Title

Early motor repertoire in very low birth weight infants in India is associated with motor development at one year.

Abstract

Background

Most studies on Prechtl's method of assessing General Movements (GMA) in young infants originate in Europe.

Aim

To determine if motor behavior at an age of 3 months post term is associated with motor development at 12 months post age in VLBW infants in India.

Methods

243 VLBW infants (135 boys, 108 girls; median gestational age 31wks, range 26–39wks) were video-recorded at a median age of 11wks post term (range 9–16wks). Certified and experienced observers assessed the videos by the "Assessment of Motor Repertoire – 2 to 5 Months". Fidgety movements (FMs) were classified as abnormal if absent, sporadic or exaggerated, and as normal if intermittently or continually present. The motor behaviour was evaluated by repertoire of co-existent other movements (age-adequacy) and concurrent motor repertoire. In addition, videos of 215 infants were analyzed by computer and the variability of the spatial center of motion (C_{SD}) was calculated. The Peabody Developmental Motor Scales was used to assess motor development at 12 months.

Results

Abnormal FMs, reduced age adequacy, and an abnormal concurrent motor repertoire were significantly associated with lower Gross Motor and Total Motor Quotient (GMQ, TMQ) scores ($p<0.05$). The C_{SD} was higher in children with TMQ scores <90 (-1SD) than in children with higher TMQ scores ($p=0.002$).

Conclusion

Normal FMs (assessed by Gestalt perception) and a low variability of the spatial center of motion (assessed by computer-based video analysis) predicted higher Peabody scores in 12-month-old infants born in India with a very low birth weight.

Keywords:

General movements
Fidgety movements
Movement recognition
Computer-based assessment
Neurodevelopmental assessment

Abbreviations:

GMA	General movement assessment
AMR	Assessment of motor repertoire – 2 to 5 months
FMs	Fidgety movements
PDMS–2	Peabody Developmental Motor Scales–2
TMQ	Total motor quotient
GMQ	Gross motor quotient
FMQ	Fine motor quotient
Q	Quantity of motion
C	Centroid of motion

1. Introduction

Being born preterm or with a very low birth weight (VLBW) is associated with significant motor impairment persisting throughout childhood.[1] As many as 10 to 15 % of VLBW infants are reported to develop cerebral palsy (CP),[2] and sustained adverse outcomes in adolescence and adulthood make preterm birth a major public health issue.[3] The use of early assessment tools to facilitate optimal development may reduce later problems in daily life,[4] but it remains difficult to predict accurately which infants are at the highest risk of impairment.[5] Prechtl's General Movement Assessment (GMA) has shown good clinical utility among neonatal assessments for preterm infants up to a post-term age of 4 months.[5] The GMA estimates the integrity of the infants' nervous system by observing the quality of general movements (GMs) from video recordings. The GMs occur as writhing movements (present until 6 to 9 weeks post term age) and fidgety movements (present between 9 to 20 weeks post term age). Particularly the absence of fidgety movements (FMs) enables us to predict CP.[6, 7] Important principles for the assessment of FMs is that the infant must be in a quiet, alert state, they could best be observed if the infant is in supine position, and they disappear when the infants starts to be fussy or cries, is drowsy or sleeps. [8]

Fidgety movements are interspersed with pauses and can occur as isolated, intermittent, or continual events.[9] It is unclear whether this temporal organization of FMs has any relevance for the later outcome. In addition to the global assessment by means of GMA, a detailed assessment of the motor repertoire can be carried out using the Assessment of Motor Repertoire – 2 to 5 months (AMR).[8] Certain aspects of the motor repertoire have been shown to be associated with the neurological outcome at 7 to 11 years,[10] with minor neurological dysfunctions at school age, [11] and with motor and/or cognitive outcomes at 10 years.[12] Major advantages of GMA and AMR include that they are non-intrusive, require no expensive equipment, and can be used by trained observers in clinical settings. However, there will be a high demand for skilled observers if GMA is to be used large scale for screening of high-risk infants. In order to provide non-trained observers with decision support, a number of computer-based assessment tools have been presented with variable results. [13-15]

