring procedures was evaluated throughout both data collection periods. During the 21-month assessments the inter-rater reliability was measured on average at every 10th assessment and during the 4-year assessments the inter-rater reliability was measured on average at every 20th assessment. The therapist's score was compared to that of another therapist observing the assessment. At the 21-

month old assessments, examination of inter-rater reliability yielded an intra-class correlation coefficient of .99. At the 4-year old assessments the intra-class correlation coefficient was .86. Both of these coefficients indicate strong agreement between raters when administering the tests.

The time between testing periods may also affect the strength of the association between earlier and later scores. It has been stated that the time between assessments affects the relationship of the scores, with shorter intervals between testing periods resulting in higher correlation coefficients (Kopp & McCall, 1982). In a recent study, the association between the Test of Infant Motor Performance (TIMP) (Campbell, Kolobe Osten, Lenke, & Girolami, 1995) at 90 days and the Alberta Infant Motor Scale (AIMS) (Piper & Darrah, 1994) at 6-months old ($r = .67$) was higher than the association between the TIMP at 30 days and the AIMS at 6-months ($r = .46$) or at 12-months old ($r = .32$) (Campbell et al., 2002). Similarly, Palisano (1986) reported that the predictive validity of age-equivalent scores of the PDGMS for healthy full-term infants was better between 15-months and 18-months old ($r = .85$) than between 12-months and 18-months old ($r = .60$). A study of the predictive ability of the Bayley Infant Neurodevelopmental Screener (BINS) (Aylward, 1995) for high-risk infants reported lower correlation coefficients as the time span between testing increased. The association between BINS 6-month and 24-month old scores ($r = .62$) was less than the association between the 6-month and 12-month old scores ($r = .72$) (Aylward & Verhulst, 2000). Thus the poor association between 21-month and 4-year old balance scores may be partially attributed to the 27-month interval between assessments of the children in our study.

Child Factors

The narrow age range of the children included in the study further restricted the number of balance items administered at 21-months and 4-years old. The children were assessed within 2 weeks of reaching 21-months old (mean = 21.13, *SD* = 0.16) and 4-years old (mean = 48.17, *SD* = 0.34). This narrow of an age range for assessing children is not typical for clinical testing, and may have contributed to the extreme homogeneity of the children's scores.

A wider age range of children sampled at both ages may have resulted in more variability in the scores of the children, and may have provided more opportunity to yield a stronger association between the two major age groupings (21-months and 4-years old). Previous studies that have included the PDGMS for the assessment of the motor abilities of children have often tested children spanning a wider age range; ranging from 12 to 48 months (Doty, McEwen, Parker, & Laskin, 1999; Palisano et al., 1995; Pless, Carlsson, Sundelin, & Persson, 2002; Provost et al., 2000; Schmidt et al., 1993). For example, 2-year old children included in a study ranged in age from 24-months to 35-months old (Provost et al., 2000). This is a sharp contrast to the 21-month old assessment ages that spanned 5 weeks (20-months, 2-weeks old to 21-months, 3 weeks old) and the 4-year old assessment ages that spanned 6 weeks (47-months, 3-weeks old to 49-months, 1-week old) in our study. The narrow age range of the children in our study limited the range of balance scores obtained.

The young ages of the children in this study may also have influenced the poor relationship observed between the two testing sessions. Studies of cognitive testing have demonstrated that tests of intelligence administered during the first 2 years of life do not predict scores of intelligence in later childhood. Stronger associations between test scores are often more evident as the age of the children being tested increases (Kopp & McCall, 1982). Intelligence tests administered at school age have better predictive value then intelligence tests administered during the preschool years (Moffitt, Caspi, Harkness, & Silva, 1993). For example, the Bayley Mental Scale has poor predictive ability at 4-months old to detect cognitive delays that present at 3- to 8- years old (Harris & Langkamp, 1994). This may be due to the fact children's scores on tests become more stable as the children get older. Motor development may be similar to cognitive development, with a child's gross motor scores being less stable before 2 years old. The results of a larger study, including the sample for this study, reported scores on the PDMS on the same children at 9, 11, 13, 15, and 21 months of age. Their PDMS scores did not remain stable across time for the majority of the infants (Darrah et al., 2003).

The children in this study were all typically developing, which may also have contributed to the homogeneity of balance scores. A sample including children with motor disabilities would have resulted in more between–child variability in balance scores because the children with motor disabilities would likely have scores much lower on all versions of the balance subscale. Prediction of future outcome is reported to improve as the severity of the condition increases. McCall and Carriger (1993) reported higher predictions to later IQ with a sample of infants born pre-term or with neurological impairments.

In summary, item characteristics of the PDGMS and PDGMS-2 at 21-months old, the time between test administration, the narrow age range of the children at 21-months and 4-years old, the young ages of the children, and the homogeneity of abilities of the group prevent us from making any strong conclusions about the influence of development on balance scores.

Predictive Validity of Peabody Balance and Stationary Subscales

The predictive validity of the PDGMS balance subscale scores obtained at 21 months of age was poor in this study with high specificity, but very low sensitivity values. The prevalence rates of scores below the identified cut-off at 4-years of age were also unexpectedly high. The 16^{th} percentile cut-off is typically used clinically as a cut-off differentiating between normal and suspicious/delayed motor development and was identified a priori as the cut-off for both 21-month and 4-year old balance scores. However, because no children scored below the 16^{th} percentile cut-off at 21-months old, both the 16^{th} and 25^{th} percentiles were used as cut-off points for the 21-month old balance scores. The 16^{th} percentile was retained as the cut-off point at 4 years of age because it is used clinically to classify children as having suspicious/delayed gross motor development.

