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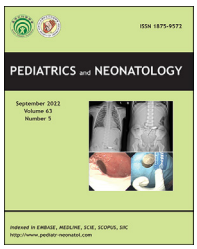

Original Article

General movements assessment and Alberta Infant Motor Scale in neurodevelopmental outcome of preterm infants

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Aim: We aimed to compare the General Movement Assessment (GMA) and the Alberta Infant Motor Scale (AIMS) in preterm infants for the prediction of cerebral palsy (CP) and neurodevelopmental delay (NDD). Additionally, we aimed to evaluate the diagnostic compatibility of the General Movement Optimality Score (GMOS), the Motor Optimality Score (MOS), and AIMS for detecting CP and NDD.
Method: Seventy-five preterm infants with gestational age (GA) 24–37 weeks were enrolled. Group 1 was composed of infants with 24–28 GA (n = 22); groups 2 and 3 consisted of infants with 29–32 GA weeks (n = 23) and 33–37 GA (n = 30) weeks, respectively. The infants were assessed during the writhing period, the fidgety period, and at 6–12 months of corrected age with GMOS, MOS, and AIMS, respectively.
Results: In the writhing period, a cramped-synchronized pattern was observed in 17 (22%) infants, whereas a poor repertoire pattern was observed in 34 (45%) infants. In the fidgety period of the 63 infants, 29 (46%) presented with fidgety movements absent. The MOS and AIMS scores of the infants in group 1 were significantly lower than the other groups, which were statistically significant (p = 0.004, p<0.001). High and positive compatibility (Kappa coefficient: 0.709; p = 0.001) was found between AIMS and GMOS scores and between AIMS and MOS scores

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(Kappa coefficient: 0.804; $p < 0.001$). In all groups, a statistically significant association was found between total GMOS scores ($p = 0.003$) and the presence of fidgety movements ($p = 0.003$). GMOS, MOS, and AIMS were found to be associated with CP and NDD ($p < 0.001$). *Conclusion:* GMA is an important tool for the prediction of CP and NDD. The combined use of GMOS, MOS, and AIMS may guide the clinical practice for the valid and reliable diagnosis of CP and NDD.

1. Introduction

Over the past decades, advances in clinical management such as the use of prenatal corticosteroids, intratracheal surfactants, and mechanical ventilators have dramatically improved the survival rates of preterm and low-birth-weight infants.[1] Despite the diminished rates of mortality, severe neurological morbidity of these infants continues to be a global health problem. There is an increased number of neuromotor impairments on a spectrum from developmental coordination disorder to cerebral palsy (CP).[2] Although transient neurological problems that disappear in the second year of life occur in 40–80% of preterm infants, 4–20% of extremely low birth weight infants develop severe and definite neurological sequelae.[3]

CP occurs as a result of a brain injury to the fetus or infant that causes a non-progressive permanent disorder limiting the development of posture and movement.[4] Extremely preterm infants are at an increased risk of CP, with an incidence ranging from 8 to 40%.[5] The evaluation of infants at risk for neurodevelopmental delay (NDD) and CP is based on the combination of clinical history, standardized motor and neurologic assessment, and neuroimaging.[6]

Prechtl's qualitative General Movement Assessment (GMA) is a reliable and valid tool that evaluates the spontaneous movements of infants and predicts the later adverse neurodevelopmental outcomes.[7] The sensitivity of the GMA in recognizing CP was reported as 100% sensitivity with 98% specificity.[8] Einspieler et al.[9] used an optimality list at preterm to early term age; combined GMA and the optimality list was described as the General Movement Optimality Score (GMOS). They reported that GMOS distinguishes between normal and abnormal GMs (General Movements). Although several studies reported that GMOS differentiates typical and atypical early motor function, the prediction of long-term neurodevelopmental outcomes is not clear.

