Early Human Development (2008) **84**, 297–303

available at www.sciencedirect.com

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A comparison of the general movements assessment with traditional approaches to newborn and infant assessment: Concurrent validity ☆

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Accepted 16 July 2007

KEYWORDS
Neurobehavioral assessment;
Preterm infant;
General movements;
Functional motor assessment

Abstract

Background: Assessment of the quality of general movements (GMs) is an early clinical marker for prediction of cerebral palsy.
Aims: To explore how the General Movements Assessment (GMsA) relates to traditional newborn and infant measures currently in use.
Study design: A prospective cohort design was used to examine concurrent validity of the GMsA in Neonatal Intensive Care (NICU) survivors ($n=100$) at three age points: preterm (34 weeks gestational age GA), term (38–40 weeks GA), and post term (12 weeks adjusted age [AA]) with traditional assessments (see below).
Correlation analysis was used to determine the strength of the associations between tests at each age point.
Subjects: Preterm infants born at ≤ 32 weeks gestational age and birth weight <1500 g ($n=108$) were recruited sequentially from the NICU of a large teaching hospital and referral centre. Infants with diagnoses of metabolic disorders, cardiac, chromosomal, or congenital abnormalities were excluded.
Outcome measures: Test of Infant Motor Performance (TIMP), Einstein Neonatal Neurobehavioral Assessment Scale (ENNAS), Alberta Infant Motor Scales (AIMS).

☆ Supported by the Canadian Institute of Health Research (MOP-49552), the Hospital for Sick Children Foundation: New Investigator Grant Program, the Fonds de recherche du Québec, and the Centre de recherche interdisciplinaire en réadaptation.

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doi:10.1016/j.earlhumdev.2007.07.004

Results: A low-strength relationship ($r = <0.25$) was found between the GMsA and the traditional tests which increased across age points ($r = 0.25–0.50$). Relationships between the traditional tests over time was characterized by stronger associations ($r = 0.50–0.75$).
Conclusions: Evidence of concurrent validity of the GMsA with traditional assessments was not found. These early findings support Prechtl's suggestion that GMs reflect a unique neurologic construct, different from traditional tests and reinforce the complementary perspective which the GMsA brings to neonatal assessment.

Selection of the method of assessment in the evaluation of preterm infant for the prediction of long term developmental outcome is an important consideration. When assessments are used as discriminative tools, the intactness and maturity of the immature central nervous system are assessed in neonates and infants at high-risk for neurologic impairment and subsequent disability [1]. Traditional assessments document behavioral and neurodevelopmental repertoires, control of posture and movement and other observable responses to environmental stimuli. Typically performed by specialist physicians or occupational and physical therapists, these tools emphasize elicited responses. However, clinical use can be limited such that the infant's behavioral state affects performance and those whose physiological status is unstable may be unable to tolerate the stress of handling. Further, while good sensitivity is reported, traditional assessments are limited as predictive tools since they also demonstrate low specificity. Consequently there is typically a *high rate of false positive* identifications, resulting in the over-referral of infants at risk [1]. This may contribute to inefficiencies in the delivery of high cost rehabilitation services. Given these limitations, it is of interest to determine how the General Movements Assessment (GMsA), a qualitative method, compares to traditional newborn and infant measures which utilize a quantitative approach to the assessment of neurological integrity.

The GMsA is a novel, promising approach to the evaluation of the preterm infant [2]. Distinguished from traditional evaluations which handle the fragile preterm to elicit different responses, the GMsA is carried out through serial videotaped observations of the quality of specific movement patterns. Prechtl states that detection of abnormal general movements (GMs), believed to reflect integrity of underlying brain mechanisms, is a more accurate method for the early identification of infants with neurological deficits than those currently in use [3].

