The Turkish Journal of Pediatrics 2024; 66: 287-296
https://doi.org/10.24953/turkjpediatr.2024.4513

Original Article

The role of certain perinatal features in the early motor repertoire of infants

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ABSTRACT

Background. Lower gestational age negatively affects the neurodevelopmental outcomes of infants. Early motor repertoire is a reliable way to predict neurodevelopmental outcomes. This study aimed to determine the correlation between gestational age and early motor repertoire in infants and also the roles of multiple pregnancies, gender, cranial utrasonography (USG) results, and birth weight in this relationship.

Methods. This study included 139 infants, who were video recorded 9-17 weeks post-term. The recordings were evaluated using the Motor Optimality Score-Revised (MOS-R). Structural equation modeling tool was used for the path analysis of the models.

Results. There was a weak positive correlation between gestational age and the MOS-R. In the relationship between gestational age and the MOS-R, multiple pregnancies, gender, and USG outcomes had a moderating effect. While abnormal USG, male gender, and singleton pregnancy increased this correlation to a moderate level, normal USG reduced the strength of the correlation. Female and twin pregnancies were non-significant in the model. Birth weight had a full mediating effect on the relationship between gestational age and the MOS-R.

Conclusions. Infants with younger gestational age or lower birth weight, male infants, and infants with problems on cranial USG may have poorer early motor repertoire.

Key words: birth weight, gestational age, motor repertoire, gender, cranial ultrasonography.

Factors like gestational age, birth weight, multiple pregnancy, and gender are associated with the neurodevelopmental outcomes of infants.[1,2] Lower gestational age and birth weight cause increases in the prevalence of cerebral palsy (CP).[3] Infants surviving very low/extremely low birth weight face increased risk in terms of death, growth retardation, and delayed neurodevelopment.[4] Additionally, multiple-pregnancy infants are four times more likely to have CP compared to singletons.[5] Triplet and quadruplet infants have higher CP prevalence than twins.[6] When examined in terms of gender, CP is observed more frequently in boys compared to girls and boys are at a disadvantage in terms of the risk of a more severe motor disorder.[7,8]

Damages occurring in the central nervous system (CNS) structures of infants due to problems such as intraventricular hemorrhage, hypoxic ischemic encephalopathy, and epilepsy and the severity of this damage may provide information about the developmental outcome of infants.[9] With the aim of determining injury to CNS structures, cranial ultrasonography (USG) is a common and predictive tool used for infants at risk for adverse outcomes.[10]

Detailed General Movements Assessment (GMA) is one of the most rapid and effective

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Received 9th May 2023, revised 6th Aug 2023, 28th Dec 2023, 1st Mar 2024, 19th Apr 2024, accepted 5th May 2024.

methods to assess CNS functions of an infant by examining the early motor repertoire of the infant.[11] Additionally it is one of the tools that can most accurately predict later neurological deficits.[11,12] It is possible to define the motor repertoire and posture of an infant with detailed GMA. Higher scores in the Motor Optimality Score-Revised (MOS-R) obtained as a result of detailed GMA show optimal neurodevelopmental outcomes, while lower scores indicate adverse neurodevelopmental outcomes.[13] Due to all these features, the MOS-R may guide early intervention practices.

If the MOS-R can accurately predict the neurodevelopmental outcome of an infant, it is expected that it will be affected by other variables impacting neurodevelopmental status. Many studies in the literature have shown that many perinatal characteristics are associated with the long-term outcome of infants.[4-8] However, the relationship between these variables and the MOS-R has not been determined. With the establishment of this relationship, the variables that may affect the motor repertoire of an infant will be clarified, and the data can be interpreted accordingly. Thus, we expect that by observing the infant's motor repertoire and predicting the developmental outcome, we can contribute to obtaining more accurate results in starting early intervention. For this reason, the aim of the current study was to provide answers to the following questions:

Is there a correlation between MOS-R and the gestational age of infants?

