

The comparison of general movements assessment and neurological examination during early infancy

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This prospective single-blinded study was performed to evaluate general movements (GMs) in group of high-risk, low-birth-weight and preterm infants and to compare results with neurologic examination. All infants' neurologic examinations, Gross Motor Function Measurement (GMFM) and Bayley-III Scale were performed at the corrected age of 12 months. A total of 22 infants were included. Eight infants (group-1) (mean: 31.6±3.29 weeks, range: 25-36 weeks) had normal GMs in all recordings and were ultimately evaluated as "normal"; 12 (group-2) (mean: 31.6±3.29 weeks, range: 25-35 weeks) had abnormal GMs during writhing movements period but had normal GMs in subsequent recordings and were evaluated as "normal"; and 2 infants (group-3) (mean: 29.5±7.78 weeks, range: 24-35 weeks) with consistent abnormal GMs who were evaluated as "abnormal." Complete agreement (kappa=1) was found between GMs and neurologic examination and significant agreement between GMs and cranial ultrasonography (kappa=0.76). When results of GMFM and Bayley-III were compared; statistically significant differences were found between group-1 and group-2 in "standing" parameter of GMFM (p<0.05) and "cognitive" parameter of Bayley-III (p<0.05). GMs assessment can help determine neurologic disorders in high-risk infant populations as an adjunct to other diagnostic techniques.

Key words: general movements, preterm infants, low birth weight, neurological examination, Bayley-III.

Prematurity and low-birth-weight (LBW) are the most important risk factors for abnormal neurologic outcomes. Cerebral palsy (CP) is an important neurologic disease that has higher prevalence and has an effect on decreasing maturity following preterm birth. Extremely preterm infants (postmenstrual 22-32 weeks) have the highest risk for CP^{1,2}.

Prechtl's method on the qualitative assessment of general movements (GMs) has proven to be a valid and reliable technique for the functional assessment of the immature nervous system. Several studies have shown that the analysis of GMs plays a major role in predicting the neurologic outcome of premature infants³⁻¹⁰. Subsequent fetal studies on the importance of

different prenatal movement patterns revealed an onset of GMs at 9 weeks postmenstrual age. GMs continue to be present during the entire prenatal period until approximately 5 to 6 months post-term¹¹.

Recent studies focused on the relationship between GMs and cognitive function, behavioral problems or minor neurologic dysfunction¹²⁻¹³. The aim of this study was to evaluate GMs in a group of preterm LBW infants, and to compare the results with neurologic examination findings.

Material and Methods

This prospective study was planned and performed as single-blind in a preterm infant

cohort in the Division of Child Neurology Unit and Neonatal Intensive Care Unit, Istanbul Medical Faculty, Istanbul University between 2011 and 2013. The study was approved by the Ethics Committee of the Faculty of Medicine, Istanbul University, 1769 in 03.11.2011. Informed consents were received from parents.

Patients

Preterm LBW infants with a gestational age of <37 weeks and birth weight <2500 g in the Neonatal Intensive Care Unit (NICU) were included in the study. The exclusion criteria for the study were; infants with congenital malformations, genetic and metabolic diseases, ongoing mechanical ventilation therapy, and infants whose parents did not want to participate in the study. Twenty-two preterm low-birth-weight (LBW) infants (14 girls and 8 boys) were included in the study. After the following assessments, the infants were divided into groups according to GMs results. Group 1 included 8 infants who had normal GMs in all recordings and were ultimately evaluated as “normal”; group 2 comprised of 12 infants who had abnormal GMs during writhing movements period (38-48 weeks postmenstrual age) but had normal GMs in the following recordings and were ultimately evaluated as “normal”; and group 3 constituted of 2 infants who had consistent poor repertoire (PR) GMs and cramped-synchronized (CS) GMs, and absent fidgety movements (FMs) in the fidgety period (46-60 weeks postmenstrual age), who were ultimately evaluated as “abnormal.”

Assessments of general movements (GMs)

A video camera was stabilized on a tripod and the infants were filmed midsagittally or laterally from above. The video recording period was 20-30 minutes for preterm and writhing movements and 10-15 minutes for the FMs period, excluding crying, fussing or sucking durations. During recording periods the infants were in a supine position in the incubator or on the bed depending on their ages. Any stimulus that could affect GMs was avoided, such as mirrors, toys or communication with parents. The infants were required to wear thin vests with arms and legs bare or only with diapers. The room/incubator temperature were adjusted according to the infants needs.