GMs, spontaneous movements involving the whole body, are endogenously generated (ie: not elicited by external stimuli). A typical trajectory of movement patterns emerges at consistent times across post conceptional age [2] suggesting a sustained and specific maturational progression. Refinement of the GMs begins in two distinctive stages. At preterm and term age, normal GMs show a variable sequence of arm, leg, trunk and neck movements. They wax and wane in intensity, force and speed, having a gradual beginning and end. Rotations along the axis of the limbs and slight changes in the direction of movements make them fluent and elegant, creating the impression of complexity and variability [2]. They are present until 6–9 weeks post term when 'fidgety' GMs emerge. Fidgety GMs (FMs) are small and elegant movements of moderate speed and variable acceleration, of neck, trunk and limbs, in all directions, continual in the awake infant. FMs prevail, the highest prevalence occurring ~12 weeks post term, until infant movements become more voluntary [4]. Infants with intraventricular hemorrhage, periventricular leukomalacia, birth asphyxia who went on to abnormal neurological outcomes showed a very different pattern of GMs than that observed in typically developing infants [2]. In those infants, preterm and term GMs lost their complex and variable character (poor repertoire, cramped-synchronized or chaotic). Subsequently, fidgety movements can be either abnormal or absent. Therefore, qualitative abnormalities of the GMs are related to abnormal outcome and may be interpreted as an early clinical sign of brain dysfunction. Prechtl advocates that early identification of cerebral palsy is best achieved through the analysis of GMs [4].

The GMsA has only been studied in selective populations of very high risk infants, reflected by the finding that 25–30% of the subjects developed cerebral palsy. These earlier studies reported a relatively high agreement between GMsA and the neurologic exam at preterm, term and post term age [3–5]. The quality of FMs at post term age show greatest sensitivity (94–100%) and specificity (85–96%) [2] for two-year outcome on developmental tests and the standard neurological examination [3–6]. Consistently abnormal GMs (cramped synchronized movements) and absent FMs are associated with a high risk for the development of cerebral palsy [2], whereas abnormal FMs may be associated with later minor neurological dysfunction, attention-deficit-hyperactivity disorder, and aggressive behavior at school age [7].

The present study differs from the previous literature in two ways: it utilizes a more representative sample of preterm neonatal intensive care unit (NICU) survivors and explores relationships between the GMsA and traditional infant assessments used in the clinical setting.

A review of the literature highlights three well developed assessments with strong psychometric properties suited to the assessment of young preterm infants: Einstein Neonatal Neurobehavioral Assessment Scale (ENNAS) [8], Test of Infant Motor Performance (TIMP) [8], a functional motor assessment of postural control highly associated with demands for movement placed on infants by caregivers in naturalistic interactions [9], and Alberta Infant Motor Scales (AIMS), a norm-referenced assessment of the infant movement repertoire birth-walking [8]. Because they all examine the construct of integrity of the nervous system, we hypothesized a high correlation between the GMsA and traditional assessments. They share an emphasis on maturational changes in early developmental motor patterns, related to neurological integrity and are used to identify infants at risk. However, it is not evident whether these differing approaches measure similar concepts in different ways or if their underlying constructs are different.

The purpose of this study was to examine the concurrent validity of the GMsA using traditional neonatal and infant assessments: TIMP, ENNAS and AIMS.

1. Methods

1.1. Subjects

A prospective cohort design was used to examine the concurrent validity of the GMsA in NICU survivors at three age points: preterm (34 weeks gestational age [GA]), term (38–40 weeks GA) and post term (12 weeks adjusted age [AA]). Adjusted age was determined by subtracting the adjustment for prematurity in weeks from the postnatal age in weeks. Subjects were selected by weekly chart review of consecutive admissions to an NICU in a large teaching hospital. All preterm infants born at <32 weeks gestational age were eligible. Infants were excluded if they had a diagnosis of a metabolic disorder, cardiac, chromosomal, or congenital abnormality: these represent risk factors for abnormal developmental outcomes not specifically motor related.

1.2. Procedures

This study received scientific and ethical approval from the Institutional Review Board of McGill University. The research coordinator screened the medical records for eligible families who were contacted by telephone and the study objectives and procedures explained. Informed written consent was obtained. Data was collected from the medical records on perinatal characteristics. Subjects were assessed in the NICU and follow-up clinic. At a given time point, the assessments were done by the same examiner. The subjects were evaluated at preterm (GMsA, TIMP), term (GMsA, TIMP, ENNAS) and 12 weeks AA (GMsA, TIMP, AIMS). Any items shared between the traditional tests were scored on a 'one-time' basis. To collect data for the GMsA, each subject was filmed in supine per Prechtl's method [2].