If there is, what are the roles of multiple pregnancy, gender, cranial USG results, and birth weight in this relationship?

Materials and Methods

Study design

This prospective cohort study was approved by the local non-interventional clinical research ethics committee (GO 21/895). Informed voluntary consent forms were signed by the families of infants included in the study.

Participants

The study included all infants at risk for neurodevelopmental problems with post-term age of 3-5 months who were referred to our outpatient clinic and applied to the Pediatric Neurology Unit of Ondokuz Mayıs University Children's Hospital between September 2021 to September 2022. Infants with major brain malformations, genetic disorders, musculo-skeletal problems (brachial plexus lesion, torticollis etc.), epilepsy, sepsis, or hypoxic ischemic encephalopathy were excluded from the study (Fig. 1). The sample size was determined as 100-150 participants to reach the minimum satisfactory size for the structural equation model.[14] As a result, the study was completed with 139 infants.

Outcome measures

Detailed General Movement Assessment (GMA): The detailed GMA evaluates motor repertoire via 3-5 minute videos of infants aged 9-17

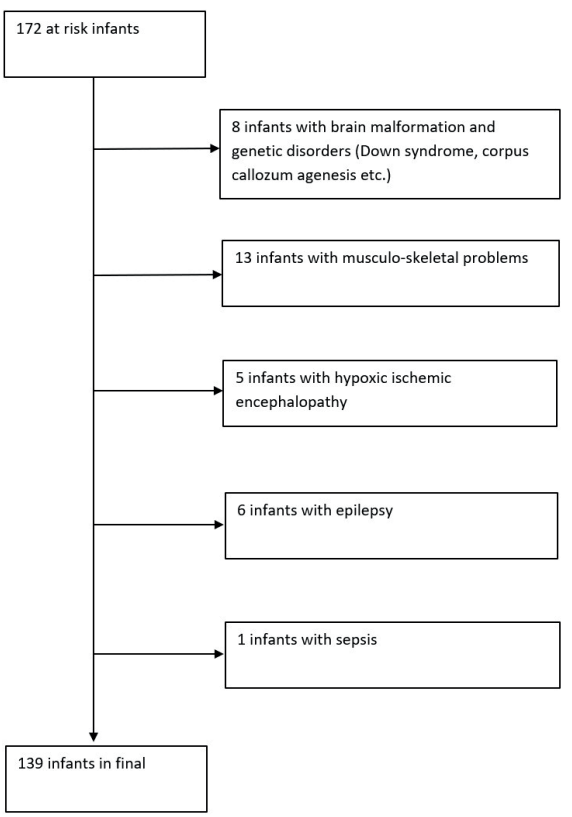

Fig. 1. Flow chart.

weeks. In detailed GMA, videos are assessed in 5 subcategories: The subcategories are fidgety movements, observed movement patterns, age-adequate movement repertoire, observed postural patterns, and movement character. Fidgety movements are scored as normal (12 points), abnormally exaggerated (4 points), and absent (1 point). Observed movement patterns are scored as normal patterns dominant (4 points), normal and atypical patterns equal (2 points), and atypical patterns dominant (1 point). Age-adequate movement is scored as present (4 points), reduced (2 points), and absent (1 point). Observed postural patterns are scored as normal patterns dominant (4 points), normal and atypical patterns equal (2 points), and atypical patterns dominant (1 point). Movement character is scored as smooth and fluent (4 points), abnormal but not cramped-synchronized (2 points), and cramped-synchronized (1 point). The MOS-R is obtained by adding the points in these subcategories. As a result, the MOS-R may be a maximum of 28 and minimum 5 points.[13] According to MOS-R classifications, 25-28 points are optimal.[13]

Clinical Characteristics: Clinical characteristics of the infants were obtained from the infant files (Table I).

