

Correlation of the Bayley scales of infant-toddler development-3rd edition and neuro-sensory motor assessment in preterm infants during the first year of life.

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The aim of this study was to determine the best cut-off score for determining motor delay in the Motor Scale of the Bayley Scales of Infant-Toddler Development-3rd Edition (Bayley-III) when compared to the Neuro-Sensory Motor Development Assessment (NSMDA) for low birth weight and preterm infants during the first year of life. One hundred and sixty infants born before 32 weeks of gestation and with birth weights of 1500 grams or less were included. Classifications of delay using different Bayley-III cut-offs were cross-tabulated with the NSMDA functional classification. Predictive values of sensitivity, specificity, positive predictive value, and negative predictive value were calculated with 95% CIs. The sensitivity of a Bayley-III cut-off <85 was 100% at 1, 8, and 12 months and 92.3% at 4 months. The best score on the Bayley-III for identifying infants with mild/moderate/severe motor problems on the NSMDA was 80 (100% at 1, 4, and 8 months; 91.3% at 12 months). For identifying motor impairments using the Bayley-III in low birth weight and preterm infants at 1, 4, 8, and 12 months old, the proper cut-off scores are 80-85.

Key words: infant, assessment, cut-off, Bayley-III, low birth.

Preterm infants (born at less than 37 weeks of gestation) are at risk for neurodevelopmental delay. Infants born at a very low birth weight (<1500 g) or born very early (\leq 32 weeks) are considered high risk.^{1,2} Advances in perinatal and neonatal care over the last 10 years, including prenatal steroid treatment and the use of exogenous surfactant at tertiary care centers, have increased the survival rates of preterm infants; however, the rates of motor disorders, including cerebral palsy (CP), continue to be of great concern.³

The American Academy of Pediatrics published guidelines for the follow-up of preterm infants in 2006.⁴ The guidelines recommended a neuromotor evaluation at least twice during

the early years of life for early diagnosis in very low birth weight (less than 1500 g) infants and those born very early (less than 32 weeks of gestation).⁴ Defining motor development of infants in the first year of life is important for ensuring necessary interventions are implemented, and increasing evidence indicates that this is a critical period for cerebral development.⁵ Neuronal differentiation, including the development of dendrites, axons, neurotransmitter and synapse production, and myelination, starts during the 2nd trimester and progresses rapidly during the first year of life.⁶ Cerebral plasticity is high during early infancy, and interventions may be more effective during this period^{5,7}; therefore, it is

important to describe, classify, and diagnose neurodevelopmental delays in the first year of life. While there are several tools available for the evaluation of motor development in infants during this period, including the Pechtl Analysis (GMs), Neurosensory Motor Development Assessment (NSMDA), Bayley Scales of Infant-Toddler Development-3rd Edition (Bayley-III), and the Test of Infant Motor Performance (TIMP)^{8,9}, the Bayley-III and NSMDA are the only tools that can be used throughout these early years.⁷

Another systematic review evaluating motor development during infancy emphasized that the Bayley test is the most common method for neuromotor and developmental evaluation.⁷ The Bayley-III, which was developed in 2006, was updated to ensure the separate calculation of composite scores for cognitive, language, and motor parameters.¹⁰ The Bayley-III was also updated to provide better information for understanding neuromotor development during early infancy.¹¹ The Bayley-III, while one of the most commonly used evaluation tests, is often impractical in clinical settings due to the time required for administration and scoring and the cost of equipment and test forms, which restricts test administration to psychologists or certain health professionals with specialized training. Furthermore, recent evidence has led to worries that the Bayley-III may hide developmental delays and overestimate scores.¹²⁻¹⁴ Of note Anderson et al.¹⁵ performed a recent study of preterm children using the Bayley-III at 2 years. They predicted motor outcomes at 4 years with excellent specificity for motor impairments; however, the sensitivity for motor impairments other than CP was low.¹¹ There is growing interest in determining the best cut-off scores for the Bayley-III because the use of cut-offs has clinical significance for determining motor impairment within the population.^{13,16,17}