The Motor Optimality Score (MOS) is a detailed GMA that evaluates age-specific motor repertoire including fidgety movements, other movements, and postural patterns that should be present between 9 and 20 weeks postnatally. It was reported that MOS has a high reliability for detecting NDD and CP.[10,11]

The Alberta Infant Motor Scale (AIMS) is an observational discriminative test used to evaluate gross motor development from birth until the achievement of walking independently. It is an inexpensive and quick method that does not require excessive handling of the child. The 5th or 10th percentiles were adopted as cut-off points to calculate the prevalence of delayed gross motor development.[12] The sensitivity and specificity values of AIMS to recognize delayed gross motor development at 8 months of age are 86% and 93%, respectively.[13]

The aim of the present study is to evaluate the spontaneous motor development of preterm infants who were born between 24 and 37 weeks of gestational age (GA) by using GMOS in the writhing period and MOS in the fidgety period, as well as to compare the findings of GMA and AIMS at 6–12 months of corrected age. In addition, we aim to assess the prognostic value of GMA and AIMS for detecting CP and NDD.

2. Material and methods

This prospective study was conducted between February 2019 and February 2020 at Bahcesehir University School of Medicine, Goztepe Medical Park Hospital Neonatal Intensive Care Unit (NICU). The present study was executed in accordance with the Declaration of Helsinki and approved by the Clinical Research Ethics Committee of the same university (20 February 2019, 2019–04/06).

2.1. Study population

Neonates with a gestation between 24 and 37 weeks that stayed in the NICU until discharge were enrolled ($n = 75$). The study sample was divided into three groups according to GA: group 1 was composed of infants ($n = 22$) whose GAs were 24–28 weeks, group 2 consisted of infants ($n = 23$) whose GAs were 29–32 weeks, and infants with GAs of 33–37 weeks ($n = 30$) constituted group 3.

Premature infants who had congenital malformations and chromosomal disorders were not included in the study.

Demographic and clinical data about mothers and neonates were collected in terms of birth weights (BW), GA, genders, modes of delivery, Apgar scores ≤ 3, multiple pregnancies, intraventricular hemorrhages (IVH), periventricular leukomalacia (PVL), and hypoglycemia.

2.2. General Movement Assessment (GMA)

Parents were asked whether they wanted to have their infants serially video recorded; written informed consents were obtained prior to enrollment from those who agreed

to participate. The infants were videoed for a detailed assessment of GMOS during the writhing period (from birth to 4 weeks of corrected age) and MOS during the fidgety period (3–5 months of corrected age). The first videos were recorded during the NICU stay, and the second videos were recorded postnatally as inpatients or outpatients at 10–16 weeks. All video recordings were individually evaluated by three certified observers (AA, AG, YC) in GMA; all were blinded to the infants' clinical histories. General movements were categorized as normal or abnormal, according to qualitative age-specific features.

2.3. Procedure for assessment of motor repertoire (GMOS)

An optimality score (OS) of motor repertoire was calculated at writhing age. The GMOS was calculated from the following categories: quality (max 4 points), sequence (max 2 points), amplitude (max 2 points), speed (max 2 points), space (max 2 points), rotary components (max 2 points), onset and offset (max 2 points), and tremulous movements (max 2 points). The global assessment included GMs classified as normal, poor repertoire, cramped-synchronized, or chaotic.[14]

The preterm infants were assessed in the writhing period when they were up to 37 weeks of gestation. GMOS differentiated the normal GMs (median 39 [37–41 points]), the poor repertoire GMs (median 25 [22–29 points]), and the cramped-synchronized GMs (median 12 [10–14 points]). The OS for chaotic GMs (mainly occurring at late preterm age) was similar to those for cramped-synchronized general movements (median 14 [12–17 points]).[14]

2.4. Procedure for assessment of Motor Optimality Score (MOS)

The assessment of motor repertoire (through MOS) is an evaluation of the quality and quantity of the motor repertoire concurrently noted during GMA in the fidgety period (3–5 months of corrected age). It is calculated from the following categories: fidgety movements (max 12 points), repertoire of coexistent other movements (max 4 points), quality of other movements (max 4 points), posture (max 4 points), and movement character (max 4 points). The maximum MOS was 28 points. In the present study, 63 infants were assessed with MOS using video recordings when they were 3–5 months old.[15]

2.5. Alberta Infant Motor Scale (AIMS)

AIMS assesses gross motor development of children aged 0–18 months, detecting through 58 items in prone, supine, sitting, and standing positions. Unobserved skills were assigned 0 points, and observed skills were assigned 1 point. The pediatric neurologist examined all infants between 6 and 12 months of corrected age. After the neurologic examination, the neurodevelopment of the infants was assessed using AIMS. The scores at or below the 5th percentile were classified as abnormal.