Procedures

Videos recorded at the Pediatric Neurology Unit, Faculty of Medicine, Ondokuz Mayıs University were evaluated by researchers AK and AL at the Faculty of Physical Therapy and Rehabilitation, Hacettepe University. Early motor repertoires of the infants were evaluated via videos by detailed GMA according to the score sheet revised in 2019, and the MOS-R was calculated.[13] For this, a single video including 3-5 minutes of spontaneous motor movements that was taken while the infant was post-term age of 9-17 weeks in which they were active

Table I. Characteristics of infants.

		Infants (n= 139)
Gestational age, week: median (min max) (IQR)		33 (24-40) (30-37)
	Gestational age ≤ 29 weeks, n (%)	27 (19.4)
	Gestational age between 30-36 weeks, n (%)	76 (54.7)
	Gestational age ≥ 37 weeks, n (%)	36 (25.9)
Birth weight, gram: median (min-max) (IQR)		1856 (620-4470) (1420-2660)
Gender, female, n (%)		53 (38.1)
Multiple pregnancy, n (%)		35 (25.2)
Hospitalization duration, day: median (min-max)		20 (0-270)
Abnormal ultrasonography, n (%)		30 (21.6)
Respiratory distress syndrome, n (%)		39 (28)
Hyperbilirubinemia (TSB value < 25mg/dL), n (%)		17 (12.2)
Congenital hypothyroidism, n (%)		5 (3.6)
Preeclampsia, n (%)		12 (8.6)
Video recording age, week: median (min-max)		12 (9-17)
Weight for gestational age, n (%)	-3 SD	4 (2.9)
	-2 SD	8 (5.7)
	-1 SD	52 (37.5)
	0	7 (5.0)
	1 SD	53 (38.1)
	2 SD	13 (9.4)
	3 SD	2 (1.4)

IQR, interquartile range (25th-75th percentiles); SD, standard deviation; TSB, total serum bilirubin.

and awake, partly dressed, without stimulation in supine position. This was assessed by two raters who were blind to the infants' medical histories, and certified and experienced in detailed GMA.[11] In case of any disagreement, the videos were re-evaluated until a consensus was reached.

Two categories were included in the model as with or without a problem on cranial USG, being female or male, and multiple pregnancy of twin or singleton. Birth weight and gestational age were included as continuous variables in the model.

To identify the correlation between gestational age and the MOS-R and additionally, the role of birth weight, gender, being singleton/twin, and cranial USG results in this correlation, the model in Fig. 2 was created.

Statistical analysis

Statistical analyses were performed using the IBM SPSS v25 software. The fit of numerical variables to normal distribution was determined using visual (histogram and probability graphs) and analytical methods (Kolmogorov-Smirnov). Number and percentage values were calculated for descriptive statistics. The Kruskal-Wallis test was used to compare three numerical data groups that were not normally distributed (MOS-R of infants were divided into three groups according to gestational age). Post hoc analyses of 3 nonnormally distributed groups were performed using the Mann-Whitney U test after Bonferroni correction. For comparison of two numerical data groups without normal distribution, the Mann-Whitney U test was used, the Chi square test was used for comparison of categorical data groups. The relationship between numerical variables were calculated using the Spearman correlation coefficient. Statistical significance level was accepted as $p<0.05$ (except for moderating variable analysis in normal USG that considers $p<0.1$). To test mediation and moderation effects, the "IBM AMOS Graphics 25.0" software was used. Path analysis was performed using the SPSS Amos Graphics Structural Equation Modeling tool.