The NSMDA is a valid and reliable criterion-referenced test that assesses the quality of children's motor development and associated systems. It uses age-normalized criteria along with functional grading of performance.^{18,19} It can reveal differences between normal and abnormal motor development in children. Spittle et al.⁷ recommended the NSMDA as one of the best assessments for distinguishing

between children with normal motor function and those with minimal, mild, moderate, or severe motor dysfunction who would benefit from treatment. However, the Bayley-III is a norm-referenced test that assesses the acquisition of fine and gross motor milestones. It has been criticized for overestimating developmental milestones and also for decreasing the number of preterm infants eligible for early intervention.²⁰ The aim of this study, therefore, was to determine the best cut-off score for determining motor delay in the Motor Scale of the Bayley-III compared to the NSMDA at 1, 4, 8, and 12 months of age in low birth weight and preterm infants.

Material and Methods

Participants

The study sample was recruited, and consent was obtained from the Department of Neonatology. This cross-sectional study included one hundred sixty children born before 32 weeks of gestation and with birth weights of 1500 g or less during the first year of life. Infants were excluded if they had congenital anomalies, sensory impairments (e.g., blindness, deafness), chronic lung disease, genetic syndromes, or if they needed early physiotherapy interventions. The infants received their routine neonatologist control during the study period. They were not included in any physiotherapy program in order to prevent possible effects of therapy on neurodevelopment.

Approval was obtained from the local Medical, Surgical, and Drug Studies Ethics Committee of the university for this study (Project No: LUT 09/168), and all parents provided written informed consent.

Procedures

The first author (who has 7 years of clinical experience) underwent a training course covering the assessments before the study and administered the Bayley-III and NSMDA. Infants were divided into groups of six and assessed first with the Bayley-III or the NSMDA. The same infants were assessed with the second assessment tool (Bayley-III or NSMDA) 1 week later. The order in

which the assessments were administered for each infant was determined randomly. The NSMDA was used for the criterion measure. Infants' ages were adjusted for prematurity. The administration of the tests followed the manual's guidelines. The evaluation using the original Bayley Test Battery Kit was performed approximately 2 hours after feeding on a large cushion on the floor or when sitting on the mother's lap at the table. The infant did not receive any medication that would influence the assessment during the evaluation. The testing time ranged from 1 to 2 hours, depending upon the mother-infant feeding interaction, age, and cooperation of the infant. Bayley-III and NSMDA scores were not calculated during the evaluation process, but only after evaluation of all 160 infants.

Assessments

Neuro-Sensory Motor Developmental Assessment (NSMDA)

The NSMDA consists of six sections that evaluate motor development.^{18,19} These are age-appropriate gross and fine motor function, neurological status, and infant patterns of movement, postural development, and motor responses to sensory input. A neuro-sensory motor developmental score is determined by summing the scores in each of these six areas. Infants with NSMDA scores of 6–8 were classified as having normal motor function, scores of 9–11 as having minimal motor problems, scores of 12–14 as having mild motor problems, and scores of 15–20 as having moderate to severe motor dysfunction. The biggest advantage of the NSMDA is its ability to differentiate between normal motor function and minimal, mild, moderate, or severe motor dysfunction.^{18,19}

Bayley-III Infant and Toddler Developmental Scale (Bayley-III)

The Bayley-III is divided into five subgroups (cognitive, language, motor, social-emotional, and adaptation subgroups)²⁰, and it provides four types of norm-reference scores (scale, composite, classification percentage, and growth scores). There are also confidence intervals for each scale and the developmental equivalent for age among the subtests. The

composite score is calculated by adding the lower test scale scores with a total score ranging from 40–160, a mean of 100, and a standard deviation of 15. The confidence interval shows the actual score range that the child can receive. The developmental equivalent for the age shows the developmental age of the child according to the total raw score. The standard score is 40–160, and the suggested normal score is 100–115. For all motor, cognitive, and language development, 130 points or more is very high, 110–119 is high average, 90–109 is normal, 80–89 is low average, 70–79 is borderline, and 69 or lower is poor. General motor performance consists of gross and fine motor performance, while general language performance consists of expressive and receptive language performance.²⁰ The motor composite scores of the Bayley-III were calculated for all infants in this study.