GMA is based on clinical observations. Studies evaluating whether there are differences in GMs between different ethnic or cultural groups are, to the best of our knowledge, not available. Most studies have been performed in Europe, although more studies are now coming also from Brazil, China, Iran and South Africa[9, 16-18]. It has further been claimed that GMA studies have a risk for bias because study samples are selected retrospectively, based on available video recordings rather than well-defined high-risk cohorts.[19] No study has so far dealt with the general movements and motor repertoire of Indian infants, and studies on the feasibility of GMA and AMR in low-resource settings are limited.

The aim of the present study was to determine the feasibility of the assessment of fidgety general movements and their concurrent motor repertoire in VLBW infants in a follow-up clinic at a tertiary teaching hospital in South India. We also investigated associations between the temporal organization of FMs, the concurrent motor repertoire, and motor development at 12 months post-term age. We expected to find higher Peabody Developmental Motor Scale–2 (PDMS–2) scores at 12 months with increased frequency of FMs and age adequate concurrent motor repertoire. Finally, we wanted to examine the association between computer-based video analyses carried out during the fidgety movement period and the motor development at 12 months post-term age.

2. Material and methods

2.1 Design

The present study is a longitudinal cohort study of VLBW preterm infants discharged from a level III Neonatal Intensive Care Unit (NICU) in South India. The infants' FMs and concurrent motor repertoire were assessed between 9 and 16 weeks post-term age, and their motor development was assessed at 12 months post-term age using Peabody Developmental Motor Scales-2 (PDMS–2).

2.2. Participants

Participants in the study included a subgroup of infants recruited from a cohort study of VLBW infants with a birth weight ≤ 1500 grams. They had been discharged from the NICU at Christian Medical College, Vellore, Tamil Nadu, India, between December 2010 and January 2013, and reported for follow-up at 2 to 3 months corrected age. Data on neonatal morbidity were collected from the hospital's patient records. Intraventricular hemorrhage was classified according to Papille et al.[(20)] From a total of 345 participants, the video recordings of 18 infants could not be assessed due to crying or fuzzing (n=8), rolling or moving out of mattress (n=5), casting on leg (n=1), hypokinesia (n=1), and a total video length of less than 1 minute (n=3). From the remaining 327 infants, 2 children died before the assessment at 12 months; 82 infants had no PDMS–2 assessment carried out because they missed the follow-up appointment (n=15) or their parents were unable to cover a distance > 6 hours (n=67). Hence, the final study population for assessment of FMs and early motor repertoire comprised 243 infants. Twenty-eight of the infants with both GMA and PDMS–2 data were excluded from computer-based video analysis due to displacement on the mattress (n=21), errors in the video set-up (n=2), or technical problems (n=5). Thus the final study population for computer-based video analysis comprised 215 infants.

In order to determine the validity of our results for the whole VLBW population in the unit, data on neonatal morbidity was also collected for 267 VLBW infants who were discharged alive during the study period but were not approached for consent. Mortality before discharge was 16% among VLBW infants during the study period.

2.3. Video recordings and analysis of the early motor repertoire

Recordings, approximately 5 minutes long, were performed during active wakefulness using a standard set-up containing a stationary digital video camera (SANYO VPC-HD2000) placed at the foot end of a mattress. The video recordings were classified according to Prechtl's method.[(8)] Depending on the duration of pauses, the temporal organization of FMs was classified as "continual" if the FMs were only interspersed with brief pauses and as "intermittent" if the pauses were prolonged. FMs were classified as "normal" if continual or intermittently present, as "abnormal" if excessive in amplitude and speed, as "sporadic" if interspersed with longer than intermittent pauses, or as "absent" altogether.[(8, 9)]

FMs and the concurrent motor repertoire were assessed by three authorized and experienced GMA observers (L.A., T.F., and R.T.V), who were unaware of the infants' clinical histories and neurological statuses. The assessments were carried out by two of the observers and FMs were assessed independently. The concurrent motor repertoire was assessed by the same observers, who replayed the videos. In case of disagreement, both observers re-assessed the video together and a consensus was reached.