General movements involve the whole body in

a variable sequence of arm, leg, neck, and trunk movements. The movements of the different body parts do not occur in a complex way as seen in normal GMs during preterm, term, and early postterm age (first two months). GMs are called preterm GMs before term and “writhing movements” from term until approximately 6-9 weeks post-term. The form and character of GMs of normal infants, 6 to 9 weeks post-term, change from the writhing type to a fidgety pattern^{11,14}. The types of normal GMs are defined as follows:

Preterm GMs: Preterm infant may occasionally have large amplitude GMs that are often fast in speed.

Writhing movements: These movements are characterized by small to moderate amplitude with slow to moderate speed.

Fidgety movements: FMs (46-60 weeks postmenstrual age) are small movements with moderate speed and variable acceleration of the limbs, trunk, and neck in all directions in the awake infant, without fussing and crying. FMs are present until around 6 months of age when intentional and antigravity movements occur and start to dominate¹¹.

The types of abnormal GMs are defined as: PR GMs, CS GMs, and chaotic (Ch) GMs (Table I). If the nervous system is impaired, FMs can be either abnormal or absent. A GMs-certified physiotherapist, recorded the videos of the spontaneous motor activities of infants from birth until corrected 5 months of age. No video recording was performed in the first 3 days of life because there are many physiologic and behavioral state fluctuations in this period of newborns¹¹. Two to five video recordings were obtained for each infant in our study. The 1st (29-31 weeks), 2nd (32-37 weeks), and 3rd (38-44 weeks) recordings were examined for “preterm and writhing movements,” and the 4th (48-50 weeks) and 5th (50-55 weeks) recordings were evaluated for FMs.

The evaluating physiotherapist was blinded to the prenatal and postnatal history of the infant. The findings were classified as normal (N), PR, or CS in the writhing period, and as normal fidgety (N), abnormal fidgety (AF), or absence of fidgety (F-) movements in the fidgety period.

The first assessments of the study cohort were

Table I. Abnormal General Movements¹¹

Poor Repertoire GMs (PR)	Movements of different body parts do not occur in the complex way seen in normal GMs and whereby the sequence of GMs is monotonous; speed, amplitude and intensity lack the normal variability
Cramped-synchronized GMs (CS)	This abnormal GMs pattern appear rigid as they lack usual fluent character and muscles contract and relax almost simultaneously.
Chaotic GMs (Ch)	In this pattern movements consistently appear jerky and occur in large amplitude and high speed.
Abnormal FMs	Amplitude and speed of FMs are exaggerated. These movements are seen rarely.
Absence of FMs	FMs could not observe.

GMs: General Movements, FMs: Fidgety Movements

made by observing the GMs only. The patients were classified as normal or abnormal according to GMs results. After a one-year follow-up period, the prenatal and postnatal history of the patients, including examinations such as cranial ultrasonography, were reviewed from their data to provide bias about the clinical status of the patients before assessments.

Developmental outcome measures

At corrected 12 months of age, reflexes and motor development of infants were examined by a specialist of child neurology who was blinded to the study groups. The Modified Ashworth Scale (MAS) is the most commonly used clinical measure of muscle spasticity¹⁵. In the present study, muscle tone was evaluated while infants were in supine position using MAS. The following muscles were evaluated using MAS: musculus (m) biceps brachii, m. triceps brachii, m. iliopsoas, adductor muscles of the hip (m. adductor longus, m. adductor brevis, m. adductor magnus, m. gracilis), hamstrings (m. biceps femoris, m. semitendinosus and m. semimembranosus), m. gastrocnemius.

Motor development was assessed using Gross Motor Function Measurement (GMFM). GMFM is commonly used to measure changes in gross motor function and to enable the development of scientific research studies on children with CP. The GMFM consists of 88 items in five dimensions: supine-prone (lying and rolling), sitting, crawling-kneeling, standing and walking-running¹⁶. In our study, supine-prone, sitting, crawling-kneeling and standing parameters of GMFM were used.

The Bayley-III Scale was used to assess motor, cognitive, and language development.

The latest revision of the Bayley-III Scale is commonly used to identify infants at risk for developmental impairment and includes distinct composite scores: cognitive, language, and motor¹⁷.