Specificity was excellent (100%) in our study. All of the children that were classified above the 16^{th} percentile at 4-years old on both the PDGMS balance subscale ($n = 58$) and the PDGMS-2 stationary subscale ($n = 37$) were also identified above both the 16^{th} and 25^{th} percentile cut-off points at 21-months old. Sensitivity was unacceptable using both measures. Only three children out of 41 children who were identified below the 16^{th} percentile at 4 years of age on the PDGMS balance subscale were identified below the 25^{th} percentile at 21 months of age on the PDGMS balance subscale. On the PDGMS-2 stationary subscale, only three out of 20 children identified as below the 16^{th}

percentile at 4 years of age were identified as scoring below the 25th percentile cut-off point at 21-months of age on the PDGMS balance subscale. The three children identified were the same for both the PDGMS balance and PDGMS-2 stationary subscales. Their total gross motor scores were examined at 21-months old on the PDGMS and at 4-years old on both versions of the test. Two of these three children had total PDMGS percentile ranks below the 16th percentile at 21-months old (14th percentile and 2nd percentile). All three of the children ranked at the 4th percentile on the total PDGMS at 4-years old. Only one of these children ranked below the 16th percentile at 4-years old on the total PDGMS-2 (5th percentile).

Screening tests are recommended to have no less than 80% sensitivity and specificity when identifying children with delays (Meisels, 1989). The consistently low sensitivity of the PDGMS balance subscale and PDGMS-2 stationary subscale in our study suggests that children would be under-identified at 21-months old as being at risk of having a delay in balance development at 4-years old. It is concerning that no children scored below the 16th percentile at 21 months of age, suggesting balance delays are not as easily detected by the PDGMS balance subscale at 21-months old. However, the total PDGMS did identify eight children with scores below the 16th percentile. This suggests that total gross motor scores should be included when discussing a child's performance on the subscales of a test.

Prevalence rates were high on both the PDGMS balance subscale (53%) and the PDGMS-2 stationary subscale (26%) for classification of children below the 16th percentile at 4-years old. Considering the children were typically developing, the results would suggest that when either the PDGMS balance subscale or PDGMS-2 stationary subscale is used as a gold standard, too many children are identified as scoring below the 16^{th} percentile at 4-years old. The prevalence rates in our study are high compared to the general population. The prevalence rate is 5% to 10% of all children having developmental motor disabilities, or 8% to 10% of all children having developmental coordination disorder in the general population (Barnhart, Davenport, Epps, & Nordquist, 2003; Hamilton, 2002; Macintyre, 2000; Sellers, 1995; Shevell et al., 2003). It is interesting to note the total gross motor scores of the children that scored below the 16^{th} percentile in this study. Of the 41 children identified by the PDMGS balance subscale, 40 of the children had PDGMS total gross motor scores below the 16^{th} percentile. The number was less using the PDGMS-2, with only 9 of the 20 children scoring below the 16^{th} percentile on both the stationary subscale and the total gross motor scale. The high prevalence rate presents a dilemma because one must question the validity of the 4-year old test scores as 'gold standards'. It is difficult to determine which age level, 21-months or 4-years, is most consistent with long-term abilities. This is a question that will need to be further evaluated as the children get older. The fact that these children will be followed to 7 years of age represents an opportunity to further investigate the relationship of scores at 21-months and 4-years old with outcomes at later ages.

Clinically, therapists have expressed concern about the PDGMS-2 under-identifying children in comparison to the PDGMS. Our results suggest that at 4-years the PDGMS identifies an unacceptable number of children below the 16^{th} percentile rank. The PDGMS-2 appears to do a better job of classifying children than the PDGMS, although it too identifies more children below the 16^{th} percentile than would be expected based on published rates of motor problems.

Physical Measures and the PDGMS-2 Stationary Subscale

The relationships between physical measures and the relationships between the physical measures and PDGMS-2 stationary subscale raw scores at 4-years old were also explored. The relationships between the 4-year old physical measures were fair to good. The good association between height and weight (r = .75) was consistent with a previous study of the relationship between height and weight of school-aged children (r = .85) (Habib & Westcott, 1998). In our study, 4-year old weight had the greatest variability, followed by height and head circumference. Each of the relationships between 4-year old physical measures and 4-year old PDGMS-2 stationary subscale raw scores had low correlation coefficients (r = .02 to .05). This result from our study differed from a study of balance measured with the Functional Reach Test (FRT). The FRT scores of the 5- to 13-year old typically developing children had a moderate association with height (r = .53) and weight (r = .53) (Habib & Westcott, 1998). One explanation for the higher correlation coefficients in this study is the wider age range. Children's ages ranged from 5- to 13-years old and thus captured more variability in FRT scores and physical measures. The low association between head circumference and 4-year old PDGMS-2 stationary subscale scores (r = .02) in our study is similar to that of the relationship between AIMS total scores, another measure of gross motor abilities, and head size of 15-month old children. There was a low association (r = .08) between the head size and total score on the AIMS for 15-month old typically developing children (Bartlett, 1998).

The relationships between the balance scores and physical measure ratios of 4-year old typically developing children were also evaluated. The 4-year old ratio for weight/height (0.16) was the same as the ratio for the 50^{th} percentile of weight/height for

4-year olds obtained from growth charts (Centers for Disease Control & Prevention, 2000a, Centers for Disease Control & Prevention, 2000b). The height and head circumference measurements of the 4-year old children in our study spanned a good range individually, but when these two measures were expressed in a ratio the values were very similar. The average head circumference/height ratio was 0.50 (*SD* = .02), suggesting a child's head circumference was half of his or her height.

The narrow age range may have limited the variability of the physical measures and physical measure ratios. Children within a narrow age range have similar physical variables, such as strength and limb proportions, that interact to produce similar patterns of movement and similar balance scores (Ulrich, 1997). Children at other ages may have different ratios. For example, during a growth spurt, the head circumference/height ratio may be very different and this change in ratio may affect balance abilities. Ecological task analysis (ETA) suggests that a critical proportion between two variables can influence motor abilities. The authors suggest that the head circumference/height ratio may have an influence on balance performance. This is one physical measure ratio that may need to be considered in the calculation of normative scores of development (Burton & Davis, 1996). A previous study of ball skills in children (5- to 14-years old) and adults (19- to 33-years old) revealed a critical proportion between hand size and ball size that influenced throwing styles. Children switched from a one-hand throw to a two-hand throw when the relative ball diameter (ball diameter/hand width) was between 1.00 and 1.25 (Burton et al., 1993). Just as the ball diameter/hand width ratio of a child affected the throwing pattern, the head circumference/height ratio of a child may affect the balance score. The value of the 4-year old head circumference/height ratio (.50) and its limited variability are interesting findings. The influence changes in this ratio may have on the balance scores were not captured by our study because of the homogeneity of ratio scores among the children. However a study including a wider age range of children or a group of children with typical and delayed development would be interesting and may reveal a relationship between physical measure ratios and balance scores. The homogeneity of the group of children was one limitation of the study.