The presence and normality of individual movement and postural patterns, the quality of the concurrent motor repertoire, and the repertoire of co-existent other (age-adequate) movements were evaluated using the AMR.[10] Two items of the original AMR were removed from the present study: the item “saccadic arm movements” was removed so as not to be confused with exaggerated FMs, and “mouth movements” were disregarded because they co-occur with “tongue movements. ”Hand-face contact” and “hand-mouth contact” were regarded as one item. In accordance with Bruggink et al.,[10] the repertoire of co-existent other (age-adequate) movements was scored as “absent” if less than five normal movement patterns were observed, as “reduced” if five or six normal movement patterns were observed, and as “age-adequate” if seven or more normal movement patterns were observed. The quality of the concurrent motor repertoire was considered to be “normal” if smooth and fluent, and as “abnormal” if monotonous, jerky, or stiff. [11, 12] In accordance with Bruggink et al.,[10] we classified arm midline movements, postural pattern as “symmetrical” or “asymmetrical” and finger postures as “variable” or “few.”

2.4. Computer-based video analysis

The computer-based video analysis has been described elsewhere.[14, 15, 21] Briefly, a motion image was calculated based on subtracting subsequent frames in the video stream. Quantitative data were exported based on pixel values in the motion image. The quantity of motion (Q) is an estimate of the amount of movement in a video sequence and is calculated as the sum of all pixels changing between frames divided by the total number of pixels. The mean (Q_{mean}) and standard deviations (Q_{SD}) of the Q were calculated. The centroid of motion (C) is the spatial center of the pixels changing between frames reflecting the center of movement. The C can be seen as a correlate to the center point of the total movement of the infant. The variability of C was quantified as the standard deviation of the centroid (C_{SD}).

2.5. Assessment of motor development at 12 months of age

The motor development was assessed at 12 months post-term age by an occupational therapist (HBJ) who was unaware of the GMA results and used the Peabody Developmental Motor Scales-2 (PDMS–2). [22] Six motor functions were assessed in subtests of PDMS–2: 1) reflexes, 2) stationary, 3) locomotion, 4) object manipulation, 5) grasping, and 6) visual-motor integration. The subtests contribute to a Total Motor Quotient (TMQ). A quotient of 90 to 110 is considered as an average performance,[22] a score below 90 indicates the need for intervention. Each subtest also contributes either to the Gross Motor Quotient (GMQ) or the Fine Motor Quotient (FMQ).

2.6. Statistical analysis

IBM SPSS Statistics (Statistical Package for Social Sciences), version 21 (IBM, Armonk, New York) was used for statistical analysis. The PDMS–2 quotients and computer-based variables were not normally distributed examined by the Shapiro-Wilks test and non-parametric tests were applied. The estimated group medians and interquartile range for PDMS–2 quotient scores for infants with normal and abnormal FMs and early motor repertoire categories were calculated. The Kruskal-Wallis Test or the Mann-Whitney U test was applied to evaluate the association between GMA, AMR and PDMS–2 quotients. Logistic regression was applied to evaluate associations between computer-based video analysis scorings and dichotomized PDMS–2 quotients. Loss to follow-up was addressed by comparing clinical characteristics of the study group with those of infants who did not met for follow-up at 9 to 16 weeks post-term age. Throughout all analyses, $p<0.05$ (two-tailed tested) was considered to be statistically significant.

2.7. Ethics

The study was approved by the Institutional Research Board and Ethics Committee, Christian Medical College, Vellore, India, and the committee's recommendations were adhered to. Written informed consent was obtained from parents/legal guardians of all participating infants.