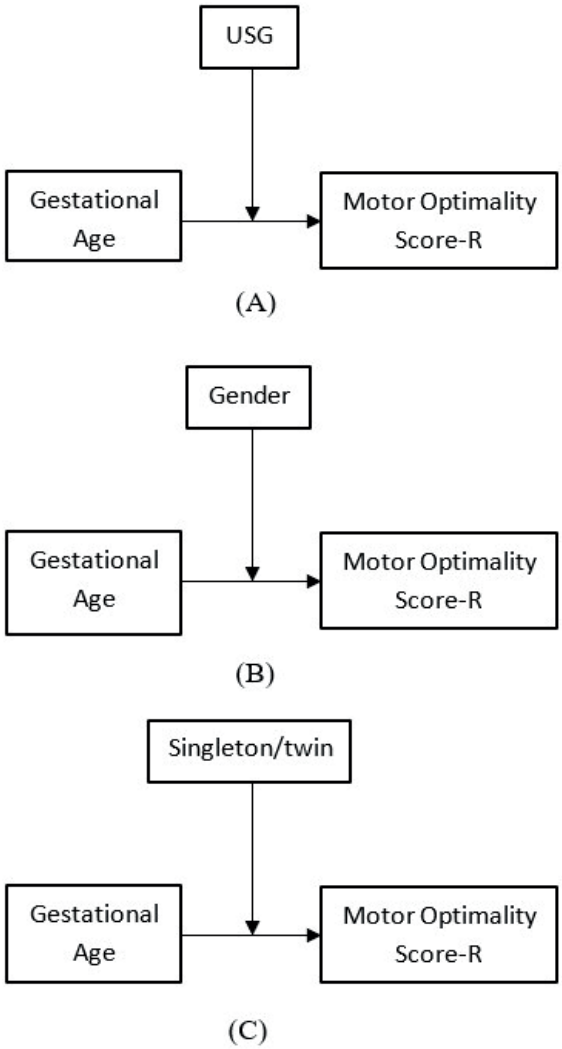

Fig. 2. Testing various moderator variables.

Results

A total of 139 infants, 53 girls (38.1%) and 86 boys (61.9%), were included in the study. The median gestational age of the infants was 33 weeks (min 24 weeks, max 40 weeks). Median birth weight was 1856 g (min 620 g, max 4470 g). According to Fenton growth charts, there were 4 infants within -3 standard deviations (SD), 8 infants in -2 SD, and 52 infants in -1 SD between gestational age and birth weight.[15] There were 104 singleton infants and 35 twin infants (Table I).

Comparison of perinatal characteristics of the infants is given in Table II.

Table II. Comparison of perinatal characteristics of infants (n= 139).

		Birth weight		P value
		<2500 gram	≥2500 gram	
Gestational age, week: median (IQR)		31 (29-34)	38 (37-39)	**<0.001**[a]
		Gender		
		Girl	Boy	
Gestational age, week: median (IQR)		34 (30-38)	33 (30-36)	0.95[a]
Birth weight, gram: median (IQR)		1840 (1290-2830)	1863 (1430-2520)	0.83[a]
		Multiple pregnancies		
		Single	Twin	
Gestational age, week: median (IQR)		33 (29.5-38)	33 (31-34)	0.65[a]
Birth weight, gram: median (IQR)		1960 (1340-2980)	1800 (1440-2000)	0.21[a]
Gender, n (%)	Girl	40 (28.8)	13 (9.4)	0.89[b]
	Boy	64 (46)	22 (15.8)	
		Ultrasonography		
		Normal	Abnormal	
Gestational age, week: median (IQR)		34 (30-37)	32 (29-35)	0.08[a]
Birth weight, gram: median (IQR)		1980 (1540-2780)	1430 (1200-1855)	**0.003**[a]
Gender, n (%)	Girl	44 (31.6)	9 (6.5)	0.30[b]
	Boy	65 (46.8)	21 (15.1)	
Multiple pregnancie, n (%)	Single	79 (56.8)	25 (18)	0.22[b]
	Twin	30 (21.6)	5 (3.6)	

[a]Mann-Whitney U test; [b]Chi-Square Test; IQR, interquartile range (25th-75th percentiles)

The median MOS-R was 24 (min 6, max 28). Forty-nine of the infants (35.2%) had the optimal MOS-R. While 21 infants (15.1%) had absent fidgety movements (n=18 preterm, n=3 term; n=9 female, n=12 male), 2 infants (1.4%) had abnormal fidgety movements (n=2 preterm, n=2 male). None of the infants had cramped synchronized movements. The details of the MOS-R and subcategory scores are presented in Table III.