The examiners were occupational therapists trained in administration and scoring of the traditional tests. The GMsA tapes were judged by an expert (AFB). Inter-rater reliability is established for all assessments [2,8,9]. For the purpose of the study, ten GMs cases were judged for inter-rater reliability, resulting in 100% agreement. All examiners were blind to medical history and perinatal course.

1.3. Measures

1.3.1. GMSA [2]

GMs were judged as normal/abnormal according to Prechtl's method [2]. At preterm and term, abnormal subjects are classified as: 1) *poor repertoire (PR)*; 2) *cramped-synchronized (CS)*. Movements were classified as *CS* when observed during at least one recording [10]. At 12 weeks AA, normal fidgety movements (FMs) include *continual (NF++)* and *intermittent (NF+)*. Both *abnormal (Fa)* and *absent (F–)* FMs are categorized as abnormal [2].

1.3.2. TIMP [8]

A norm-referenced measure designed to evaluate organization of posture and movement for functional activities in infants between 34 weeks post conceptual age (PCA) and four months AA. Items are scored on a 5–6 point scale and added to yield a total score (continuous). Total scores are categorized as 'average' (within +1.0 and −.5 SD of age mean), 'low average' (−.5 and −1.0 SD below age mean), 'below average' (−1.0 and −2.0 SD below age mean) and 'far below average' (below −2.0 SD below age mean) (categorical). Construct, criterion content, concurrent and predictive validity for standardized motor outcomes are published [8,9]. The TIMP has been shown to be responsive to physical therapy intervention [11,12].

1.3.3. ENNAS [8]

ENNAS evaluates muscle tone, primitive reflex patterns and behavioral elements (orienting responses and behavioral state) to assess neurologic and behavioral organization of the neonate at term. Total deviance score of 0–2 failed items is categorized 'normal', a score of 3–6 'suspect', a score of >6 'abnormal'. Findings for concurrent validity report strong associations between ENNAS and the neurological examination [8]. Negative predictive value for developmental outcomes at school age is high; high false positive rate is a limitation [8].

1.3.4. AIMS [8]

Weight bearing, posture and antigravity movements are assessed spontaneously in developmental positions and judged according to visual standards, measuring the construct of motor maturation. The score for each developmental position is summed to obtain a total raw score converted to an age-based percentile rank (continuous). Content, construct, concurrent [13] and predictive validity with other standardized motor evaluations are established [8].

1.4. Statistical analysis

To test whether scores on the neonatal assessments were significantly associated and therefore document the

Table 1 Clinical and demographic factors ($n=108$)

Variable	Mean (SD)	Range
Birthweight (grams)	1075.6 (258.4)	(540–1500)
GA (weeks)	28.6 (2.5)	(23.3–32.0)
Variable	**Median (IQ)**	**Range**
Ventilated *(total # days)*	6 (26.5)	(0–86)
Variable	**Frequency**	**%**
ELBW (401–1000 g)	42	38.9
VLBW (<1500 g)	66	61.1
Small for gestational age	27	25
Brain lesion	11 (Grade I=7; Grade II=1; Grade III=2; Grade IV=1)	10.2
Bronchopulmonary dysplasia (BPD)[1]	27	25.0
Female	44	40.7
Male	64	59.3

ELBW: extremely low birthweight; GA: gestational age; VLBW: very low birthweight; IQ: inter-quartile range; BPD[1]: $O_2 \geq 28$ days [21].

Table 2 Distribution (%) of categorical scores for General Movements Assessment, TIMP, ENNAS and AIMS at preterm, term and post term age points ($n=100$)