3. Results

Included infants were significantly younger than those not included in the follow-up (GA 31 vs. 32.1w, respectively; p=0.001) and had retinopathy of prematurity more than stage 2 more often (13 vs. 8%; p=0.034). There were no other clinical characteristics that had significant differences between the two groups. This indicated that the study sample was representative of VLBW infants discharged alive from this unit. Clinical details of the 243 infants included in the study and the 267 infants not approached for consent are presented in Table 1.

3.1. Assessment of the early motor repertoire

The median length of video recordings was 5 minutes (range 1–5), and the recordings were performed at a median age of 11 weeks post term (range 9–16). The details of FMs and their temporal organization are given in Table 2. Thirty-one infants (13%) were classified with abnormal, 212 (87%) with normal FMs. Eleven (4%) infants were classified with absent or reduced repertoire of co-existent other movements (age-adequacy). Five of them had video length of more than 5 minutes and 5 between 2 and 3 minutes. One infant had a video of 1 minute and 40 seconds. Further details about the motor repertoire are presented in Table 3. Lack of midline movements was observed in 10 (91%) of 11 infants with a reduced or absent age-adequate repertoire, and in 41 (18%) of 232 infants with an age-adequate repertoire of co-existent other movements.

3.2. Motor development at 12 months post-term age

The PDMS–2 was performed at a median age of 12 months (range 11–16) post term. Of the 243 children, 178 (73%) had an average (90 to 110), 43 (18%) a higher-than-average (>110), and 22 (9%) a lower-than-average (<90) Total Motor Quotient. The median TMQ was 103 (range 44–122), the median GMQ was 100 (range 50–119), and the median FMQ was 106 (range 46–124).

3.3. Association between early motor repertoire and later motor development

The temporal organization of FMs was significantly associated with the GMQ and the TMQ; the highest scores were achieved by infants with continual FMs (Table 2). Abnormal FMs were significantly more prevalent in children with TMQ scores < 80 (p=0.030). Reduced or absent age-adequacy and an abnormal concurrent motor repertoire were associated with lower GMQ and TMQ scores. Table 3 shows details in the association between the motor repertoire at 9–16 weeks post term and PDMS–2 quotients at 12 months post term.

3.4. Association between computer-based video analysis and later motor development

115 (54%) of the 215 infants who underwent computer-based video analysis were boys; their median birth weight was 1320 grams (range 760–1500), their median gestational age 31 weeks (range 26–39). Sixteen infants (7%) had a TMQ <90, and 4 of these had abnormal FMs. The C_{SD} was significantly higher in infants with a TMQ <90 than in children with a TMQ >90 (p= 0.002). None of the quantity of motion variables (Q_{mean} and Q_{SD}) were associated with a PDMS–2 quotient.

4. Discussion

The present study demonstrates that Prechtl's GMA and the computer-based video analysis of general movements are feasible in a follow-up program for preterm infants in India. The VLBW cohort in this study had a low prevalence of absent FMs and a low prevalence of abnormal motor outcomes at 12 months post term. However, abnormal FMs, an abnormal quality of the concurrent motor repertoire, and reduced or absent age-adequacy of the concurrent motor repertoire were significantly associated with lower gross and total motor scores at 12 months post term on the PDMS–2. In consistence with our hypothesis, infants with continual FMs had the highest TMQ scores at 12 months post term. The present study also found that infants with a less variable spatial center of movements assessed by computer-based video analysis had higher TMQ scores on the PDMS–2 at 12 months of age.

This is the first study to use Gestalt perception and computer-based video analysis of FMs and the concurrent motor repertoire in preterm infants in India. A large cohort of VLBW infants was included. Infants in the same birth-weight stratum who were not included in the study constituted almost identical neonatal risk classifications but had a slightly higher birth weight and gestational age and less neonatal morbidity. Since the differences were subtle, we suggest that our sample is representative of VLBW infants discharged alive from this unit.

