General Movement Assessment in Babies Born Preterm: Motor Optimality Score–Revised (MOS-R), Trajectory, and Neurodevelopmental Outcomes at 1 Year

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Objective To assess the association between the General Movement Assessment (GMA) findings, including Motor Optimality Scores–Revised (MOS-R) at 16 weeks, and neuromotor outcome assessed by the Amiel-Tison Neurological Assessment at 9 months of corrected age and the Developmental Assessment Scales for Indian Infants (DASII) at 1 year of corrected age in preterm ≤32 weeks.

Study design Serial GMA videos of infants born preterm ≤32 weeks were recorded on day 7, 35 weeks of postmenstrual age, 40 weeks of postmenstrual age, and 16 weeks of corrected age. The association between GMA findings, including MOS-R scores and GM trajectory between 35 to 40 weeks and the Amiel-Tison Neurological Assessment and DASII scores, was assessed by Spearman correlation, Fisher exact tests, and ordinal regression.

Results Moderate correlations were observed between MOS-R and the DASII motor DQ (Spearman r = 0.70, $P < .001$) and between MOS-R and DASII Mental DQ (r = 0.65, $P < .001$). The GMA trajectory at 35-40 weeks was associated with DASII motor DQ (Fisher exact, $P = .002$), and also with the Amiel-Tison Neurological Assessment at 9 months of corrected age ($P < .01$ by the Fisher exact test). On analysis by performing ordinal regression of predictive values of the general movements (GM) at 7 days of age, GM at 35 weeks, GM at 40 weeks, GM at 16 weeks, and MOS-R at 16 weeks, MOS-R alone was a statistically significant predictor of motor DQ at 1 year of age (OR −0.59; 95% CI −0.97 to −0.22; Wald statistics, $P < .02$).

Conclusions Consistent with findings in high-income countries, GMA including MOS-R scores performed in Indian infants born preterm during the neonatal period and early infancy is associated with neurodevelopmental outcomes in the first year of life. GMA can help initiate focused early intervention in low- and middle-income settings, where resources may be limited. *(J Pediatr 2023;8:100084)*.

Survivors of preterm birth are at increased risk of neurodevelopmental impairment and disability.[1] Five to 10% of infants born preterm before the 32nd week of gestation suffer from major neurologic disorders, including cerebral palsy (CP) and severe intellectual disability.[2] Early identification of such babies remains a challenge but is important, considering that there is a potential benefit of early intervention when the brain is most responsive to repair due to plasticity.[3-6]

The Prechtl General Movement Assessment (GMA) is a diagnostic tool based on visual gestalt perception of videoed age-specific normal or abnormal general movements.[7] The validity of the assessment of general movements in children born premature as a tool to predict early infantile CP was described in a systematic review.[8] Another study[2] investigated GMA neonatal trajectories and their association with neurodevelopment at 3 months of corrected age in infants born preterm. Findings of Cramped Synchronized (CS)-CS and Poor Repertoire (PR)-CS trajectories at term-equivalent age indicate the need to refer the infant to neurodevelopmental intervention during the neonatal intensive care unit (NICU) stay, whereas normal (N)-N or PR-N trajectories suggest normal short-term neurodevelopment, especially a lower risk of CP. GMA, including the Motor Optimality Score or the revised version, the Motor Optimality Score–Revised (MOS-R), are established methods to predict neurologic impairments in children during the preterm, term, and infancy period.[7] MOS-R scores ≤23 at 14-16 weeks of corrected age are predictive of motor, cognitive, and neurosensory motor impairment, and scores ≤15 are predictive of CP.[9]

AT	Amiel-Tison Neurological Assessment	GMA	General Movement Assessment
CP	Cerebral palsy	LMICs	Low- and middle-income countries
CS	Cramped Synchronized	MOS-R	Motor Optimality Score–Revised
DASII	Developmental Assessment Scales for Indian Infants	N	Normal
EPT	Extremely preterm	NICU	Neonatal intensive care unit
FM	Fidgety movement	PMA	Postmenstrual age
GM	General movements	PR	Poor Repertoire