When infants were divided into three groups in terms of gestational age as very preterm (29 weeks and younger), preterm (30-36 weeks), and term (37 weeks and older), there was a statistically significant difference between the MOS-R of these three groups (p=0.004). The MOS-R of the very preterm infant group was lower than those of the other two groups (very preterm-term p=0.004 and very preterm-preterm p=0.002).

A weak positive correlation existed between gestational age and the MOS-R (p<0.01, r=0.26).[16] Of the variability in the MOS-R, 6.8% could be explained by gestational age. According to the model, multiple pregnancy, gender, and USG results had a moderator effect on the correlation between gestational age and the MOS-R. Abnormal USG increased this correlation to a moderate level (p<0.05, r=0.39), and 15.1% of the variability in the MOS-R was explained. Being a male increased this correlation to a moderate level (p<0.01, r=0.3), and 8.8% of the variability in the MOS-R was explained. Being singleton similarly increased the level of the correlation to moderate (p<0.01, r=0.32) and 10.1% of the variability in the MOS-R was explained. Normal USG findings weakened the level of this correlation (p=0.08<0.1, r=0.165). Being a female or a twin was non-significant in the model. Birth weight fully mediated the relationship between gestational age and the MOS-R (p<0.001, r=0.235) (Fig. 3 and Table IV).

Table III. Detailed general movement assessment of infants.

		Premature (≤37 week) n=111		Term (>37 week) n=28	
		Female n (%)	Male n (%)	Female n (%)	Male n (%)
MOS-R	25-28 is optimal	14 (35.9)	23 (31.9)	7 (50)	5 (35.7)
	20-24 is mildly reduced	18 (46.2)	34 (47.2)	5 (35.7)	8 (57.2)
	9–19 is moderately reduced	7 (17.9)	14 (19.4)	2 (14.3)	1 (7.1)
	5–8 is severely reduced	-	1 (1.4)		
Fidgety score	Normal	32 (82.1)	59 (81.9)	12 (85.7)	13 (92.9)
	Exaggerated	-	2 (2.8)	-	-
	Absent	7 (17.9)	11 (15.3)	2 (14.3)	1 (7.1)
Observed movement patterns	Normal > Abnormal	38 (97.4)	67 (93)	13 (92.9)	12 (85.7)
	Normal = Abnormal	1 (2.6)	4 (5.6)	1 (7.1)	2 (14.3)
	Normal < Abnormal	-	1 (1.4)	-	-
Age-adequate movement repertoire	Age-adequate	21 (53.9)	38 (52.8)	11 (78.6)	8 (57.2)
	Reduced	11 (28.2)	17 (23.6)	3 (21.4)	3 (21.4)
	Absent	7 (17.9)	17 (23.6)	-	3 (21.4)
Observed postural patterns	Normal > Abnormal	21 (53.9)	35 (48.6)	8 (57.2)	10 (71.4)
	Normal = Abnormal	12 (30.7)	22 (30.6)	5 (35.7)	2 (14.3)
	Normal < Abnormal	6 (15.4)	15 (20.8)	1 (7.1)	2 (14.3)
Movement character	Smooth and fluent	7 (17.9)	10 (13.9)	3 (21.4)	3 (21.4)
	Abnormal, not CS	32 (82.1)	62 (86.1)	11 (78.6)	11 (78.6)
	CS	-	-	-	-

CS, Cramped synchronized; MOS-R, Motor Optimality Score-Revised.