Limitations of the Study

The generalizability of the results of this study is limited to a population of typically developing children; no inferences can be made of the scoring patterns of children with identified gross motor difficulties.

Clinical Implications

The results from this study have implications for physical therapy practice. First, our results confirm that subscale scores should be used with caution for assessment and intervention decision making. Anecdotally, clinicians use subscale scores on the PDGMS and PDGMS-2 to make assessment and intervention decisions. For example, if a child received a low score on the balance subscale, he or she may receive intervention services because the assumption is that the child's balance development is delayed. Our results at the 21-month and 4-year old assessments indicate a very poor ability to identify accurately at 21-months old those children who will score low on the PDGMS balance subscale or PDGMS-2 stationary subscale at 4-years old. The PDGMS balance and PDGMS-2 stationary subscales describe a child's current balance abilities, but the total gross motor quotient should be included when determining diagnosis and placement, as suggested by the authors of the PDGMS and PDGMS-2 (Folio & Fewell, 1983; Folio & Fewell, 2000). The gross motor quotient is a measure of a child's gross motor development, and is derived from the standard scores of the subtests; therefore it is more representative of many skills than just one subscale.

Second, there are implications on how clinicians interpret and use the Peabody results. Clinicians have expressed concern that the PDGMS-2 under-identifies children in comparison to the PDGMS. Our results suggest that the PDGMS actually over-identifies children with scores below the 16^{th} percentile cut-off, denoting a balance delay. The PDGMS prevalence rate (53%) of balance delays identified at 4-years old is greater than that expected in the general population (5 - 10%). The PDGMS-2 stationary subscale also over-identified balance delays at 4-years old, with a prevalence rate of 26%, therefore further study of the PDGMS-2's accuracy in identifying children is recommended. The poor relationship between 21-month and 4-year old scores suggests identification of a developmental delay is difficult with the administration of a one-time assessment. The very low sensitivity of the PDGMS balance subscale and the PDGMS-2 stationary subscale also suggests children who score below the 16^{th} percentile at 4-years old were not identified at 21-months old. Even if a developmental test had 80% sensitivity, a recommended sensitivity level, it would not detect 20% of children with developmental delays with a single test administration. Literature supports the concept of serial assessments, which may lead to earlier identification of delays and implementation of early intervention services (Bartlett, 2000; Meisels, 1989). Clinicians should be aware of the factors that influence correlation coefficients between measures at different ages when reviewing developmental literature.

Finally, the study's limitations have highlighted the importance of paying attention to child and testing characteristics when reading developmental literature about relationships. A study including children with differing motor abilities and a wide age range would result in high correlation coefficients. For example, the high concurrent validity (r = .97) between the gross motor sections of the Vulpe Assessment Battery for the Atypical Handicapped Child and the PDGMS may have been influenced by the sample that included children ranging from 23- to 70-months old with mild to severe motor impairments (Jain, Turner, & Worrel, 1994). Our study had a sample that included typically developing children within a narrow age range, factors that likely decreased the relationships between the variables.

Future research considerations

Future research should explore the association between physical measure ratios and the total PDGMS-2 raw scores and percentile ranks. Further exploration of the physical measure ratios, especially the head circumference/height ratio, amongst typically and non-typically developing children may provide information about a critical ratio children need to perform well on the PDGMS-2 at different ages. A wider age range of children should be included in future studies to allow for more variability in items and the potential revelation of associations between earlier and later PDGMS-2 total raw scores. The predictive abilities of the PDGMS-2 should be explored using the total gross motor scales rather than a subscale.

Summary

This study explored the relationship between the 21-month and 4-year old balance scores obtained by typically developing children on the PDGMS and PDGMS-2. This study also explored the relationships between physical measures and balance scores of children at 4-years old. Secondary data on 78 of the same children that participated in infant and preschool longitudinal studies was analyzed.

The low correlation and poor predictive ratios in our study were affected by some key factors. The characteristics of the PDGMS and PDGMS-2 led to a small range of balance scores, especially at 21-months old. The homogeneity of the participants further reduced the range of scores because the children were typically developing and spanned a very narrow age range. The time between testing periods and the young age of testing may have affected the results also. All of these factors should be considered when analyzing associations and predictive validity.

Conclusions

The results suggest 21-month old PDGMS balance scores are not predictive of 4-year old PDGMS balance or PDGMS-2 stationary scores. The PDGMS-2 stationary subscale score should be used in conjunction with clinical observations and the PDGMS-2 total gross motor score when assessing a child's balance abilities. In this study, the physical characteristics did not influence balance performance in the sample of children. Also, the exploration of relationships has revealed that test factors and child characteristics need to be examined carefully in studies evaluating relationships across time.

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Appendix A

Power Analysis

Two power analyses were performed because two types of statistics will be used. The Pearson correlation coefficients will be used to analyze objectives #2 and #4. Stepwise regression will be used to analyze objective #1. The power analysis for both correlation and regression are presented below.

Power Analysis for Correlation

Using a two-tailed test at $\alpha = .05$, a power and sample size table is used to calculate power (Portney and Watkins, 2000). With n = 78 and a correlation coefficient of .30, the power is 78%.