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We have very limited data on MOS-R and neurodevelopmental outcomes from low- and middle-income countries (LMICs). Our study primarily aimed to test the correlation between the MOS-R at 16 weeks of corrected age and neuromotor outcome using the Amiel-Tison Neurological Assessment (AT) at 9 months of corrected age and the developmental quotient of the Developmental Assessment Scales for Indian Infants (DASII) at 1 year of corrected age in children born preterm ≤32 weeks. The secondary objective was to study the correlation between GMA trajectory and neuromotor outcomes with AT at 9 months of corrected age and Motor DQ by DASII at 1 year of corrected age.

Methods

This prospective cohort study was conducted in a tertiary teaching hospital in India. The recruitment of infants started in September 2018, and follow-up at 1 year of corrected age was completed in March 2020. All neonates preterm at ≤32 weeks of gestational age were included. Neonates with major congenital anomalies were excluded.

Approval from the institutional ethics committee was obtained before commencing the study. Written informed consent for the videos was taken from all parents for video recordings and for participation in the study. The consent form mentioned that the video assessment was an interim to identify possible motor impairment early and to start intervention if necessary, and the final diagnosis of motor impairment would be confirmed in evaluations at 9 months and 12 months corrected age.

Data Collection

Data regarding baseline and clinical characteristics over the course of the NICU stay were collected from enrolled neonates. Serial GMAs were recorded with an initial assessment 7 days after birth. The second was done at completed 35 weeks (±3 days) of postmenstrual age (PMA), the third at 40 weeks (±5 days) of PMA in the high-risk clinic, and a fourth assessment at corrected age 16 weeks (±7 days). To provide a reliable assessment of GMA, the recording procedure was standardized. Infants were video-graphed using a smartphone camera, a Sony 16 MP camera Exmor RS sensor supporting a resolution of 4616 × 3464 pixels (the same camera in NICU and follow-up), for 2 minutes in an alert behavioral state, lying supine with minimal clothing. The parents were counselled about the GMA, the procedure to record the videos, the timings when they needed to be recorded, and the clinical utility of the videos, to ensure their active participation.

GMA Scoring

The GM videos were recorded by one of the authors, who stored them and shared them without patient identifiers with 2 independent assessors, who were both GMA trained and blinded to the clinical history and hospital course of the neonate. Both scored the videos independently and, in case of discrepancy, the author informed both assessors who then saw the videos together and arrived at a consensus. GMAs at 32 weeks were scored N or PR. At 35 weeks and 40 weeks, GMs were scored as N, PR, or CS or chaotic. GMA trajectory was scored as N-N, N-PR, PR-N, PR-PR, PR-CS, CS-PR, CS-CS, CS-N, and N-CS, similar to a previous study.[8]

GMAs of all the infants at 16 weeks of corrected age were scored as fidgety, absent fidgety, and abnormal fidgety. MOS-R scores were also done at 16 weeks of corrected age. The MOS-R is based on 5 different subcategories; (1) temporal organization of fidgety movements (FMs) (maximum 12 points), (2) observed movement patterns other than FMs (maximum 4 points), (3) age-adequate movement repertoire (maximum 4 points), (4) observed postural patterns (maximum 4 points), and (5) movement character (maximum 4 points). We classified the scores as per the study by Örtqvist et al.[8] A MOS-R from 25 to 28 is considered optimal, 20-24 is mildly reduced, 9-19 is moderately reduced, and 5-8 is severely reduced.[7]

Developmental Interventions/Assessments

Infants with moderately reduced and severely reduced scores were started on early intervention based on reports that MOS-R scores ≤23 are predictive of motor, cognitive, and neurosensory motor impairment and scores ≤15 are predictive of CP.[9] The main principle of early intervention was to train parents for an individualized home program based on the infant's level of development to support and facilitate the achievement of developmental milestones. Postural support was given to facilitate the infant's midline orientation to promote symmetry in different positions like prone, sidelying, and supine while supporting the infant's response as a basis for social interaction and for increasing the infant's variation of movements.