2.6. Neurological examination

Neurological examinations were performed between 6 and 12 months of corrected age as well as at 18–24 months. Due to the onset of the COVID-19 pandemic, longer-term follow-up could not be accomplished.

2.7. Statistical method

All statistical analysis was done with the SPSS Statistics 23 package program. Descriptive statistics are shown as arithmetic mean ± standard deviation for quantitative variables, frequency, and percentages for qualitative variables. Differences between GA groups were evaluated with a one-way analysis of variance when examined in terms of quantitative characteristics, and with the chi-square test when examined in terms of qualitative characteristics. The differences between the GA groups in terms of the total score and sub-score averages of the writhing and fidgety period evaluations and the total score average of the AIMS assessment were determined by a one-way analysis of variance. The differences between GA groups in terms of AIMS percentile groups were determined by the chi-square test. When a statistically significant difference was detected as a result of a one-way analysis of variance, the Tukey Test was used in post hoc analysis. Fisher's Exact Test was conducted to determine the relationship between the prognostic values of AIMS, GMOS, and MOS and the diagnosis of CP and NDD. The agreement between GMOS, MOS, and the normal/abnormal diagnosis of AIMS was determined by Kappa coefficient analysis consistency. In addition, sensitivity and specificity values between GMOS, MOS, and normal or abnormal diagnosis of AIMS were also calculated. Statistical significance was accepted as $p < 0.05$.

3. Results

A total of 75 preterm infants with a gestation between 24 and 37 weeks were included. Group 1 consisted of 22 neonates (29.3%), whereas 23 neonates (30.7%) and 30 neonates (40%) constituted groups 2 and 3, respectively. Baseline characteristics of the infants are shown in Table 1.

Table 2 shows that there was a statistically significant difference in terms of the GMA in the writhing and fidgety periods in all groups. According to the GMOS, normal GMA was the lowest in infants with 24–28 weeks of gestation (group 1), whereas CS (cramped synchronized) and PR (poor repertoire) were the highest ($p = 0.013$). Moreover, the assessments of the upper-lower extremities and the sequence were the lowest in group 1, which were also statistically significant ($p = 0.004$, $p = 0.016$, $p = 0.041$). There was a significant positive correlation between the GA of the preterm infants and the total GMOS score (Kappa coefficient $= 0.382$, $p = 0.003$); as the GA of the preterm infants increased, the total GMOS score increased.

As shown in Table 2, according to MOS, no significant differences were found between the fidgety period groups in posture, movement character, repertoire, and quality of other movements. There was a statistically significant but

Table 1 Characteristics of the study sample.

	Group 1 (GA ≤28 weeks) (n = 22)	Group 2 (GA 29–32 weeks) (n = 23)	Group 3 (GA 33–37 weeks) (n = 30)	p value
GA (weeks), (mean ± SD)	26.2 ± 1.8	30.4 ± 2.3	34.9 ± 2.1	<0.001
BW (g), (mean ± SD)	909.55 ± 167.63	1526.96 ± 340.05	2027.17 ± 519.21	<0.001
Gender (female), n (%)	13 (33.3)	12 (30.8)	14 (35.9)	0.675
Apgar score ≤3, n (%)	0 (0)	3[13]	3[10]	0.238
Single birth, n (%)	10 (31.3)	12 (37.5)	10 (31.3)	0.872
Twin birth, n (%)	9 (30.0)	8 (26.7)	13 (43.3)	
Triplet birth, n (%)	3 (33.3)	3 (33.3)	3 (33.3)	
PVL, n (%)	3 (13.6)	1 (4.3)	2 (6.6)	0.487
IVH (Stage 1–2), n (%)	10 (45.5)	7 (30.4)	5 (16.7)	0.078
IVH (Stage 3–4), n (%)	6 (60.0)	2 (20.0)	2 (20.0)	0.071
Hypoglycemia, n (%)	2 (9.1)	2 (8.7)	3[10]	0.986

GA: gestational age, BW: birth weight, PVL: periventricular leukomalacia, IVH: intraventricular hemorrhage.

weak correlation between the GA and fidgety movements plus the MOS score (Kappa coefficient = 0.384 p = 0.003 and Kappa coefficient = 0.273, p = 0.045).