Measures	Category	Preterm *n* (%)	Term *n* (%)	Post term *n* (%)
GMsA	Normal	32 (32.0)	52 (52.0)	–
	Poor repertoire	63 (63.0)	36 (36.0)	–
	Cramped synchronized	5 (5.0)	12 (12.0)	–
	Normal (NF++)	–	–	48 (48.0)
	Normal (NF+)	–	–	28 (28.0)
	Abnormal (Fa)	–	–	14 (14.0)
	Abnormal (F−)		–	10 (10.)
TIMP	Average	11 (11.0)	19 (19.0)	38 (38.0)
	Low average	25 (25.0)	23 (23.0)	41 (41)
	Below average	36 (36.0)	51 (51.0)	21 (21.0)
	Far below average	5 (5.0)	7 (7.0)	0 (0.0)
	Missing	23 (23.0)	0 (0.0)	0 (0.0)
ENNAS	Normal	–	5 (5.0)	–
	Suspect	–	29 (29.0)	–
	Abnormal	–	61 (61.0)	–
	Missing		5 (5.0)	
AIMS	Normal (<10 %ile)	–	–	63 (63.0)
	Abnormal (>10 % ile)	–	–	37 (37.0)

GMsA: General Movements Assessment.
TIMP: Test of Infant Motor Performance.
ENNAS: Einstein Neonatal Neurobehavioral Assessment Scale.
AIMS: Alberta Infant Motor Scale.

concurrent validity of the GMsA at each age point, correlation coefficients were computed: Cramer's *V* coefficients were used when at least one of the two variables was nominal (GMsA and TIMP at preterm, term, post term); Tau C coefficients were used when the variables were both ordinal (GMsA and ENNAS at term; GMsA and AIMS at post term). Pearson's Product Moment correlation coefficient (*r*) was used when both test scores were continuous (TIMP and the ENNAS at term; TIMP and the AIMS at post term). When one score was ordinal and the second score was continuous, Spearman Rank Order coefficient was used [14]. 95% confidence intervals were computed when possible determine the significance and strength of the association.

GMs categories were dichotomized (normal: N; abnormal: PR+CS) and 12 weeks AA (normal: NF+ and NF++; abnormal: Fa and F−). In order to determine normal vs abnormal categories for the continuous scores of infant measures used, TIMP (normal: average+low average; abnormal: below average+far below average) and ENNAS (normal: normal+suspect; abnormal: abnormal scores) scores were also dichotomized.

Portney's guidelines to judge the relative strength of the associations between variables state that correlations below 0.25 show a low-strength association, values between 0.25 and 0.50 show an association of fair strength, those of .50 to 0.75 indicate moderate association and those above 0.75 show a very good to excellent association [14]. For the purposes of the study, a correlation coefficient of at least 0.40 between test scores was established to indicate that tests were measuring related constructs [15].

Logistic regression was used to determine if traditional neonatal assessments could predict an abnormal GMsA after controlling for perinatal factors: e.g. birth weight, gestational age at delivery, presence of IVH, number of days on ventilation. A backwards stepwise method was used with the level of significance set at $p>0.10$ to remove a variable from the predictive model.

2. Results

2.1. Sample characteristics

A total of 131 families were approached for recruitment (December 2001−November 2003). Of these, 23 declined to participate: initial sample was 108. Before 12 weeks AA, 8/108 withdrew (4 moved; 4 were lost to follow-up clinic) leaving 100 subjects to analyze. There were no statistically significant differences in the perinatal characteristics of subjects who participated and those who refused. Intraventricular hemorrhage was diagnosed in the presence of hyperechogenicity in the lateral ventricles and was classified in four grades according to Volpe [16] Table 1 describes clinical and demographic variables.

2.2. Performance on tests

Clinical and demographic factors are presented in Table 1. The distribution of categorical scores are presented in Table 2. The GMsA was administered to all subjects across age points. The TIMP was not administered to a number of subjects ($n=23$) due

Table 3 Means, standard deviations and ranges of continuous scores of the TIMP, ENNAS and AIMS at preterm, term and post term age points

Measures	Age point	*n*	Mean (SD)	Range
TIMP (Total scores)	Preterm	77	30.8 (8.3)	7−57
	Term	100	48.6 (12.3)	20−80
	Post Term	100	93.9 (14.5)	61−123
ENNAS (Total deviance scores)	Term	95	7.5 (2.8)	0−18
AIMS (Percentile Scores)	Post Term	100	17.1 (11.7)	2−55

TIMP: Test of Infant Motor Performance.
ENNAS: Einstein Neonatal Neurobehavioral Assessment Scale.
AIMS: Alberta Infant Motor Scale.

to medical instability at preterm. Similarly, ENNAS at term ($n=5$) was not administered (Table 3).