A motor assessment was done by Amiel Tison Neurological assessment (AT) at 9 months of corrected age, because AT has good predictive ability until 9 months.[10] AT is a simple neurodevelopmental evaluation of tone (active and passive), posture, motor activity, and postural reactions that can be used to identify neuromotor abnormalities in the first year of life. Infants were classified as having normal tone, hypertonia (axial or appendicular), or hypotonia (global or axial). Neuromotor findings (tone and reflexes) were scored as normal, mildly deviant, and severely deviant. Based on neuromotor, functional consequences, neurosensory, neurobehavior, and head growth, infants were classified as impaired with no disability (mild) and impaired with disability (severe). The final classification was based on type of tone abnormality and severity.[11,12] This assessment was done by a developmental pediatrician who had also previously scored a subset of GMA videos but saw the patient without knowledge of the previous GMA score and patient identifiers.

At 12 months of corrected age, the infants underwent DASII evaluation.[13] DASII is a neurodevelopmental assessment tool standardized for Indian infants, based on the Bayley

Scale of Infant Development. It is considered as a gold standard for measuring motor and mental development from 0 to 30 months of age in Indian infants. It is a numerical scale with 2 subscales for the motor (67 items) and mental (163 items) domains. The DASII was administered by a trained clinical psychologist who was blinded to the GM and AT performance of the children. On the basis of the performance of the infants in motor and mental clusters, a Motor and Mental DQ was obtained. The DASII-DQ motor and mental scores were classified as normal (85-105), mild (70-84), moderate (55-69), and severe (<55) delay.

Statistical Analyses

This study was conducted to primarily to test the correlation between the MOS-R at 16 weeks of corrected age with the neuromotor outcome using the DASII developmental quotient at 1 year of corrected age in infants born ≤32 weeks preterm. From a pilot conducted at our unit before conducting this study, we found a Spearman correlation coefficient value of 0.35 between these 2 variables. A sample size of N = 62 was estimated using Z transformation for a predicted correlation coefficient for 0.35 with beta error of 0.2 (power of 80%) and an alpha error of 0.05. We decided to enroll 70 infants in the study that would adjust for loss to follow-up of 10%.[14]

Standard descriptive statistics included means (SD) or medians (IQR) as appropriate for continuous variables and counts and percentages for categorical variables. Correlation between MOS-R at 16 weeks corrected age with DASII DQ scores (Motor and Mental) at 1 year of corrected age was calculated using nonparametric Spearman correlation. Associations between classifications of MOS-R at 16 weeks of corrected age and GMA trajectory between 35 to 40 weeks with DASII motor classifications were assessed using the Fisher exact test. We also looked at the predictive values of the GM at 7 days of age, GM at 35 weeks of maturity, GM at 40 weeks of maturity, and GM at 16 weeks and MOS-R at 16 weeks by performing ordinal regression taking motor DQ at 1 year of corrected age as the dependent outcome variable. All *P* values are 2 sided and were considered statistically significant if *P* value was <.05. Analysis was performed by using IBM SPSS 21 software (IBM Corp).

Results

Neonates (n = 321) were assessed for eligibility during the study period; the parents of 82 neonates did not consent to participate, 21 neonates were excluded due to congenital anomalies, and 56 neonates did not meet the eligibility criteria. Therefore, 162 neonates were eligible; 9 died during the NICU stay, 18 were transferred to other hospitals, and 64 could not be contacted for follow-up or were unable to send videos. In total, 71 infants with complete follow-up through 12 months of corrected age were included in the study. The baseline characteristics of the study population are described in Table I.