Statistical Analysis

The Statistical Package for the Social Sciences (SPSS) version 21 for the Macintosh (IBM SPSS Statistics; IBM Corporation, Armonk, NY, USA) was used to analyze the data. The number of cases was calculated using GPower V.3.1.7 (University of Kiel, Kiel, Germany). To achieve 80% power to detect a difference with 95% confidence using a correlation model, a sample size of 100 participants was required for this study.^{18,19} According to our analysis results, power was 17% for 1 month, 71% for 4 months, 96% for 8 months, and 86% for 12 months. These results were supported by findings in the literature. Burns et al.^{18,19} showed that 8 months was the best evaluation time period for determining normal and abnormal neurodevelopment in high-risk infants. The variables were investigated using one-sample Kolmogorov-Smirnov tests to determine whether or not they were normally distributed. Descriptive analyses are presented using medians and minimum-maximum for the non-normally distributed and ordinal variables. A confidence interval (CI) of 95% was used for the Bayley-III composite scores. Bayley-III motor composite scores and NSMDA scores were presented as the median (minimum, maximum) values. Spearman's rank correlation was used to evaluate the Bayley-III parameters and NSMDA variables. The results, provided as rho- and p-values, are interpreted at the

0.05 significance level. When evaluating the relationship, a correlation coefficient of 0.00–0.24 was accepted as “poor,” 0.25–0.49 as “moderate,” 0.50–0.74 as “strong,” and 0.75–1.00 as “very strong”.²¹ A p-value less than 0.05 was considered statistically significant. Classification of moderate to severe delays using different Bayley-III cut-offs were cross-tabulated. The cut-off point was selected for NSMDA scores >11 for determining mild, moderate, and severe motor dysfunction. NSMDA scores >11 and predictive values of sensitivity, specificity, positive predictive value (PPV), and negative predictive value (NPV) were calculated with 95% Confidence Intervals (CIs) by using Receiver Operating Characteristics (ROC) curve analysis. The overall level of agreement between NSMDA scores >11 and each Bayley-III classification was computed by summing the proportion of true positive and true negative classifications. Agreement was ranked, with lower ranks indicating better prediction.

Results

The birth characteristics of high-risk infants are shown in Table I. Eighty-six male (53.75%) and 74 female children (46.25%) were included in the sample.

Test Scores

Table II presents the outcomes of the Bayley-III motor and NSMDA scores for infants at 1, 4, 8, and 12 months of age. The median for the Bayley-III motor scale composite scores was higher than 85.

Table III shows the correlations between the NSMDA and Bayley-III Motor Scale Composite Scores at 1, 4, 8, and 12 months. We found a very strong correlation between the Bayley-III motor scores and NSMDA scores, the most significant of which was observed at 8 months old.

An exploration of the Bayley-III motor composite score that best predicted NSMDA index scores >11 revealed that the selected cut-offs were 85, 80, and 70 (Table IV). The sensitivity and NPV were greatest for the Bayley-III cut-off scores <85 that agreed with the NSMDA in identifying delays at 1, 4, 8, and 12 months, while the specificity and PPV were highest for Bayley-III cut-off scores <70. PPV was poor at 1 month for cut-off scores <85 because two infants scored below 11 on the NSMDA. In addition, the overall agreement of the Bayley-III cut-off scores <80 was most significant at 1, 8, and 12 months; however, at 4 months, Bayley-III cut-off scores <85 best agreed with the NSMDA.