2.3. Comparison of tests

2.3.1. Preterm age

The cross tabulated frequencies of TIMP by GMsA were calculated (Table 4). The 95% confidence interval on Tau C [−0.11; 0.23] included 0 and the correlation was therefore not significantly different from 0. The value of all correlation coefficients are given in Table 5. Although the correlation was extremely weak, the percentage of subjects testing abnormal on the GMsA increased as TIMP scores decreased (56% of "low average" TIMP scores had an abnormal GM score, 75% of "below average" and 100% of "far below average").

The results from the logistic regression indicated that, although the number of days on ventilation was marginally associated with the GMsA (as the number of days increased, the risk of testing abnormal on GMsA at preterm also increased, $p=0.06$), the TIMP total scores did not have a significant predictive power for the GMsA abnormal status. The regression coefficient ± SE (−0.012 ± 0.033) was not statistically significant ($p=0.719$) at preterm.

Table 4 Crosstabulations of dichotomized GMsA with TIMP and ENNAS at preterm, term and 12 weeks AA

TIMP (preterm age)	General movements assessment: Normal (N)	Abnormal (CS + PR)	Total
	%	%	%
	n	*n*	*n*
Normal	16.9	11.7	28.6
	13	9	22
Abnormal	29.9	41.6	71.4
	23	32	55
Total	36	41	77

TIMP | ENNAS (term age)	Normal (N)		Abnormal (CS + PR)		Total	
Normal	14.0	23.2	38.0	28.4	52.0	51.6
	14	22	38	27	52	49
Abnormal	5.0	12.6	43.0	35.8	48.0	48.4
	5	12	43	34	48	46
Total	19.0	35.8	81.0	64.2	100.0	100.0
	19	34	81	61	100	95

TIMP (12 weeks AA)	Normal (NF++/NF+)	Abnormal (F−/Fa)	Total
Normal	37.4	41.4	78.8
	37	41	78
Abnormal	1.0	20.2	21.2
	1	20	21
Total	38.4	61.6	100
	38	61	99

TIMP: Test of Infant Motor Performance; ENNAS: Einstein Neurobehavioral Neonatal Scale; AA: adjusted age; TIMP normal = average + low average; TIMP abnormal = below average + far below average; ENNAS normal = normal + suspect; ENNAS abnormal = abnormal; CS = cramped synchronized; PR + poor repertoire; NF++ = continual; NF+ = intermittant; Fa = abnormal; F− = absent.

Table 5 Strength of associations between assessments at preterm, term and 12 weeks AA

GMsA	Preterm	Term	12 weeks AA
TIMP	0.12 (Tau C)	0.11 (Tau C)	0.31 [a] (Tau C)
ENNAS	–	0.21 (Cramer's *V*)	–
AIMS	–	–	0.17 (Cramer's *V*)

TIMP	Preterm	Term		Post term	
ENNAS	–	0.67 [a] (*r*)	0.61 [a] (*p*)	–	–
AIMS	–	–	–	0.57 [a] (*r*)	0.56 [a] (*p*)

GMsA: General Movements Assessment.
TIMP: Test of Infant Motor Performance.
ENNAS: Einstein Neonatal Neurobehavioral Assessment Scale.
AIMS: Alberta Infant Motor Scale.
Pearson Product Moment Coefficient: (*r*).
Spearman Rank Order Coefficient: (*p*).
[a] Significant difference: $p<.01$.

2.3.2. Term age

The cross tabulated frequencies of TIMP and ENNAS by GMsA at term were calculated (Table 4). The 95% confidence interval on Tau C [−0.08; 0.26] included the 0 and the correlation was therefore not significantly different from 0. Table 5 shows that Cramer's *V* between ENNAS and GMsA was marginally significant ($r=0.21$, $p=0.056$). The results from the logistic regression indicated that none of the perinatal variables were associated with the GMsA at term, but the ENNAS scores were. In fact, the regression coefficient ± SE (0.27 ± 0.98) indicated that as the total deviance scores increased, the probability of obtaining an abnormal score on the GMsA increased (95% CI on odds ratio [1.08;1.59]). The percentage of the GMsA scores explained by the ENNAS deviance score was nonetheless low at 12.1% (Nagelkerke R^2).