Table I. Baseline characteristics of neonates enrolled in the study

Variables	No. of cases (%), N = 71
Gestational age, wk, mean (SD)	30.3 (±1.8)
Birth weight, g, mean (SD)	1289.42 (±301.1)
Sex	
Male, No. (%)	42 (59.2%)
Female, No. (%)	29 (40.8%)
Gestational age, wk	
<28	6 (8.4%)
$28^{0/7}$-$29^{6/7}$	22 (31%)
$30^{0/7}$-$32^{6/7}$	43 (60.6%)
Birth weight, g	
ELBW (<1000)	12 (16.9%)
VLBW (1000-1499)	41 (57.7%)
LBW (1500-2500)	18 (25.4%)
Apgar at 1 min <7	22 (31%)
Apgar at 5 min <7	4 (5.6%)
Small for gestational age*	36 (50.7%)
Respiratory distress syndrome	42 (59.1%)
Intraventricular hemorrhage (any grade)	13 (18.3%)
IVH (grade 2 and greater)	2 (2.8%)
Patent ductus arteriosus	24 (33.9%)
Retinopathy of prematurity (any stage)	29 (40.8%)
Bronchopulmonary dysplasia	2 (2.8%)
Necrotizing enterocolitis (stage 2 and greater)	2 (2.8%)
Clinical sepsis	46 (64.8%)
Culture-proven sepsis	12 (16.9%)

*Defined as having birth weight less than the 10th percentile for specific gestational age using Fenton charts.

High agreement was observed between both the assessors of the video recordings, with initial disagreement on 2 neonates at 35 weeks, 1 neonate at 40 weeks, and 1 infant at 16 weeks of corrected age, which were all resolved by consensus review. GMA findings across time points assessed are presented in Table II.

Four infants had absent or abnormal FMs at 16 weeks and in comparison with their DASII assessed at 12 months of corrected age, 2 of the 4 infants had severe motor and 2 severe motor delay. Three had moderate mental and one severe mental delay. Thus, the GMA at 16 weeks had a significant association with motor and mental DQ. We also compared MOS-R scores at 16 weeks with motor DQ by DASII at 12 months of corrected age in Table III. MOS-R was significantly associated with Motor DA (Fisher exact test, $P < .0001$).

All of the infants with significantly reduced MOS-R scores had moderate or severe motor delay, whereas none of the infants with optimal MOS-R scores had moderate or severe motor delay. MOS-R scores at 16 weeks of corrected age were moderately correlated with the DASII motor DQ (r = 0.70, $P < .001$) and the DASII Mental DQ (r = 0.65 $P < .001$) at 1 year of corrected age.

On comparing the GMA at 16 weeks with AT at 9 months of corrected age, of the 4 infants with absent or abnormal FMs, 3 had severe hypertonia, and 1 had severe hypotonia. Three infants (4.23%) had significantly reduced MOS-R scores, all of whom had severe hypertonia. Four (5.63%) had moderately reduced MOS; 3 had severe hypertonia,

Table II. GMA type of movement across time points of assessment

Types of general movement	Time point of assessment, No. (%)			
	7 d	35 wk	40 wk	16 wk
Normal	11 (15.5%)	20 (28.1%)	39 (54.9%)	–
Poor repertoire	60 (84.5%)	44 (62%)	25 (35.2%)	–
Cramped synchronized	0	7 (9.9%)	7 (9.9%)	–
Chaotic	0	0	0	–
Fidgety	–	–	–	67 (94.4%)
Absent fidgety	–	–	–	3 (4.2%)
Abnormal fidgety	–	–	–	1 (1.4%)

and 1 had severe hypotonia. All the children with moderate and severely reduced MOS-R scores were commenced on early intervention Three children had FMs but moderately reduced MOS-R scores and were commenced on early intervention. Nine (12.68%) infants had optimal scores on MOS-R of whom, and only 1 infant had mild hypertonia.

GMA trajectories from 35 to 40 weeks of PMA stratified by DASII Motor DQ classifications at 1 year of corrected age are shown in Table IV. Nineteen (26.76%) neonates stayed PR-PR, of whom 13 (68%) had moderate or severe delay. Thirteen (18.3%) neonates had an N-N trajectory, of whom only 3 (23%) had moderate motor delay and none had severe motor delay. Three neonates had N-PR, of whom none had moderate or severe motor delay. Twelve neonates (16.9%) had CS either at 35 or 40 weeks, of whom 4 (33.33%) had moderate or severe delay. Thus, neonates who stayed PR-PR or had CS either at 35 weeks or 40 weeks had the greatest frequency of motor disability, whereas those with N-N and N-PR had a lower incidence of motor disability. The GMA trajectory at 35-40 weeks was significantly associated with DASII motor DQ (Fisher exact test, $P = .002$).