Table I. Birth Characteristics of the Preterm Infants.

n=160 (min-max)		n (%)	Median 31 (18-51)
Gestational age (weeks)			29.28 (24-32)
Birth weight (gram)			1230 (600-1500)
Apgar scores	1 st minute		6 (1-9)
	3 rd minute		7 (3-10)
	5 th minute		9 (4-10)
Type of birth	Vaginal Birth	19 (11.9)	
	Caesarean section	141 (88.1)	
Multiple pregnancy	Singleton	96 (59.4)	
	Twins	54 (33.8)	
	Triplets	6 (4.4)	
	Quadruplets	4 (2.5)	

min: minimum; max: maximum

Table II. Descriptive Statistics for Performance on the Bayley III and NSMDA.

n=160	1 month	4 months	8 months	12 months
	Median (Min-Max)	Median (Min-Max)	Median (Min-Max)	Median (Min-Max)
Corrected age (days)	32 (25-37)	121 (114-128)	240 (235-247)	360 (355-367)
Bayley-III Motor	101.5 (70-118)	103 (46-130)	91 (46-127)	91 (46-127)
NSMDA	6 (5-25)	6 (6-27)	7.5 (6-30)	8 (7-35)

Min: minimum; max: maximum; Bayley-III: Bayley Scales of Infant-Toddler Development-3rd Edition; NSMDA: Neuro-Sensory Motor Development Assessment

Table III. Correlation Coefficients Between Bayley-III Motor Section and NSMDA Scores.

	r (Spearman rho (rs))	p
NSMDA-Bayley-III Motor		
1 month	-0.79	<0.001
4 months	-0.79	<0.001
8 months	-0.93	<0.001
12 months	-0.88	<0.001

Bayley-III: Bayley Scales of Infant-Toddler Development-3rd Edition; NSMDA: Neuro-Sensory Motor Development Assessment **p<0.01

Discussion

This study investigated the best cut-off score for determining motor delays on the Motor Scale of the Bayley-III compared to the NSMDA for low birth weight and preterm infants during the first year of life. The correlation between the Bayley-III motor composite and NSMDA scores was significant (0.75–1.00). The sensitivity, specificity, NPV, and agreement scores for the Bayley-III cut-off scores <85 were also strong.

Campbell et al.¹⁶ investigated the concurrent validity of the TIMP and Bayley-III in 145 preterm infants at a corrected age of 6 weeks. They found that the mean Bayley motor composite scores was 116±8 (min: 94, max: 136).¹⁶ In this study, the median for the Bayley-III motor score at 1 month was lower than their results, but higher than 100. The reason for this difference is likely the study sample; our study sample included infants born at ≤32 weeks of gestation and a birth weight of ≤1500 g, while Campbell et al.¹⁶ included infants born at 29–34 weeks. Eickmann et al.²² evaluated the cognitive, motor, and language

development of 45 moderate-risk premature infants, aged 6–12 months (mean gestational age at birth: 33 weeks, birth weight: 1762 g) with the Bayley-III.²² There was no difference between the cognitive, language, and motor development of term and premature infants, but lower motor scores (106.1±11.4) were found in premature infants born under 1500 g (p=0.04) and those with a 5-minute Apgar score below 7 (p=0.003).²² However, our results were similar to those of Yu et al.²³, who included infants born under 1500 g and at less than 37 weeks of gestation. They found a mean Bayley-III motor score of 91.3±8.4 in preterm infants at the age of 12 months.²³ In the current study, the median Bayley-III motor scores were higher at 1 and 4 months than at 8 and 12 months. This decline in the motor development of infants became more prominent over time and may have been due to the increase in the motor skills that need to be performed by the infants as time goes by. In addition, this could be related to not receiving any early physiotherapy intervention or due to the cross-sectional nature of this study. Studies that have used the Bayley-III test to evaluate

Table IV. Results for Prediction of NSMDA Scores >11 Using Different Bayley-III Combinations and Cut-offs.