AIMS was applied to 63 of the infants who were followed up at 6–12 months of age. AIMS scores were <5 percentile in 12, 5, and 4 infants in groups 1, 2, and 3, respectively (p = 0.004). As the GA of the infants decreased, the total AIMS score decreased, which was statistically significant (p = 0.005). Furthermore, as the GA increased, the AIMS score moved closer to normal values (Table 3).

The associations between GMOS – AIMS and MOS – AIMS are presented in Table 4. There was a high consistency between the GMOS and AIMS scores (Kappa coefficient = 0.709, p = 0.002). The sensitivity and specificity of GMOS and AIMS were 95.24% and 81.82%, respectively. GMOS and AIMS (<5th percentile) were found to be 95.24% compatible to determine the infants with abnormal neurodevelopment. The GMOS score distinguished 81.82% of the infants as normal – they were also normal according to AIMS. There was also a good agreement between MOS and AIMS scores (Kappa coefficient = 0.804, p = 0.001). The sensitivity and specificity of MOS and AIMS was 100% and 86.36%, respectively. To determine the infants with abnormal neurodevelopment, MOS and AIMS (<5th

Table 2 General movement assessment during writhing and fidgety periods.

General movement assessment during writhing period	Group 1 (GA ≤28 weeks) (n = 22)	Group 2 (GA 29–32 weeks) (n = 23)	Group 3 (GA 33–37 weeks) (n = 30)	p value
Global Assessment, n (%)				0.013
N	1 (4.5)	5 (21.7)	11 (36.6)	
CS	10 (45.5)	3[13]	5 (16.7)	
PR	11 (50)	15 (65.3)	14 (46.7)	
Neck and Trunk (max 4 points)	2.36 ± 1.18	2.74 ± 0.92	2.83 ± 1.12	0.331
Upper Extremities (max 18 points)	8.82 ± 3.59	11.57 ± 3.15	12.30 ± 4.08	0.004
Lower Extremities (max 18 points)	8.00 ± 4.40	10.91 ± 3.70	11.67 ± 4.65	0.016
Sequence (max 2 points)	0.86 ± 0.56	1.22 ± 0.60	1.30 ± 0.70	0.041
General movement assessment during fidgety period	**Group 1 (GA ≤28 weeks) (n = 22)**	**Group 2 (GA 29–32 weeks) (n = 23)**	**Group 3 (GA 33–37 weeks) (n = 30)**	**p value**
Total Score (MOS), (mean ± SD)	15.25 ± 6.63[b]	19.30 ± 7.06[a]	20.22 ± 5.65[a]	0.045
Fidgety Movements, (mean ± SD)	4.50 ± 4.62[b]	8.20 ± 4.87[a]	9.52 ± 4.34[a]	0.003
Repertoire of other movements, (mean ± SD)	2.80 ± 1.01	2.95 ± 1.10	2.78 ± 1.00	0.860
Quality of other movements, (mean ± SD)	2.35 ± 1.18	28.5 ± 1.09	2.13 ± 0.63	0.084
Posture, (mean ± SD)	3.10 ± 1.02	2.90 ± 1.17	2.83 ± 1.07	0.690
Movement character, (mean ± SD)	2.50 ± 1.32	2.70 ± 0.98	2.96 ± 1.02	0.304

GA: gestational age, N: Normal, CS: Cramped-Synchronized, PR: Poor Repertoire, MOS: Motor Optimality Score.
[a] Different lowercase superscripts indicate statistically significant differences between groups.
[b] Different lowercase superscripts indicate statistically significant differences between groups.

Table 3 Alberta infant motor scale (AIMS) assessment.

		Group 1 (GA ≤28 weeks) (n = 22)	Group 2 (GA 29–32 weeks) (n = 23)	Group 3 (GA 33–37 weeks) (n = 30)	p value
AIMS Assessment Period (month), (mean ± SD)		6.31 ± 1.2	7.51 ± 2.3	7.49 ± 1.8	0.113
Total Score, (mean ± SD)		19.15 ± 8.25	25.21 ± 15.92	28.09 ± 8.34	0.005
Percentile	≤5 p	12 (63.2)	5 (26.3)	4[20]	0.004
	6–24 p	–	4 (57.1)	4 (50)	
	≥25 p	9 (24.3)	10 (27.0)	18 (48.6)	

AIMS: Alberta Infant Motor Scale, GA: gestational age.