We compared GMA trajectories with AT at 9 months of corrected age. Thirteen neonates had an N-N trajectory, of whom only one had severe tone abnormality, whereas of the 19 who had a PR-PR, severe tone abnormality was found in 17 infants. Twelve neonates had CS either at 35 weeks or 40 weeks or both, of whom 9 had a severe tone abnormality. Thus, a N-N trajectory was associated with mild tone abnormalities whereas a PR-PR or CS at either 35 weeks or 40 weeks or both was associated with severe tone abnormalities. The GMA trajectory was significantly associated with AT at 9 months of corrected age ($P < .01$ by Fisher exact test).

We also looked at the predictive values of the GM at 7 days of age, GM at 35 weeks of maturity, GM at 40 weeks of maturity, and GM at 4 months of maturity at age 16 weeks after birth (MOS-R and GM at 16 weeks of age) by performing ordinal regression taking Motor DQ at 1 year of corrected age as dependent outcome variable, which was classified on an ordinal scale as normal (85-100), mild (70-84), moderate (55-69), and severe (<55). In this analysis, we found that MOS-R alone was a statistically significant predictor of motor DQ at 1 year of age (OR −0.59; 95% CI −0.97 to −0.22; Wald statistics, $P < .02$).

Discussion

Most studies on GMs with MOS-R, GM trajectories, and neurodevelopmental outcomes in infants born preterm are from high-income countries. Considering that GMA is the cornerstone assessment for early prediction of neurodevelopmental impairment to start early intervention, it is important to assess the use of GMA in LMIC settings, where resources are limited. This study was conducted in a tertiary center in India with NICU facilities, high-risk follow-up facilities, and provision of an early intervention center. Although we found significant associations between early GMA findings and later neurodevelopmental outcomes, our findings may not be generalizable to all LMIC settings.

Our findings are similar to those of the systematic review that analyzed the scientific evidence from 10 studies on GMA in 2243 infants born premature as a prognostic measure of infantile CP diagnosed at 2 years of corrected age.[2] Similar to our study, 8 studies classified the GMs according to Prechtl's original classification,[15,16] whereas 2 studies used the Hadders–Algra classification,[17] which differentiates

Table III. Association between MOS-R at 16 weeks and DASII Motor DQ at 1 year

MOS-R scores at 16 wk of age	Number	Motor DQ at 12 mo of age			
		Normal (score >85)	Mild (score 70-85)	Moderate (score 55-69)	Severe (score <55)
Optimal (score 25-28)	9	7	2	0	0
Mildly reduced (score 20-24)	55	9	27	17	2
Moderately reduced (score 9-19)	4	0	1	3	0
Severely reduced (score 5-8)	3	0	0	1	2

Fisher exact test $P < .0001$.

Table IV. Association between GMA trajectory and DASII Motor DQ at 1 year of age

GMA trajectory 35-40 wk	Number	Motor DQ at 1 y			
		Normal (score >85)	Mild (score 70-85)	Moderate (score 55-69)	Severe (score <55)
N-N	13	4	7	2	0
N-PR	3	0	3	0	0
PR-N	24	9	9	5	1
PR-PR	19	0	6	12	1
PR-CS	3	0	2	0	1
N-CS	3	2	0	1	0
CS-PR	3	1	2	0	0
CS-N	2	0	0	1	1
CS-CS	1	0	1	0	0
Total	71	16	30	21	4

Fisher exact test, $P = .002$.

movements as normal and abnormal. Three studies did not assess GMA movements in the writhing period. One-half of the studies that were included affirmed that the sensitivity of GMA as a prognostic tool for CP in infants born preterm is 100%, with only one study showing lower sensitivity of 50%. Specificity was more variable, ranging between 77.6% and 97%. Studies that used the Prechtl classification of GMA reported greater sensitivity and specificity compared with those following the Hadders–Algra procedure. Given that the systematic review included studies with follow-up through 2 years of age, the primary outcome assessed was CP. Because our follow-up was until 1 year of corrected age, we classified infants as having moderate or severe motor delay, which is associated with high risk for CP.