Only 8 (3%) infants showed no FMs; 5 (2%) infants had exaggerated FMs, 18 (8%) had sporadic FMs suggestive of more uncertain outcomes.[(8)] In accordance with this, only 9% had a lower-than-average TMQ on the PDMS–2 at 12 months post term. The prevalence of CP among VLBW infants has been reported to be between 1 and 16%.[(2, 23-26)] Numbers from India are scarce, and the high incidence of fetal growth restriction [(27, 28)] results in a higher proportion of small but more mature infants when birth weight is used as an inclusion criterion. Another explanation for the small number of children with abnormal FMs and a poor motor performance at 12 months might be that the most severely ill infants do not survive the neonatal period.

The present study found a significant association between infant motor repertoire and later motor development even within the normal range. This is consistent with other studies suggesting that the quantity and quality of early motor repertoire is associated with later development.[(10-12)] In particular, normal FMs, an age-adequate repertoire of co-existent other movements, and a normal quality of the concurrent motor repertoire were all associated with a better gross motor function at 12 months post term. A normal quality of the concurrent motor repertoire was also associated with higher FMQ scores. Interestingly, infants with few finger postures had lower FMQ scores. This is in accordance with Bruggink et al., who found variable finger postures to be less frequent in children developing a complex minor developmental dysfunction.[(10)] In contrast to Bruggink et al., we found no associations between the postural pattern or arm midline movements and later motor development.[(10)]

The temporal organization of FMs was classified in detail in 2004,[(8)] but its clinical significance is still unclear except for the well-established relationship between absent FMs and CP. The present finding of higher motor scores in infants with continual FMs suggests that the temporal organization of FMs is clinically relevant for the later motor function within the high/normal range.

Our assessment of associations between the computer-based video analysis of fidgety general movements and later motor development confirmed previous findings of a correlation between a high variability of the spatial center of movements and an increased risk of a poor motor outcome.[(15, 21)] So far, computer-based analysis of GMs cannot replace Gestalt assessment of GMs. However, both methodological approaches could rather complement each other and improve our understanding of GMs. Furthermore, the obvious clinical benefit using computer-based assessment of GMs could be a reduced demand for skilled GMA observers to be used in large scale screening of infants. The clinical usability of computer-based movement analysis for predicting later motor performance remains to be clarified in more comprehensive follow-up studies. Motor assessment at a later age is required to establish the clinical significance of our findings.

5. Conclusion

In conclusion, we found that Gestalt perception and computer-based video analysis of FMs in VLBW infants are feasible in South India. The findings on the early motor repertoire suggest an association with the motor development at 12 months post-term age. Presence of FMs, a normal quality of the concurrent motor repertoire, variable finger postures, and low variability of the spatial center of movements assessed by computer-based video analysis indicate a normal and healthy motor development. Our findings also indicate that continual FMs are associated with a better motor outcome.

6. Conflict of interest

The authors declare no conflict of interest.

7. Acknowledgements

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Table 1

Clinical characteristics of the study cohort (birth weight ≤1500 g): comparing the study group with infants who were not included in the follow-up at 9 to 16 weeks post term age.

	Study group (n=243)		Not included (n=267)		
	Median	IQR	Median	IQR	*p*-value
Gestational age (weeks)	31.0	30.0-33.0	32.1	30.2-34.0	0.001
Birth weight (g)	1300	1150-1440	1320	1200-1420	0.295
	n	%	n	%	
Boys	135	56	135	51	0.260
Sepsis with cardiorespiratory instability and/or meningitis	14	6	11	3	0.390
Severe BPD with supplemental oxygen at discharge	5	2	4	2	0.632
Cystic PVL	8	3	3	1	0.092
Non-cystic PVL	20	8	13	5	0.123
Cerebral ultrasound					
- IVH I-II	34	14	27	10	0.177
- IVH III-IV	4	2	3	1	0.612
Hypoglycemia	19	8	28	11	0.348
ROP > grade II	32	13	20	8	0.034
PDA	30	12	29	11	0.601
NEC	4	2	6	2	0.625
Shock	35	14	47	18	0.326
Hyperbilirubemia	176	72	191	72	0.823

Abbreviations: IQR, interquartile range; BPD, bronchopulmonary dysplasia; PVL, periventricular leukomalacia; IVH, intraventricular hemorrhage with grading according to Papile; [20] ROP, retinopathy of prematurity; PDA, patent ductus arteriosus; NEC, necrotizing enterocolitis

Table 2

Temporal organization of fidgety movements at 9 to 16 weeks post term and Peabody Developmental Motor Scale quotients at 12 months post term.