Table 4 The association between GMOS, MOS, and AIMS.

	AIMS (≤5 p) abnormal (n = 21)	AIMS (>5 p) normal (n = 44)	Kappa coefficient; p value
Abnormal GMOS (n = 28)	20	8	0.709; 0.001
Normal GMOS (n = 37)	1	36	
Abnormal MOS (n = 27)	21	6	0.804; <0.001
Normal MOS (n = 38)	0	38	

GMOS: General Movement Optimality Score, MOS: Motor Optimality Score, AIMS: Alberta Infant Motor Scale.

percentile) were 100% compatible. In addition, the GMOS score was able to distinguish 86% of the infants as normal who were also normal according to AIMS.

The relationship between the prognostic values of AIMS, GMOS, and MOS and the diagnosis of CP and NDD is demonstrated in Table 5. All three scales had statistically significant associations with CP and pathological findings ($p < 0.001$). Infants identified as abnormal by AIMS, GMOS, or MOS were more likely to develop CP or NDD. Similarly, the infants who were detected as normal by GMOS and MOS (n = 53) had normal neurodevelopment. Seven infants with CP and 14 infants with NDD were detected as abnormal by GMOS. Of the infants who were evaluated with AIMS (n = 63), 44 were predicted as normal and 19 infants were predicted as abnormal. Of the 44 infants predicted as normal, 40 had normal development; 3 of the 19 infants predicted as abnormal had normal development. Of the 43 infants who had normal development, 40 (90.9%) infants had normal results in AIMS.

In the present study, according to GMOS, we predicted that 19 infants may develop CP and NDD during the writhing period. The pediatric neurologist evaluated the infants during the 18–24 months period. CP and NDD were diagnosed based on neurological examinations and neuroimaging. 7 infants were diagnosed with CP and 14 infants had NDD. All infants with CP had abnormal results in GMOS and MOS, and 6 of them were in group 1. Moreover, 6 infants with CP had abnormal results in AIMS. Of the 14 infants with NDD, 7 were in group 1 and 6 were in group 2. However, while GMOS and MOS detected all the cases as abnormal, AIMS detected only 10 infants as abnormal.

4. Discussion

In this study, to identify high-risk preterm infants, we prospectively analyzed the spontaneous motor development of preterm infants by using GMOS in the writhing period, MOS in the fidgety period, and AIMS at 6–12 months of corrected age. We demonstrated that at 28 weeks of gestation and earlier, abnormal GMs are associated with lower AIMS scores at 6–12 months.

Table 5 The association between assessment tools and diagnosis.

		CP n (%)	NDD n (%)	Normal development n (%)	p value
AIMS (n = 63)	Abnormal (n = 19)	6 (31.6)	10 (52.6)	3 (15.8)	<0.001
	Normal (n = 44)	1 (2.3)	3 (6.8)	40 (90.9)	
GMOS (n = 75)	Abnormal (n = 51)	7 (13.7)	14 (27.5)	30 (58.8)	<0.001
	Normal (n = 24)	–	–	24 (100.0)	
MOS (n = 63)	Abnormal (n = 34)	7 (20.6)	13 (38.2)	14 (41.2)	<0.001
	Normal (n = 29)	–	–	29 (100.0)	

GMOS: General Movement Optimality Score, MOS: Motor Optimality Score, AIMS: Alberta Infant Motor Scale, CP: cerebral palsy, NDD: neurodevelopmental delay.

Previous studies have shown that approximately 40% of children with CP were born preterm and that 8—10% of preterm infants develop CP.[16] Moreover, studies have demonstrated that growing in an incubator instead of in utero may negatively affect the development of the brain, sensory, and motor systems for those between 23 and 40 weeks of gestation.[17—19] The first two years of life are a unique period due to the rapid plasticity of the brain. For this reason, early and periodic evaluations of motor development are essential for the early identification of high-risk infants in order to initiate early intervention programs and provide optimal therapies.[20]

As GA and BW decrease, the complications of prematurity — including IVH and PVL — are seen more frequently and may induce a risk for neurodevelopmental abnormalities.[3,21] Stolinska and colleagues conducted a study with 302 extremely low BW (ELBW) and 285 very low BW (VLBW) infants and reported that 165 ELBW and 285 VLBW infants were diagnosed with neurosensory abnormalities, including CP, at 2 years of corrected age.[21] In the present study, of the 75 preterm infants, 7 (9.3%) developed CP. Of the 7 infants with CP, 6 of them were in group 1, which was consistent with the literature.