2.3.3. Post term age

The cross tabulated frequencies of TIMP by GMsA at post term age were calculated. The 95% confidence interval on Tau C [0.16; 0.47] did not include the 0 and the correlation was therefore significantly different from 0, although it is considered only a fair association. Spearman's rho was not significantly different from 0 (95% CI [−0.08; 0.29]).(Table 4). The results from the logistic regression indicated that while none of the perinatal variables was associated with the GMsA at 12 weeks, TIMP scores were. The regression coefficient + SE (−0.05 + 0.02) indicated that as the TIMP scores decreased, the probability of obtaining an abnormal score on the GMsA at post term age increased (95% CI on odds ratio [0.92;0.99]). The percentage of the GMsA score explained by the TIMP score was low at 12.6% (Nagelkerke R^2).

3. Discussion

Validation studies of the GMsA have shown excellent concurrent validity with the neurological exam [5]. This study further addresses the concurrent validity of the GMsA with traditional neonatal and infant neurobehavioral and motor assessments.

In reviewing the methods to determine concurrent validity, Streiner and Norman [15] emphasize the difficulties in finding a gold standard free of associated error measuring an identical construct to the target test. A realistic anticipation for an acceptable correlation between a new scale and the criterion standard measuring the same or a similar attribute should be within the fair to moderate range ($r = 0.4–0.8$). The relationships between the GMsA and traditional assessments did not fall into this range, although the strength of the association between the TIMP and the GMsA increased at post term age. This trend is of interest in light of a recent study which suggests that fidgety movements are a pivotal part of the GMsA [17].

These early findings support Prechtl's suggestion that GMs, found to be a clinical marker for poor neurological outcome, may reflect a unique construct, differentiated from approaches measuring postural or behavioral responses. Further, the strength of the associations of the TIMP with the other traditional assessments fell within the anticipated range (≥ 0.40) at term (TIMP/ENNAS) and at post term (TIMP/AIMS), suggesting they share a similar construct (Table 5).

Our findings illustrate that the proportion of subjects identified 'abnormal' decreased from preterm (68% and 41%) to post term (24% and 21%) on GMsA and TIMP respectively (Table 2). This suggests a resolving acute irritability of the nervous system underlying a transient period of vulnerability, with an opportunity to recover, presumably due to neuroplasticity and adaptive responses to environmental stimulation [18,19]. Further, the overall health of subjects with respiratory compromise may improve during this early period. The trend towards resolution emphasizes that the abnormalities may not be permanent.

Therefore, selection of the method of assessment lies with the context of the evaluation and the outcomes desired. ENNAS predicts outcomes at school entry in NICU survivors [8] but does not have evidence of its effectiveness in program planning for intervention. The AIMS has published predictive validity [8] but a limited range of precision for school aged outcomes and no evidence for responsiveness to intervention. TIMP has been shown to be an evaluative and responsive measure. It identifies who would benefit most from direct interventions and home programs and successfully measures progress with intervention. Thus, the advantage of the TIMP lies in this area. However, the non-intrusive nature of the GMsA and the fact that it seems to add different information from that represented by traditional assessments, sets it apart as a valuable, complementary [20] assessment of fragile, physiologically unstable infants. Findings from the GMsA at preterm can contribute to the implementation of developmentally appropriate early intervention programs within the NICU [19].

A potential limitation of this study is that only preterm infants were included in the cohort, thus the results can only be generalized to that group as opposed to other high risk infant groups.

The strength of the correlations between the GMsA and traditional neonatal and infant motor assessments at preterm, term and post term were generally low. Thus, evidence of concurrent validity between traditional tests and the GMsA was not found. These early findings reinforce the unique and complementary perspective of the GMsA, which has been found to be a clinical marker for CP. Further studies of the impact of the GMsA for prediction of neurodevelopmental outcome, either in combination with traditionally administered assessments or when administered as a serial assessment are necessary in order to understand the usefulness of the GMsA for future clinical application in representative samples of preterm infants.

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