Power Analysis for Regression

Based on this study having 5 variables (k) and a sample size of 78 (n), degrees of freedom (df) is calculated as follows:

$$df = n - k - 1$$

$$= 78 - 5 - 1$$

$$= 72$$

If power is .80, k = 5 and df = 72, then $\lambda = 14$, as determined using a table of values of lambda (Portney and Watkins, 2000). Power analysis of regression is calculated as follows using a formula (Portney and Watkins, 2000):

$$\lambda = \frac{R^2}{1-R^2}(n)$$

$$14 = \frac{R^2}{1-R^2}(78)$$

$$14 - 14R^2 = R^2(78)$$

$$14 - 14R^2 = 78R^2$$

$$14 = 92R^2$$

$$R^2 = 14/92$$

$$R^2 = .1521$$

Given a sample size of 78, 5 variables, and 80% power, a R^2 of .15 ($\alpha = .05$) would be statistically significant.

Appendix B

Secondary Data Analysis Ethics Approval

Health Research Ethics Board

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UNIVERSITY OF ALBERTA HEALTH SCIENCES FACULTIES,
CAPITAL HEALTH AUTHORITY, AND CARITAS HEALTH GROUP

HEALTH RESEARCH ETHICS APPROVAL

Date: August 2003

Name of Applicant: Dr. Johanna Darrah & Ms. Julie Kowal

Organization: University of Alberta

Department: Physical Therapy

Project Title: **The Longitudinal Relationship of a Peabody Balance Scores Obtained by Children at 21 Months and 4 Years of Age**

The Health Research Ethics Board (HREB) has reviewed the protocol for this project and found it to be acceptable within the limitations of human experimentation. The HREB has also reviewed and approved the subject information letter and consent form, if applicable.

The approval for the study as presented is valid for one year. It may be extended following completion of the yearly report form, which will be sent to you in your renewal month. Any proposed changes to the study must be submitted to the Health Research Ethics Board for approval. Written notification must be sent to the HREB when the project is complete or terminated.

Glenn G. Griener

Dr. Glenn Griener
Acting Chair of the Health Research Ethics Board
(B: Health Research)

File number:
B-060803

University of Alberta

Capital Health

CARITAS HEALTH GROUP

Appendix C

PDGMS Response/Scoring Booklet
(Folio & Fewell, 1983)

Gross-Motor Scale

	Skill Categories A	B	C	D	E	
0-1 Month						
1. Aligning Head			___			
2. Aligning Head			___			
3. Rotating	___					
4. Rotating	___					
5. Aligning Head	___					
6. Crawling Movements	___					
7. Positioning Reflex: Asymmetrical Tonic Neck Reflex	___					
8. Thrusting Legs	___					
9. Turning to Back			___			
10. Thrusting Arms	___					
Cumulative Maximum	14	+	6			= 20
2-3 Months						
11. Extending Head			___			
12. Aligning Head			___			
13. Aligning Head			___			
14. Aligning Head			___			
15. Bearing Weight			___			
16. Extending Legs and Feet	___					
17. Walking Reflex	___					
18. Extending Trunk			___			
19. Aligning Head			___			
20. Kicking Legs	___					
Cumulative Maximum	20	+	20			= 40
4-5 Months						
21. Positioning: Symmetrical Posture		___				
22. Pedaling Action			___			
23. Rolling			___			
24. Extending Arm			___			
25. Extending Arms and Legs			___			
26. Propping on Extended Arms		___				
27. Aligning Head			___			
28. Sitting		___				
29. Flexing Legs			___			
30. Pulling to Sit			___			
Cumulative Maximum	20 +	6 +	34			= 60

Gross-Motor Scale continued

	Skill Categories					
	A	B	C	D	E	
6-7 Months						
31. Bearing Weight			____			
32. Protecting Reaction	____					
33. Sitting		____				
34. Rolling				____		
35. Pushing Up			____			
36. Lifting Head			____			
37. Flexing Body			____			
38. Pulling Forward				____		
39. Sitting		____				
40. Extending Arm			____			
Cumulative Maximum	22 +	10 +	44 +	4		= 80
8-9 Months						
41. Sitting		____				
42. Pivoting			____			
43. Crawling				____		
44. Creeping Position			____			
45. Rolling				____		
46. Raising Up			____			
47. Scooting				____		
48. Righting Reaction	____					
49. Raising Shoulders and Buttocks			____			
50. Bouncing			____			
Cumulative Maximum	24 +	12 +	54 +	10		= 100
10-11 Months						
51. Sitting		____				
52. Sitting Up			____			
53. Creeping				____		
54. Pivoting			____			
55. Cruising				____		
56. Lowering		____				
57. Standing			____			
58. Standing		____				
59. Stepping Movement			____			
60. Walking				____		
Cumulative Maximum	24 +	18 +	62 +	16		= 120

Gross-Motor Scale continued

	Skill Categories					
	A	B	C	D	E	
12-14 Months						
61. Creeping				____		
62. Kneeling		____				
63. Climbing Stairs				____		
64. Pivoting		____				
65. Standing and Moving Balance		____				
66. Walking				____		
67. Walking				____		
68. Rolling Ball					____	
69. Flinging Ball					____	
70. Creeping				____		
Cumulative Maximum	24 +	24 +	62 +	26 +	4	= 140
15-17 Months						
71. Creeping				____		
72. Walking				____		
73. Walking Up Stairs				____		
74. Walking				____		
75. Walking Backward				____		
76. Walking Down Stairs				____		
77. Kicking Ball					____	
78. Throwing Ball					____	
79. Standing		____				
80. Walking Sideways				____		
Cumulative Maximum	24 +	26 +	62 +	40 +	8	= 160
18-23 Months						
81. Standing Up			____			
82. Stooping		____				
83. Throwing Ball					____	
84. Running				____		
85. Kicking Ball					____	
86. Walking Balance Beam		____				
87. Jumping Down				____		
88. Walking Up Stairs				____		
89. Jumping Forward				____		
90. Jumping Up				____		
Cumulative Maximum	24 +	30 +	64 +	50 +	12	= 180