Örtqvist et al[7] reported a retrospective observational study of 53 infants born extremely preterm (EPT; 23-26 weeks, mean gestational age 25 weeks) and matched for sex and recording age with 53 control infants born at term who were confirmed to have no neurologic or psychiatric diagnoses at 12-17 years of age. The previously recorded videos were reassessed according to the Prechtl GMA (including the MOS-R) by a certified GMA expert and one of the inventors of MOS-R, both of whom were blinded to the infants' perinatal clinical histories and neurodevelopmental outcomes. The EPT group showed similar rates of aberrant FMs (n = 10, 19%; absent n = 4 and abnormal n = 6) compared with our study. Only 10 (19%) of the EPT infants showed an age-adequate motor repertoire.

We evaluated videos of 71 neonates over 4 time points between day of life 7 and 16 weeks of corrected age. Ideally, we should be evaluating a complete trajectory across these 4 time periods. We used the Prechtl classification (ie, N, PR, and CS) rather than the Hadders–Algra classification of normal and abnormal movements. As per previous studies, observing CS GMA over several weeks during preterm and term age is highly predictive (98%) for the eventual development of spastic CP. Children who later become dyskinetic display a so-called "poor repertoire of GMs," that is, a monotonous sequence of movement components.[18] Considering our small sample size and the numerous potential trajectory patterns possible over 4 time points, we used only the 35- to 40-week trajectory for our analyses. Our findings are similar to those of an observational longitudinal study[2] on 215 preterm infants with a birth weight of <1500 g. Longitudinal neonatal GM trajectories were described using a similar classification of trajectory as used in our study. N-N trajectory was seen in (59.3%). The trajectories with CS movements were the least likely to occur (2.3% had a CS-CS whereas 1.9% had a PR-CS); 23% of infants showed a PR-PR trajectory. The authors assessed outcomes as GM at 3 months. They found that 92% of the N-N and 94% of the PR-N had FMs. All the CS-CS infants had no FMs, and of the PR-PR, only 50% had FMs. The authors concluded that findings of CS-CS and PR-CS trajectories at term-equivalent age indicate the need for clinicians to refer the infant to neurodevelopmental intervention, whereas findings of N-PR and PR-PR trajectories indicate the need for closer follow-up to avoid delay in potential intervention strategies. We had a greater incidence of PR-PR infants. This may be attributed to the fact that we had more babies born small for gestational age, 36 (50.7%), in our study, in contrast to their 20% incidence of babies born small for gestational age.

Our findings suggest that a GMA including MOS-R scores performed in Indian infants born preterm during the neonatal period and early infancy is associated with neurodevelopmental outcomes in the first year of life. These findings are consistent with those from high-income countries We assessed motor outcomes using both the AT and the DASII as complementary tools. The DASII provides motor age equivalents, whereas the AT provides a more detailed assessment of the type of tone abnormality.

One limitation of our study is the small sample size, in part due to a high attrition rate. Parents from rural areas were unable to make it at the allocated appointment, probably because there were 2 visits scheduled 3 months apart (9 and 12 months), and the lack of financial reimbursement for travel could be a major reason for dropout. Thus, there exists a possibility of a bias in our results if the clinical course and GMA findings of the babies lost to follow-up differed from the included study cohort. We acknowledge that we

had the same assessor for some GMA videos and the AT evaluation. This was due to the paucity of trained personnel for both assessments and may have led to bias in the AT analyses. This concern is mitigated by the consistency between the AT and DQ findings, given that the DASII assessment at 1 year of corrected age was done by an assessor blinded to GMA results. Given that we routinely started early intervention in some children who were fidgety and had low MOS-R scores, these interventions may have influenced neurodevelopmental outcomes in these children. Whether early intervention mediates the relationship between GMA and the neurodevelopmental outcome is an area for future study. ■

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