Statistical analysis

Qualitative variables are presented as percentages and quantitative variables are shown as means with standard deviations. Cohen-Adjusted Kappa was used to correlate the assessment of GMs, cranial ultrasonography, and neurologic examinations. The percentage agreement ratio of 0.20 was accepted as non-significant, 0.21-0.40 as minimal agreement, 0.41-0.60 as moderate agreement, 0.61-0.80 as significant agreement, and 0.81-1.00 as complete agreement¹⁸. The Mann-Whitney U test was used to compare differences between the groups, and statistical significance was accepted as $p < 0.05$.

Results

At the beginning of the study 38 infants were eligible for the assessments. Sixteen were excluded from the study because they did not complete their follow-up assessments, and one died. Twenty-two high-risk infants (14 girls, 8 boys) were included in the final assessment. The gestational age ranged between 25-35 weeks (mean: 29.7 ± 3.6 weeks) and the birth weights ranged from 595 g to 2150 g (mean: 1352 ± 582 g). The demographic and clinical characteristics of the infants are shown in Table II.

Two to five video recordings were taken for GMs assessment. Two infants had five recordings, seven infants had four recordings, seven infants

Table II. Demographic and Clinical Characteristics of the Infants *

Gender (male/female), n	8/14
Gestational age (week), mean±SD	29.7 ± 3.6
Birth weight (g), mean±SD	1352 ± 582
Head circumference (cm), mean±SD	26.8 ± 2.2
APGAR score, mean±SD	
1st minute	6 ± 1
5th minute	8 ± 1
Type of pregnancy, n	
Spontaneous	18
Assisted reproductive technology	4
Type of birth, n	
Vaginal	3
Cesarean section	19
Multiple pregnancy, n	
None	19
Twin	4**
Respiratory distress syndrome, n	1
Pneumonia	4
Retinopathy of prematurity	2
Patent ductus arteriosus	3
Necrotizing enterocolitis	4
Neonatal sepsis	3

*A patient may be in more than one diagnosis

**An infant died

had three recordings, and six infants had two recordings. The GMs results of all infants are given in Table III.

The GMs results were categorized into 3 groups:

Group 1 (n=8): Infants who had normal GMs in all recordings and were ultimately evaluated as “normal” (case no: 2,5,6,8,9,12,14,17).

Group 2 (n=12): Infants who had abnormal GMs during writhing movements period (PR and CS) but had normal GMs in subsequent recordings and were ultimately evaluated as “normal” (case no: 1,3,4,7,10,11,13,16,18,19,20,22).

Group 3 (n=2): Infants who had consistent PR and CS GMs and FMs were absent in the fidgety period. These infants were ultimately evaluated as “abnormal” (case no: 15,21).

The neurologic examination was completed at the corrected age of 12 months for all infants. Increased muscle tone in both of the upper and lower extremities (upper=2, lower=3) was found in one infant, while only in the

lower extremities (lower=3) in another infant according to MAS. With the exception of these two infants, 20 had normal reflexes, muscle tone, and gross motor function. Complete agreement ($\kappa=1$) was found between GMs and the results of the neurologic examinations.

At the age of corrected 12 months, the GMFM and Bayley-III Scale were used to evaluate the infants. The scores of the GMFM and Bayley-III Scale of all infants are shown in Table IV. Two infants in group 3 (abnormal GMs results) also had lower GMFM and Bayley-III scores than the other infants.

The results of GMFM and Bayley-III Scale were compared between group 1 and group 2. We found statistically significant differences between the groups only in the “standing” parameter of GMFM ($p<0.05$) and “cognitive” parameter of the Bayley-III Scale ($p<0.05$) (Table V). No statistically significant difference was found in other parameters between the groups.

One or more cranial ultrasonography images

Table III. The results of GMs Assessment

Case no	Writhing movements			Fidgety movements		Results
	1.record 29-31 weeks	2.record 32-37 weeks	3.record 38-44 weeks	4.record 48-50 weeks	5.record 50-55 weeks	
Group I						
2	-	-	N	-	N	N
5	N	N	-	N	N	N
6	-	-	N	N	-	N
8	-	N	N	N	-	N
9	-	N	N	N	N	N
12	-	-	-	N	N	N
14	N	N	-	-	-	N
17	N	N	N	-	-	N
Group II						
1	PR	-	-	N	N	N
3	PR	PR	-	N	N	N
4	-	PR	PR	N	N	N
7	CS	PR	N	N	N	N
10	CS	N	-	N	-	N
11	PR	N	-	-	-	N
13	PR	N	-	-	N	N
16	-	PR	N	-	-	N
18	-	PR	N	N	N	N
19	PR	PR	-	N	N	N
20	CS	PR	-	N	N	N
22	PR	N	N	-	-	N
Group III						
15	CS	CS	CS	F-	F-	AN
21	CS	CS	-	-	F-	AN