Gross-Motor Scale continued

	Skill Categories										
	A		B		C		D		E		
24-29 Months											
91. Walking Down Stairs							___				
92. Walking Up Stairs							___				
93. Jumping Down							___				
94. Throwing Ball									___		
95. Throwing Ball									___		
96. Standing on One Foot			___								
97. Walking on Tiptoes			___								
98. Walking Backward							___				
99. Walking Balance Beam			___								
100. Walking Circular							___				
Cumulative Maximum	24	+	36	+	64	+	60	+	16	=	200
30-35 Months											
101. Standing Up					___						
102. Walking Down Stairs							___				
103. Kicking Ball									___		
104. Catching Ball									___		
105. Jumping Hurdles							___				
106. Jumping Down							___				
107. Standing on One Foot			___								
108. Walking on Tiptoes			___								
109. Jumping Forward							___				
110. Hopping							___				
Cumulative Maximum	24	+	40	+	66	+	70	+	20	=	220
36-41 Months											
111. Riding Tricycle							___				
112. Bouncing Ball									___		
113. Walking Up Stairs							___				
114. Jumping Down							___				
115. Walking Down Stairs							___				
116. Catching Ball									___		
117. Standing on One Foot			___								
118. Skipping							___				
119. Hopping							___				
120. Jumping Forward							___				
Cumulative Maximum	24	+	42	+	66	+	84	+	24	=	240

Gross-Motor Scale continued

	Skill Categories A	B	C	D	E	
42-47 Months						
121. Standing on Tiptoes		____				
122. Throwing Ball					____	
123. Throwing Ball					____	
124. Catching Ball					____	
125. Bouncing Ball					____	
126. Throwing Ball					____	
127. Jumping Forward				____		
128. Standing on One Foot		____				
129. Walking Backward		____				
130. Hopping				____		
Cumulative Maximum	24 +	48 +	66 +	88 +	34	= 260
48-53 Months						
131. Walking Balance Beam		____				
132. Running				____		
133. Jumping Up			____			
134. Jumping Down				____		
135. Throwing Ball					____	
136. Standing on Tiptoes		____				
137. Jumping Forward				____		
138. Jumping Forward				____		
139. Rolling Forward				____		
140. Sit-Ups			____			
Cumulative Maximum	24 +	52 +	70 +	98 +	36	= 280
54-59 Months						
141. Turning Jump			____			
142. Walking Balance Beam		____				
143. Walking Balance Beam		____				
144. Skipping				____		
145. Catching Ball					____	
146. Jumping Sideways			____			
147. Jumping Forward				____		
148. Standing on One Foot		____				
149. Rolling Forward				____		
150. Throwing Ball					____	
Cumulative Maximum	24 +	58 +	74 +	104 +	40	= 300

Gross-Motor Scale continued

			Skill Categories			
	A	B	C	D	E	
60-71 Months						
151. Walking on Tiptoes		____				
152. Jumping Hurdles				____		
153. Catching Ball					____	
154. Walking Balance Beam		____				
155. Galloping				____		
156. Hopping Speed				____		
157. Push-Ups			____			
158. Kicking Ball					____	
159. Skipping				____		
160. Sit-Ups			____			
Cumulative Maximum	24 +	62 +	78 +	112 +	44 =	320
72-83 Months						
161. Walking Balance Beam		____				
162. Kicking Ball					____	
163. Kicking Ball					____	
164. Catching Ball					____	
165. Standing Agility			____			
166. Running Speed				____		
167. Rolling Forward				____		
168. Standing on One Foot		____				
169. Jumping Up			____			
170. Push-Ups			____			
Cumulative Maximum	24 +	66 +	84 +	116 +	50 =	340

Appendix D

PDGMS-2 Examiner Record Booklet
Stationary Subscale Items
(Folio & Fewell, 2000)

Item #	Age in Months	Item NAME, Position, and Description	Score Criteria	Administration 1	2	3	4
Stationary							
1 Start: 1-2 months	0	ROTATING HEAD *(Lying on stomach, head turned to side with cheek resting on surface; examiner out of eyesight)* Shake rattle 3 times behind child's head. Repeat procedure with opposite cheek resting on surface.	2 Lifts and turns head so opposite cheek touches surface (both sides) 1 Lifts and turns head so opposite cheek touches surface (1 side only) 0 Head remains as positioned				
2	0	ALIGNING TRUNK *(Sitting, facing you)* Support child in sitting position by holding his or her wrists and arms. Observe position of child's back.	2 Holds back in rounded position for 3 seconds 1 Holds back in rounded position for 1–2 seconds 0 Arches back immediately				
3	1	ALIGNING HEAD—Front *(Sitting, head hanging forward, back to you)* With hands around trunk, support child in sitting position. Observe head alignment in relation to trunk.	2 Holds head so that a 45-degree angle (or greater) exists between chin and chest 1 Holds head up slightly from chest 0 Chin touches chest				
4	1	ALIGNING HEAD—Back *(Lying on back, pulled to sitting)* Grasp child's hands and wrists and gently pull him or her to a sitting position. Observe head alignment during movement cycle and head position at end of cycle.	2 Holds head so that a 45-degree angle (or greater) exists between back of head and back 1 Holds head up slightly from back 0 Head touches back				
5 Start: 3 months	2	ALIGNING HEAD *(Lying on back, pulled to sitting)* Grasp child's hands and wrists and gently pull to a sitting position. Observe head alignment during movement cycle and head position at end of cycle.	2 Holds head in midline through 75%–100% of movement cycle 1 Holds head in midline through 50%–74% of movement cycle 0 Holds head in midline for less than 50% of cycle				
6	2	EXTENDING HEAD *(Held in a suspended vertical position with head toward ceiling, feet toward floor)* Pick child up (facing you) with your hands around trunk. Observe head alignment.	2 Raises head at midline and holds it in alignment for 3 seconds 1 Raises head at midline and holds it in alignment for 1–2 seconds 0 Head remains extended backward or flexed forward				
7 Start: 4-5 months	2	ALIGNING HEAD *(Held at shoulder)* Hold child at your shoulder with one hand under buttocks and other on child's back. (Head is not supported.) Gently bounce child up and down 3 times.	2 Holds head in midline for 2–3 bounces 1 Holds head in midline for 1 bounce 0 Fails to hold head in midline on each bounce				
8	3	ALIGNING HEAD *(Held in suspended vertical position with head toward ceiling, feet toward floor)* Pick child up (facing you) with your hands around trunk. Slowly tilt child 45 degrees to left of midline. Without pausing, return to midline and tilt 45 degrees to right. Return to midline. Observe alignment of child's head throughout cycle. (Count 4 seconds per segment of movement cycle: left, midline, right, midline.)	2 Holds head in alignment for 75%–100% of movement cycle 1 Holds head in alignment for 50%–74% of movement cycle 0 Holds head in alignment for less than 50% of cycle				
9	3	STABILIZING TRUNK *(Sitting)* Support child in sitting position (side toward you) by holding his or her hips. Child's hands can be placed on surface for additional support.	2 Holds trunk off legs in a 30-degree angle for 5 seconds 1 Holds trunk off legs in less than a 30-degree angle for 5 seconds 0 Trunk remains in contact with legs				