Predictive values for NSMDA >11 with 95%CI						
Ages	Bayley-III cut-off <85 Motor					
	AUC (%)	Sen (%)	Spe (%)	PPV (%)	NPV (%)	Agreement ^a (%)
1 month	97.3	100	94.5	50	100	94.8
	(93.1-100)	(97.6-100)	(92.1-94.5)	(47.6-50)	(97.6-100)	(92.4-94.8)
4 months	95.3	92.3	98.3	92.3	98.3	97.2
	(86.6-100)	(90.6-94)	(96.6-98.3)	(90.6-92.3)	(96.6-98.3)	(95.5-97.2)
8 months	95.6	100	91.2	83.3	100	93.9
	(91.2-100)	(97.8-100)	(89-91.2)	(81.1-83.)	(97.8-100)	(91.7-93.9)
12 months	95.3	100	90.7	84.6	100	93.8
	(90.1-100)	(98-100)	(88.7-90.7)	(82.6-84.6)	(98-100)	(91.8-93.8)
Ages	Bayley-III cut-off <80 Motor					
	AUC (%)	Sen (%)	Spe (%)	PPV (%)	NPV (%)	Agreement ^a (%)
1 month	66.7	33.3	100	100	96.5	96.5
	(28.4-100)	(30.6-36)	(97.3-100)	(97.3-100)	(93.8-96.5)	(93.8-96.5)
4 months	88.5	76.9	100	100	95.2	95.8
	(74.6-100)	(74.7-79.1)	(97.8-100)	(97.8-100)	(93-95.2)	(93.6-95.8)
8 months	94	88	100	100	95	96.3
	(86.4-100)	(85.8-90.2)	(97.8-100)	(97.8-100)	(92.8-95)	(94.1-96.3)
12 months	95.4	95.5	95.3	91.3	97.6	95.3
	(89.2-100)	(93-98)	(92.8-95.3)	(88.8-91.3)	(95.1-97.6)	(92.8-95.3)
Ages	Bayley-III cut-off <70 Motor					
	AUC (%)	Sen (%)	Spe (%)	PPV (%)	NPV (%)	Agreement ^a (%)
1 month	66.7	33.3	100	100	96.5	96.5
	(28.4-100)	(30.6-36)	(97.3-100)	(97.3-100)	(93.8-96.5)	(93.8-96.5)
4 months	69.2	38.5	100	100	88.1	88.8
	(50.5-88)	(36.3-40.7)	(97.8-100)	(97.8-100)	(85.9-88.1)	(86.6-88.8)
8 months	88	76	100	100	90.5	92.6
	(77.8-98.2)	(73.8-78.2)	(97.8-100)	(97.8-100)	(88.3-90.5)	(90.4-92.6)
12 months	86.4	72.7	100	100	87.8	90.7
	(74.8-97.6)	(70.5-74.9)	(97.8-100)	(97.8-100)	(85.6-87.8)	(88.5-90.7)

AUC, area under the receiver-operating characteristic curve; Sen, sensitivity; Spe, specificity; NPV, negative predictive value; PPV, positive predictive value. ^aOverall agreements is calculated as the total proportion of true positive and true negative classifications. Min: minimum; max: maximum; Bayley-III: Bayley Scales of Infant-Toddler Development-3rd Edition; NSMDA: Neuro-Sensory Motor Development Assessment

premature infants have found development to be within the normal ranges for the test.

Connolly et al.¹⁷ evaluated 48 children at risk for developmental delays at ages 1 month to 2 years using the Bayley-III and Peabody-2

tests.¹⁷ They found a moderate correlation between the two tests at <6 months ($r=0.69$), a high correlation at 6–12 months ($r=0.81$) and over 18 months ($r=0.85$), and a very high correlation at 12–18 months ($r=0.95$).¹⁷ Another study reported a high degree of concordance between the Alberta Infant Motor Scale (AIMS) and the Bayley-III motor subtest ($r=0.93$).²⁴ Campbell et al.¹⁶ found a strong correlation ($r=0.54$) between the TIMP and Bayley-III in 6-week-old infants. In the current study, there was a very strong correlation between the NSMDA and Bayley-III motor parameters, which was similar that observed in the literature.