Temporal organization of FMs (%)	GMQ Median (IQR)*		FMQ Median (IQR)		TMQ Median (IQR)**	
Absent; n=8 (3)	95	(91-100)[a]	103	(94-106)	97	(94-101)[e]
Sporadic; n=18 (8)	97	(91-102)[b]	107	(92-115)	102	(90-105)
Intermittent; n=155 (65)	100	(94-106)[c]	106	(100-112)	103	(97-107)[f]
Continual; n=57 (24)	104	(98-109)[d]	109	(103-115)	107	(101-111)[g]

Five infants (2%) with exaggerated FMs (abnormal FMs) were excluded because their temporal organization could not be scored. Abbreviations: FMs, fidgety movements; GMQ, gross motor quotient; FMQ, fine motor quotient; TMQ, total motor quotient; IQR = interquartile range.
*p=0.002; [a-d] p=0.032, [b-d] p=0.019, [c-d] p=0.038; **p=0.002, [e-g] p=0.013, [f-g] p=0.031

Table 3
Motor repertoire at 9 to 16 weeks post term and Peabody Developmental Motor Scale quotients at 12 months post term.

	GMQ		FMQ		TMQ	
	Median (IQR)	*p*-value	Median (IQR)	*p*-value	Median (IQR)	*p*-value
Fidgety movements (FMs)						
Normal (continual/intermittent, n=112)	100 (94-106)	.005	106 (100-112)	.511	104 (98-108)	.042
Abnormal(exaggerated, sporadic, absent, n=31)	96 (94-102)		106 (94-115)		101 (94-105)	
Repertoire of co-existent other movements						
Age-adequate (n= 232)	100 (94-106)	.038	106 (100-112)	.069	104 (98-108)	.025
Reduced/absent (n= 8/3)	96 (91-98)		100 (97-109)		97 (94-104)	
Presence and normality of individual movement patterns						
Normal (n=239)	100 (94-106)	.189	106 (100-112)	.347	103 (97-108)	.223
Abnormal (n=4)	95(61-101)		104 (59-109)		99 (56-104)	
Presence and normality of individual postural patterns						
Normal (n=219)	100 (94-106)	.326	106 (100-115)	.053	104 (97-108)	.176
Abnormal (n=24)	99 (94-102)		104 (94-109)		103 (95-105)	
Quality of the concurrent motor repertoire						
Normal (smooth & fluent; n=154)	102 (96-106)	.022	106 (103-115)	.026	104 (98-108)	.020
Abnormal (not smooth & fluent; (n= 89)	98 (94-104)		106 (97-112)		103 (96-107)	
Observed symmetric postural pattern						
Symmetry (n=209)	100 (94-106)	.147	106 (100-115)	.180	104 (97-108)	.140
Asymmetry (n=34)	98 (94-102)		101 (97-109)		103 (97-105)	
Arm midline movements						
Present (n=95)	100 (94-104)	.304	106 (100-112)	.467	103 (97-107)	.316
Absent (N=148)	100 (94-106)		106 (100-114)		103 (97-108)	
Finger postures						
Variable (n=193)	100 (94-106)	.338	106 (100-115)	.048	104 (97-108)	.185
Few (n=45)	98 (94-104)		106 (97-112)		103 (97-107)	

Abbreviations: GMQ, gross motor quotient; FMQ, fine motor quotient; TMQ, total motor quotient; IQR, interquartile range