Item #	Age in Months	Item NAME, Position, and Description	Score Criteria	Administration 1	2	3	4
10 Start: 6 months	4	ALIGNING HEAD *(Sitting, supported with pillows around hips)* Dangle **toy on a string** 12 in. in front of child. Slowly move toy in 180-degree arc, from in front of child to his or her left side, back to front, and then to right side. (Count 4 seconds per segment of movement cycle: left, front, right, front.)	2 Holds head aligned for 8 seconds while rotating head to follow toy 1 Holds head aligned for 4–7 seconds while rotating head to follow toy 0 Holds head aligned for less than 4 seconds				
11	5	SITTING Place child in sitting position, hands on surface beside knees. When balance is secure, release child.	2 Maintains balance for 8 seconds 1 Maintains balance for 3–7 seconds 0 Maintains balance for less than 3 seconds				
12 Start: 7-9 months	6	SITTING/REACHING *(Sitting, pillows supporting hips)* Attract child's attention to **toy on a string** suspended at midline 12 in. in front of child's chest.	2 Maintains balance for 8 seconds while extending arms and hands to grasp toy 1 Maintains balance for 5–7 seconds while extending arms and hands to grasp toy 0 Maintains balance for less than 5 seconds				
13	6	PULLING TO SIT *(Lying on back, feet toward you)* Hold index fingers out, touching child's hands, if necessary, to get child to grasp them. Once fingers are grasped, say, "Get up." Pull your hands back so child's arms become straight.	2 Pulls up to sitting position 1 Pulls up 45–90 degrees from the surface 0 Pulls up less than 45 degrees or remains lying on surface				
14 Start: 10-11 months	6	SITTING Place child in sitting position and release your support.	2 Sits unsupported for 60 seconds 1 Sits unsupported for 30–59 seconds 0 Sits for less than 30 seconds				
15	7	SITTING WITH TOY Place child in sitting position and release your support. Place **toy** 12 in. in front of child. Say, "Get the toy."	2 Retrieves toy, returns to upright sitting, and maintains balance for 30 seconds 1 Retrieves toy, returns to upright sitting, and maintains balance for 15–29 seconds 0 Fails to retrieve toy, return to upright sitting, or maintain balance for 15 seconds				
16 Start: 12-15 months	9	SITTING Place child in sitting position and release your support. Give **toy** to child and say, "Play with the toy."	2 Maintains balance for 60 seconds while manipulating toy 1 Maintains balance for 30–59 seconds while manipulating toy 0 Maintains balance for less than 30 seconds				
17	10	RAISING TO SIT *(Lying on back)* Place child on back on floor. Attract child's attention to **toy** and then place it on chair where child can see it. Say, "Get the toy."	2 Pulls up to sitting position, using chair for support 1 Grasps chair and rotates body in effort to raise up 0 Remains lying on floor				
18	10	SITTING UP *(Lying on stomach)* Place child on stomach on floor. Attract child's attention to **toy**; then hold toy out of child's reach, about 2 ft. above floor. Say, "Get the toy."	2 Raises to sitting position 1 Attempts to maneuver into sitting position 0 Remains lying on floor				
19 Start: 16-26 months	13	KNEELING Place child in a kneeling position, buttocks not resting on heels. Keeping **toy** at child's eye level and about 2 ft. away, move it in arc to one side of child. Say, "Watch the **toy**." Return toy to starting position and then move it in arc to other side. (Take about 4 seconds for each segment of movement cycle: front to left, left to front, front to right, right to front.)	2 Maintains balance for 5 seconds while rotating head 1 Maintains balance for 2–4 seconds 0 Maintains balance for less than 2 seconds				