N: Normal, AN: Abnormal, PR:"Poor Repertoire", CS:"Cramped-Synchronized", F-:"Absent Fidgety"

were obtained from each infant during hospitalization. The last cranial ultrasonography obtained before discharge was included in the study. However, the ultrasonography findings were not known and were reviewed from their data when infants reached the corrected age of 12 months. We compared cranial ultrasonography and GMs assessment, and significant agreement was found between GMs and cranial ultrasonography ($\kappa=0.76$).

Discussion

In our study, which aimed to evaluate GMs and compare the GMs assessment results with

the findings of neurologic examinations, we demonstrated high consistency between GMs results and neurologic assessment in a group of high-risk, preterm LBW infants. A high degree of agreement was found between the results of GMs and neurologic examinations at the corrected age of 12 months.

Assessment of GMs is a non-invasive method that can be performed without expensive equipment¹¹. The assessment of GMs may be useful in the determination of possible neurologic impairments that may occur in the future. The assessments are dependent on Gestalt perception of the observers¹⁹; therefore,

Table IV. GMFM and Bayley-III Scores of all Infants

GMFM Scores, mean±SD	
Supine-prone	97.2 ± 1.9
Sitting	92.1 ± 13.7
Crawling-kneeling	77.3 ± 10.5
Standing	60.5 ± 10.8
Bayley-III Scores, mean±SD	
Cognitive	88.6 ± 11.2
Gross motor	84.8 ± 12.9
Language	85.8 ± 14.8

GMFM: Gross Motor Function Measure

there have been some arguments about the subjective nature of the method. However, Valentin et al.²⁰ found the inter-observer reliability of GMs to be 90%. Abnormal GMs, especially cramped-synchronized GMs, seem to be a predictor of permanent motor impairment⁴. Nakajima et al.²¹ studied 18 preterm infants with 22 weeks post-term age and concluded that the detailed score of poor repertoire GMs was not related to neurologic outcomes but indicated that FMs have specific predictive value for neurologic outcomes. In our study, PR GMs were not found predictive for neurologic outcomes and the infants with PR GMs developed normal FMs. CP was predicted through consistent and predominant CS GMs according to Ferrari et al.⁴. In the same study, the authors also indicated that it is wise to

continue video recording when CS GMs became intermittent to determine whether they were transient or consistent, and whether FMs would appear. We followed-up infants who had persistent CS GMs during the FMs period.

Cioni et al.^{3,22} showed that the results of GMs assessment were highly correlated with neurologic outcomes. According to a review²³ there is good evidence that GMs assessment can accurately predict the development of CP. In our study, infants who had persistent abnormal GMs showed CP symptoms and those who had normal GMs demonstrated normal neurologic development at a corrected age of 12 months, which supports findings in the literature. Infants with CP symptoms were included in 2-year follow-up period and were diagnosed as having CP. One infant had level-II by Gross

Table V. The differences in GMFM and Bayley-III scores between Group 1 and Group 2

	Group 1 (n=8) mean±SD	Group 2 (n=12) mean±SD	p
GMFM scores, mean±SD			
Supine-prone	100	100	1.0
Sitting	99.3 ± 1.9	98.7 ± 3.1	0.851
Crawling-kneeling	81.3 ± 11.3	85.7 ± 11.7	0.305
Standing	80.2 ± 16.7	57.3 ± 20.3	0.025*
Bayley-III scores, mean±SD			
Cognitive	95 ± 7.1	86.6 ± 8.3	0.047*
Gross motor	89.1 ± 13	85.6 ± 8.5	0.571
Language	91.8 ± 3.5	85.8 ± 12.5	0.208

GMFM: Gross Motor Function Measure

*p<0.05

Motor Function Classification Scale (GMFCS) and the other had level-V by GMFCS.