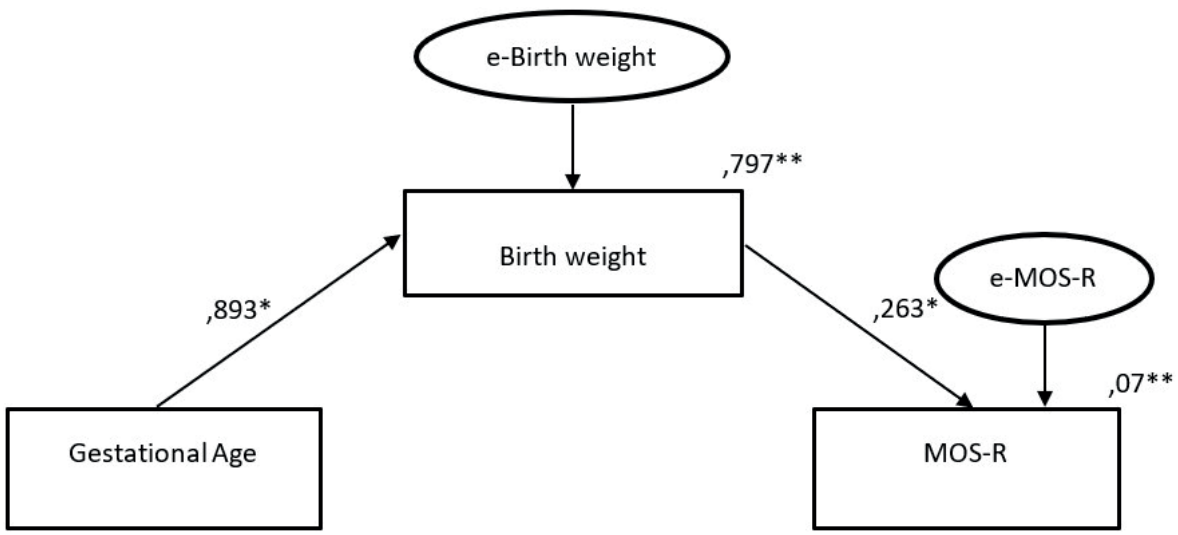

Fig. 3. Demonstration of mediation role of birth weight between gestational age and MOS-R.
(*standardized path coefficients, **coefficient of determination (i.e. R square))

Table IV. Path model and analysis.

	Standardized effects	
	Gestational age (independent variable)	Birth weight (mediator variable)
Birth weight (mediator variable)	0.893	0.000
MOS-R (dependent variable)	0.235	0.263

Mediator variable analysis results

Independent variable	Moderator variable	Dependent variable	N	P value	r
Gestational age →	Abnormal USG	MOS-R	30	**0.022**	0.39
	Normal USG		109	0.084	0.16
Gestational age →	Male	MOS-R	86	**0.004**	0.30
	Female		53	0.12	insignificant
Gestational age →	Singleton	MOS-R	104	**0.03**	0.34
	Twin		35	0.2	insignificant

Moderator variables analysis results

MOS-R: Motor Optimality Score-Revised

Discussion

We aimed to determine the correlation between gestational age and early motor repertoire of infants and additionally the roles of multiple pregnancy, gender, cranial USG results, and birth weight in this relationship. There was a weak positive relationship between gestational age and the MOS-R. Multiple pregnancy, gender, and USG findings were moderator variables of this relationship, whereas birth weight was a mediator variable.

Not all of the variables researched in this study are fully independent. For example, infants with young gestational age have proportionally low birth weights. The birth weight and gestational age of infants born as twins are generally lower than singleton infants. This situation shows that the researched variables affect each other. To remove this effect and to be able to determine the mediating and moderating effects of the variables on each other, structural equation modeling was used as the main statistical method in our research.