Item #	Age in Months	Item NAME, Position, and Description	Score Criteria	Administration 1	2	3	4
20 Start: 27–48 months	31–32	STANDING ON 1 FOOT Stand on 1 foot, hands on hips with free leg bent back at knee. Say, "Put your hands on your hips and stand on 1 foot like I did."	2 Stands on 1 foot with hands on hips for 3 seconds 1 Stands on 1 foot with hands on hips for 1–2 seconds 0 Requires help to stand on 1 foot				
21	41–42	STANDING ON 1 FOOT Stand on 1 foot, hands on hips with free leg bent back at knee. Say, "Put your hands on your hips and stand on 1 foot like I did."	2 Stands on 1 foot with hands on hips for 5 seconds 1 Stands on 1 foot with hands on hips for 2–4 seconds 0 Stands on 1 foot for less than 2 seconds				
22 Start: 49–56 months	43–44	STANDING ON TIPTOES Stand on tiptoes with hands held overhead for 3 seconds. Say, "Hold your hands over your head and stand on your tiptoes like I did."	2 Stands on tiptoes with arms held overhead and without moving feet for 3 seconds 1 Stands on tiptoes with arms held overhead and without moving feet for 1–2 seconds 0 Moves feet or heels remain on floor				
23	45–46	STANDING ON 1 FOOT Stand on 1 foot, hands on hips with free leg bent back at knee for 5 seconds. Say, "Put your hands on your hips and stand on 1 foot like I did."	2 Stands on 1 foot with hands on hips and without swaying more than 20 degrees for 5 seconds 1 Stands on 1 foot with hands on hips and without swaying more than 20 degrees for 2–4 seconds 0 Stands on 1 foot for less than 2 seconds or sways more than 20 degrees				
24 Start: 57–71 months	51–52	STANDING ON TIPTOES Stand on tiptoes with hands held overhead for 8 seconds. Say, "Hold your hands over your head and stand on your tiptoes like I did for as long as you can."	2 Stands on tiptoes with arms held overhead, without moving feet, and without swaying more than 20 degrees for 8 seconds 1 Stands on tiptoes with arms held overhead, without moving feet, and without swaying more than 20 degrees for 5–7 seconds 0 Stands on tiptoes for less than 5 seconds or sways more than 20 degrees				
25	53–54	STANDING ON 1 FOOT Stand on 1 foot with hands on hips for 10 seconds, then on other foot for 10 seconds. Say, "Put your hands on your hips and stand on each foot like I did." Count seconds out loud to encourage child to balance longer.	2 Stands on 1 foot, then on other foot, with hands on hips and without swaying more than 20 degrees for 6 seconds on each foot 1 Stands on one foot, then on other foot, with hands on hips and without swaying more than 20 degrees for 1–5 seconds on each foot 0 Stands on only 1 foot (does not change feet) or sways more than 20 degrees				
26	57–58	IMITATING MOVEMENTS *(Standing)* Stand 3 feet from child. Say, "I am going to move my arms and I want you to copy my movements." Do practice move (one not on test) to see if child understands. Do not use verbal cues. Present 6 positions one at a time at 1-second intervals.	2 Imitates 4 positions accurately 1 Imitates 1–3 positions accurately 0 Fails to imitate any position accurately				
27	59–60	STANDING ON 1 FOOT Stand on 1 foot with hands on hips for 10 seconds, then on the other foot for 10 seconds. Say, "Put your hands on your hips and stand on 1 foot and then the other like I did." Count seconds out loud to encourage child to balance longer.	2 Stands on each foot with hands on hips and without swaying more than 20 degrees for 10 seconds 1 Stands on each foot with hands on hips and without swaying more than 20 degrees for 5–9 seconds 0 Stands on each foot for less than 5 seconds, sways more than 20 degrees, or stands on only 1 foot				

Item #	Age in Months	Item NAME, Position, and Description	Score Criteria	Administration 1	2	3	4
28	59–60	SIT-UPS *(Lying down on mat)* Demonstrate sit-ups on mat. Place child in starting position on mat. Hold child's feet and say, "Do as many sit-ups as you can." Stop child after 30 seconds.	2 Completes 3 sit-ups in 30 seconds 1 Completes 1–2 sit-ups in 30 seconds 0 Fails to complete any sit-ups				
29	68–72	SIT-UPS *(Lying down on mat)* Demonstrate sit-ups on mat. Place child in starting position on mat. Hold child's feet and say, "Do as many sit-ups as you can." Stop child after 30 seconds.	2 Completes 5 sit-ups in 30 seconds 1 Completes 3–4 sit-ups in 30 seconds 0 Completes less than 3 sit-ups				
30	72	PUSH-UPS *(Lying face down on mat)* Demonstrate 3 push-ups. Say, "Do as many push-ups as you can." Stop child after 20 seconds.	2 Completes 8 push-ups in 20 seconds 1 Completes 4–7 push-ups in 20 seconds 0 Completes less than 4 push-ups				
Locomotion							
1 Start: 1-2 months	0	THRUSTING LEGS *(Lying on back)* Stimulate leg thrusts by holding child's feet and pushing them toward his or her body so knees are flexed, legs bent, and heels almost touching buttocks. Then pull child's feet out until legs are fully extended. Repeat motions. Let go of child's feet. Observe for more than 1 minute.	2 Bends and straightens legs (alternately or together) 2 times 1 Bends and straightens legs (alternately or together) 1 time or moves only 1 leg 0 Does not move legs				
2	0	TURNING FROM SIDE TO BACK *(Lying on side, legs bent to maintain balance, examiner in back of child)* Shake **rattle** 3 times behind child's back. Repeat procedure with child lying on opposite side.	2 Rolls onto back (both sides) 1 Rolls onto back (1 side only) 0 Remains on side				
3	0	THRUSTING ARMS *(Lying on back)* Stimulate arms by bringing child's hands together at midchest with elbows bent. Then stretch arms out to sides until elbows are straight and hands touch surface. Repeat. Let go of child's hands. Observe for 1 minute.	2 Bends and straightens arms (alternately or together) 2 times 1 Bends and straightens arms (alternately or together) 1 time or moves only 1 arm 0 Does not move arms				
4	2	BEARING WEIGHT *(Standing)* Hold child in a standing position facing you with his or her feet resting on table or counter top. Observe leg position and whether child can bear weight for 3 seconds.	2 Bears weight with knees flexed and feet flat for 3 seconds 1 Bears weight with knees flexed and toes touching surface for 3 seconds or with knees flexed and feet flat for 1–2 seconds 0 Fails to bear weight or legs remain straight with only toes touching surface				
5 Start: 3-4 months	2	EXTENDING TRUNK *(Lying on stomach, head turned to side, forearms resting on surface)* Attract child's attention by shaking **rattle** 1 in. above surface. Continue to shake rattle and move it 6 in. above child's head.	2 Elevates head and upper trunk 45 degrees, bearing weight on forearms or hands for 3 seconds 1 Elevates head and upper trunk 45 degrees, bearing weight on forearms or hands for 1–2 seconds 0 Elevates head less than 45 degrees				
6	3	SYMMETRICAL POSTURE *(Lying on back; feet toward you)* Shake **rattle** 18 in. from child's nose and then move it to within 12 in.	2 Brings both hands together at midline within 5 seconds (hands come up together) while maintaining midline head and body posture 1 Brings 1 hand to midline and moves the other out of midline while maintaining midline head and body posture 0 Hands remain out of midline position				