Since its introduction over 30 years ago, GMs have been used for predicting motor dysfunctions, especially CP.[22—24] Cramped-synchronized GMs and the absence of fidgety movements are recognized as good predictors of CP, while poor repertoire GMs and abnormal fidgety movements may be associated with minor neurological dysfunctions.[25,26] In the literature, there are several studies establishing the reliability and validity of GMs. In 1997, Prechtl et al. conducted a study with 130 infants having normal and abnormal fidgety movements, comparing them through assessments of neurological development performed longitudinally until the age of 2 years. They found that 67 (96%) of the 70 infants with normal fidgety movements had normal neurological outcomes. In 57 (95%) out of 60 infants, abnormal fidgety movements were followed by neurological abnormalities; of the 57 infants, 49 developed CP.[25] Bosanquet et al.[27] reviewed 19 studies including high-risk infants and reported that the GM assessment has the best evidence and strength for predictive accuracy. Noble and Boyd reported that the GMA has the best prediction of future outcomes.[24] Adde et al. conducted a prospective study with 74 preterm and term infants at low and high risks of developing neurological dysfunctions, and they showed that the GMs identified all 10 infants who were later diagnosed with CP. According to their study, the sensitivity of GMs with regard to later CP was 100% and the specificity was 98%.[28] In South Africa, a study done with 115 infants with a BW of $\leq$1250 g showed that fidgety movement outcome and the infants' final motor outcome at 12 months of corrected age were found with a sensitivity of $\geq$71% and a specificity of $\geq$89%.[29] In Turkey, a prospective single-blinded study was done with 22 preterm infants that supported high consistency between fidgety movements and neurologic outcomes.[30] Fuentefria et al.[3] reviewed 23 studies including preterm infants and reported that the AIMS assessment in infants varied from 5 months until 18 months. These studies showed significant differences in motor developmental delay between preterm and full-term infants, with a description of lower gross scores in the AIMS results for preterm infants. They also noticed that AIMS is an assessment tool indicated to identify atypical motor development in the preterm infant population.[3]

According to our study, 24 infants were evaluated with GMOS and 29 infants were evaluated with MOS. All of those infants' neurological examinations were normal, and they did not develop CP and NDD. On the other hand, of the 43 infants, 40 (90.9%) were detected as normal using AIMS. According to these findings, we observed that GMOS and MOS were powerful tools and stronger than AIMS in differentiating CP and NDD from normal development. We found that when the neurological examination was performed between 18 and 24 months of age, GMOS and MOS were abnormal in all 7 cases with CP. Moreover, AIMS only classified one case as normal who was on the 10th percentile. In the light of the literature, the 5th percentile and below were accepted as abnormal; however, 10th percentile and below also should be considered risky.[3,31]

In our study, based on the association between GMOS, MOS, and AIMS for the prediction of CP and NDD, we demonstrated that GMA is a powerful tool in detecting CP and NDD at an early age. Similar to the literature, we found that the infants who were diagnosed with NDD and CP at 18—24 months of age already had abnormal GMOS. This shows that GMOS is also a valuable tool for initiating high-risk infants to early intervention programs. In addition, AIMS (5th and lower percentiles) may be useful for the detection of infants with NDD when used between 6 and 12 months of age. We speculate that the combined use of GMA and AIMS has a higher diagnostic value for the diagnosis of CP and NDD within the first year of life.

The main limitation of the present study is that our study coincided with the global COVID-19 pandemic. Consequently, we were unable to follow up with the subjects on the exact dates we desired. In addition, we could not include more participants because of the COVID-19 restrictions.

In conclusion, as the GA of preterm infants decreases, GMOS, MOS, and AIMS scores also decrease. AIMS testing at 6—12 months has high-level positive compatibility with the GMOS and MOS scores. We suggest that the use of GMOS, MOS, and AIMS in clinical practice can be useful and reliable for the diagnosis of NDD and CP in preterm infants. We recommend future studies with large sample sizes focused on these tests to evaluate neuromotor development and early prediction of high-risk infants.

Declaration of competing interest

The authors have no conflicts of interest relevant to this article.

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