The provision of a developmental trajectory for each individual is the most important advantage of the GMs assessment, by indicating consistency or inconsistency of normal or abnormal findings. Ferrari et al.⁴ supported that infants with similar neurologic outcomes had similar developmental trajectories. In the same study, consistency in time or predominance from preterm birth to 5 months post-term age, specifically the CS character of GMs, was reported to determine development of subsequent CP. The authors also confirmed that normal FMs following transient abnormalities of GMs indicates a normal outcome, and absence of FMs suggest a neurologic deficiency. The predictive value of FMs period is known to be more effective than other periods. Several studies have demonstrated a relationship between the quality of GMs and neurologic outcomes during the FMs period^{7,9,19,24}. The quality of FMs was shown to allow valid determinations about neurologic outcomes such as the first signs of spasticity by Precht et al.¹⁴. Similar to previous studies, we observed high consistency between FMs and neurologic outcomes. Infants who had normal FMs had normal neurologic outcomes.

Repeated recordings of GMs are more valuable in the neurodevelopmental follow-up of infants rather than single GMs recording^{22,25}. In our study, we performed at least two and a maximum of five video recordings per infant from birth to 6 months. The absence of FMs is highly predictive for the development of CP and it is necessary to use at least one video recording and a second recording if FMs are not described in the first recording¹¹. Nevertheless, Mutlu et al.¹⁰ showed high consistency between FMs and neurologic outcomes using only one recording. In our study, we tried to provide at least one recording during the FMs period at 48-55 weeks of gestation. Eleven infants had two video recordings, six had one video recording, and unfortunately, five had no video recordings in the FMs period. Two infants had absent FMs and the result of their neurologic examination was CP. Adde et al.²⁶ evaluated 52 preterm and term infants' FMs recordings using computer-based software and they showed that using two video recordings

rather than one improved the computer vision-based identification of FMs. We suggest that the computer-based method in detecting FMs would be helpful and easy in future studies.

Kodric et al.²⁷ studied GMs of 26 preterm infants with 23-36 weeks gestational age and the results of GMs were compared with the results of the Bayley mental and psychomotor developmental index which was assessed between two and three years of chronologic age. The authors reported that infants with normal writhing GMs and normal FMs achieved the highest scores on the mental and psychomotor developmental index, while the infants with CS GMs. This was also true in our study, the infants who had no FMs had the lowest scores in all parameters of Bayley-III and GMFM. Bruggink et al.²⁸ showed that the quality of GMs during early infancy for preterm children was a marker for intelligence at school age. They also reported when GMs normalized before term, IQ scores were within normal limits and when GMs were persistently abnormal until 8 weeks after term IQ scores were lower. In the present study, we also compared Bayley-III and GMFM results of infants who had persistent abnormal GMs (group 3), and those with abnormal GMs with normal GMs in subsequent recordings (group 2) at the corrected age of 12 months. A statistically significant difference was found in the "standing" parameter of GMFM ($p < 0.05$) and "cognitive" parameter of the Bayley-III Scale ($p < 0.05$). High-risk infants must be closely monitored, especially in developmental terms, because of their high-risk of growth retardation²⁹. If we performed this comparison in earlier months, perhaps using other parameter (sitting, crawling, etc.) differences could occur. On the other hand, preterm infants with low scores could catch up with other infants by 12 months on the differences that we found between Bayley-III and GMFM scores in the future. We think future studies should focus on comparing results of long-term follow-up and with larger study groups.

Many studies detected the predictive value of GMs as high, as well as the neurologic assessment and cranial ultrasonography^{14,30}. Seme-Ciglencecki³¹ showed that cranial ultrasonography had a lower sensitivity but almost the same specificity as GMs. Mutlu et

al.¹⁰ found complete agreement ($\kappa=0.86$) between cranial ultrasonography findings and GMs. Cioni et al.²² found 78-83% compliance between neurologic assessment and GMs. Our findings also supported these studies with significant agreement ($\kappa=0.76$) between cranial ultrasonography and GMs.

Many studies have reported a correlation between abnormal GMs and subsequent neurologic impairments, such as CP and minor neurologic deficits^{14,19,32-34}. A limitation of our study was the inability for long-term follow-up of the infants. The other limitation of our study was that we could not recruit more patients, because it was difficult to convince the parents to join the study. We could not reassess and follow-up more infants because the parents were reluctant to bring their babies back to the hospital after a long hospitalization period in the NICU. Postpartum depression may have also had an effect on this unwillingness.

Conclusion

The assessment of the quality of GMs, especially CS GMs and FMs, can help to determine neurologic disorders in high-risk infants. In conclusion, we suggest the combination of neurologic examination, GMs, and other methods to detect neurologic impairment in high-risk, preterm LBW infants. Studies are needed with frequent follow-up examinations completed over a long-term period, with a high number of infants.

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