Appendix E

Placement of PDGMS Balance Subscale Items on the PDGMS-2
(Folio and Fewell, 1983; Folio and Fewell, 2000)

PDGMS Balance Subscale Items	**PDGMS-2 Stationary**	**PDGMS-2 Locomotor**	**Deleted**
<u>12-14 months</u> **62.** Kneeling - maintain for 5 seconds	**√ 19.**		
64. Pivoting - turns a half circle using a walk turn			√
65. Standing & Moving Balance- bend to pick-up toy and returns to standing and steps		**√ 36.**	
<u>15-17 months</u> **79.** Standing – Places 1 foot on line and attempts to position other foot		**√ 46.**	
<u>18-23 months</u> **82.** Stooping – Stoops/squats, recovers ball and returns to standing position			√
86. Walking Balance Beam – May have 1 foot on and 1 foot off for 10 steps		**Similar 48.**	
<u>24-29 months</u> **96.** Standing on 1 foot – Maintain for 1 second	**√ 20.**		
97. Walking on Tiptoes – For 5 steps with hands on hips (24-29 mo.)		**√ 59.**	
99. Walking Balance Beam – Takes 3 steps forward on beam		**√56.**	
<u>30-35 months</u> **107.** Standing on 1 foot – Maintains for 3 seconds	**√ 20. & 21.**		
108. Walking on Tiptoes – For 8 feet		**√ 64.**	

PDGMS Balance Subscale Items	**PDGMS-2 Stationary**	**PDGMS-2 Locomotor**	**Deleted**
<u>**36-41 months**</u> **117.** Standing on 1 foot – Maintains for 5 seconds	**√ 21.** **√23.** **(similar)**		
<u>**42-47 months**</u> **121.** Standing on Tiptoes – Hold for 2 seconds without feet moving	**√ 22.**		
128. Standing on 1 foot – Stand on 1 foot for 6 seconds, than other foot for 6 seconds	**√ 25.** **(similar)**		
129. Walking Backward – walks backward on a 4-foot circle without stepping off taped line more than once.			√
<u>**48-53 months**</u> **131.** Walking Balance Beam – Walks 4 steps on beam without support		**√ Similar** **56.**	
136. Standing on Tiptoes – Maintains for 8 seconds without deviating more than 20 degrees	**√ 24.**		
<u>**54-59 months**</u> **142.** Walking Balance Beam – Walk backwards 5 steps		**√ 75.**	
143. Walking Balance Beam – Walk 8 feet forward with hands on hips and not stepping off and no more than 10 degrees of sway		**√ 70.**	
148. Standing on 1 foot – Stands on 1 foot for 10 seconds and the other foot for 10 seconds, without deviating more than 20 degrees to either side	**√ 27.**		

Appendix F

PDGMS-2 Test Items and Corresponding Items in PDGMS
(Folio and Fewell, 1983; Folio and Fewell, 2000)

PDGMS-2 STATIONARY SUBSCALE ITEMS (age range in months)	**CORRESPONDING PDGMS BALANCE OR LOCOMOTOR SUBSCALE ITEMS (21-month old PDGMS-2 derived stationary subscale)**
1. Rotating (0)	3., 4. (0-1 mo.)
2. Aligning trunk – sitting (0)	
3. Aligning head – sitting (1 mo.)	14. (2-3 mo.)
4. Aligning head – back (1 mo.)	5. (0-1 mo.)
5. Aligning head – back (2 mo.)	19. (2-3 mo.)
6. Extending head (2 mo.)	11. (2-3 mo.)
7. Aligning head (2 mo.)	12. (2-3 mo.)
8. Aligning head – suspended (3 mo.)	13. (2-3 mo.)
9. Stabilizing trunk (3 mo.)	
10. Aligning head (4 mo.)	27. (4-5 mo.)
11. Sitting (5 mo.)	
12. Sitting/Reaching (6 mo.)	28. (similar) (4-5 mo.)
13. Pulling to sit (6 mo.)	30. (4-5 mo.)
14. Sitting – 60 seconds alone (6 mo.)	33. (6-7 mo.)
15. Sitting with toy – reach for toy and sit for 30 seconds (7 mo.)	39. (6-7 mo.)
16. Sitting -60 seconds playing with toy (9 mo.)	41. (8-9 mo.)
17. Raising to sit (10 mo.)	46. (8-9 mo.)
18. Sitting up (10 mo.)	52. (10-11 mo.)
19. Kneeling (13 mo.)	62. (12-14 mo.)
20. Standing on 1 foot - 3 seconds (31-32 mo.)	96. (24-29 mo.) 107. (30-35 mo.)
21. Standing on 1 foot - 5 seconds (41-42 mo.)	117. (36-41 mo.)
22. Standing on tiptoes - 3 seconds (43-44 mo.)	121. (42-47 mo.)
23. Standing on 1 foot - 5 seconds & < 20 degrees body sway (45-46 mo.)	117. (similar – excludes degrees of body sway) (36-41 mo.)
24. Standing on tiptoes - 8 seconds & < 20 degrees body sway (51-52 mo.)	136. (48-53 mo.)
25. Standing on 1 foot - 6 seconds on each foot & < 20 degrees body sway (53-54 mo.)	128. (similar - < 5 degrees body sway allowed) (42-47 mo.)
26. Imitating movements (57-58 mo.)	
27. Standing on 1 foot - 10 seconds on each foot & < 20 degrees body sway (59-60 mo.)	148. (54-59 mo.)
28. Sit-ups – 3 in 30 seconds (59-60 mo.)	140. (48-53 mo.)
29. Sit-ups – 5 in 30 seconds (68-72 mo.)	160. (60-71 mo.)
30. Push-ups (72 mo.)	157. (60-71 mo.)