Some recent studies have indicated that the Bayley-III overestimates scores when determining developmental delay.¹³⁻¹⁵ In a retrospective study that compared the Bayley-II and the Bayley-III in children at a gestational age <27 weeks and a birth weight ≤ 1000 g at 2 years over two time periods, Bayley-III motor scores were 5 points higher than the Bayley-II, and the Bayley-III determined motor delays 40% less often than the Bayley-II.¹⁴ The use of a cut-off score in the Bayley-III is therefore important for identifying developmental delays.

Conolly et al.¹⁷ showed that the overall agreement of the Bayley-III and Peabody Developmental Motor Scales-2nd edition PDMS-2 was 100 at <6 months and 85.7 at 6–12 months and 15 days. They advised clinicians that the Bayley-III could be selected to save time. In this study, the overall agreement of the Bayley-III cut-off <80 with NSMDA evaluation was best at 1, 8, and 12 months (96.5%, 96.3%, and 95.3%, respectively); however, at 4 months, Bayley-III cut-off scores <85 best agreed (97.2%). We suggest that the best agreement between the Bayley-III and the NSMDA is for Bayley-III scores <80.

Yu et al.²³ found that the sensitivity, specificity, and accuracy of the Bayley-III cut-off of 82 were 92%, 93%, and 92%, respectively, at 6 months and 91%, 95%, and 94%, respectively, at 12 months for Psychomotor Development Index (PDI) scores <70. Spittle et al.¹¹ investigated the predictive value of the Bayley-III at 2 years of age for motor development at 4 years of age in children born at less than 30 weeks of gestation. They reported that the best

combination of specificity (77%), sensitivity (74%), and accuracy (75%) was at a cut-off score of 97 for Bayley-III at 2 years.¹¹ In this study, the ability of the Bayley-III to detect infants with mild/moderate/severe motor problems (defined as an NSMDA score >11) were the best at cut-off scores of 80 and 70 at all ages. The sensitivity of the Bayley-III cut-off score <85 was 100% at 1, 8, and 12 months and 92.3% at 4 months, but the sensitivities of the Bayley-III cut-off scores <80 and <70 were lower. The specificity of the Bayley-III cut-off score <80 was 100% at 1, 4, and 8 months and 95.3% at 12 months. According to our data, the best combination of specificity, sensitivity, and accuracy was a Bayley-III cut-off score <85. Campbell et al.¹⁶ reported that any cut-off scores under the mean (100) should be used at early ages; however, our data support cut-off scores of 80–85 for Bayley-III motor scores during the first year of life because they have the highest specificity and sensitivity.

The limitations of our study include the administration of two assessment tools by the same assessor, which might have resulted in assessment bias that affected the correlation of test scores, which may have been similar to the study of Yu et al.²³ There was no other researcher who could use the assessment tools, so we could not assess inter-rater reliability. Another limitation was the cross-sectional design of this study. However, this study did include a large sample size that evaluated high-risk infants using the Bayley-III. To prevent assessment bias, infants were divided into groups of six and assessed first with either the Bayley-III or NSMDA, and the other assessment tool (Bayley-III or NSMDA) was applied 1 week later. Moreover, the assessment tool used first was selected randomly, and the test scores were calculated after completing all evaluations.

The results of this study will help clinicians determine the risk of motor developmental delays in low birth weight and preterm infants in the first year of life, during which the brain undergoes a high degree of myelination. We recommended that in order to identify motor impairment with the Bayley-III in low birth weight and preterm infants at 1, 4, 8, and 12 months old, cut-off scores of 80–85 should be used.

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