Herrero et al.[17] found no correlation between gestational age and birth weight with MOS in a study researching the motor repertoire of infants with Down syndrome (gestational age 29-41 weeks). Fjørtoft et al.[18] reached the same conclusion in a study of extremely preterm (EPT) infants (gestational age mean 26.6 SD 1.8 weeks). Our study includes a larger range of gestational ages (from 24 to 40 weeks). Additionally, as genetic problems have the potential to impact the MOS-R, infants with genetic problems were excluded from the study to remove this effect.[17,19] For this reason, our results may be different from these two previous studies.

Örtqvist et al.[20] in their study comparing EPT infants with term infants, and Salavati et al.[21] comparing very preterm infants with term infants with regards to MOS have found that preterm infants have a poorer motor repertoire. The findings of the current study support the results of these two studies. The findings of these three studies are consistent with the existing knowledge that prematurity increases the risk of poor neurodevelopment.

Dostanic et al.[22] found that GMA quality was only associated with preterm birth, while perinatal factors like being small for gestational age and gender were not associated with GMA quality in a study performed with 89 twin pairs of infants with abnormal neurological signals and/or perinatal risk factors in at least

one of the twins. In the current study, infants with pronounced risk factors were excluded (infants with hypoxic ischemic encephalopathy, sepsis, etc.). Thus, we tried to eliminate other problems that may affect the MOS-R. There is a methodological difference between the two studies as one used detailed GMA and the other used global GMA. Lower MOS-R means an increased risk of adverse outcomes.[13] The finding that very preterm infants had lower MOS-R than preterm and term infants in the current study support the knowledge that reduced gestational age and birth weight increase the risk of adverse neurodevelopmental outcomes.[3,21]

In the current study, a weak positive correlation between gestational age and the MOS-R may be attributed to the fact that the number of infants (n=76) in the preterm group (gestational age between 30-36 weeks) was much higher than in the very preterm and term groups. We suggest that the large correlation may further increase if the groups formed in terms of gestational age include equal numbers of infants. However, our results are important in terms of showing that the expected relationship between motor repertoire and research variables exists.

In studies, male gender was associated with poor neurodevelopmental outcomes, while in the cohort with gestational age younger than 32 weeks, male gender and gestational age were found to be of limited use as prognostic factors.[1] In a study comparing MOS of EPT infants with term infants, Örtqvist et al.[20] stated that gender did not cause a difference in MOS for EPT infants. In the current study, there was no statistically significant difference between the numbers of male and female infants (p=0.5). Being male affected the relationship between gestational age and MOS-R while being female was not. This result may support the correlation of male gender with poor neurodevelopmental outcomes. However, again, there is a need for studies with more participants to further clarify this topic.

Multiple pregnancy is thought to cause increased risk of neonatal morbidity and mortality.[23] The reason for this is generally linked to low birth weight and prematurity.[5] Bonellie et al.[24] stated that being a twin increased the risk of CP rather than preterm birth and low birth weight in their study researching the effect of different risk factors on cerebral palsy in twins. A systematic review in 2018 found no differences between twin-singletons in the research measuring neurodevelopmental outcomes from 1-5 years of age, while some differences were observed in studies measuring neurodevelopmental outcomes at later ages.[25] In light of all these studies, if neurodevelopment is affected by multiple pregnancy, it is expected that MOS-R will be affected. In our study, there was no statistically significant difference between the gestational age and birth weights of singleton and twin infants. Being singleton affected the relationship between gestational age and MOS-R while being twin was not. The number of EPT infants (gestational age <31 weeks) was much higher among singletons in our study which might be the reason for this finding. Additionally, 24% of singletons and 14% of twins had problems on cranial USG. The different number of infants in these two groups (singleton 104, twin 35) may be another reason for the emergence of these results.

Fjørtoft et al.[18] found EPT (<28 weeks) and/or extremely low birth weight (<1000 g) infants had poorer quality of motor repertoire compared to term infants. The authors stated that findings could not be explained by severe abnormalities on neonatal USG scans. In our study, as gestational age increased, the MOS-R increased. Infants with problems on USG had lower MOS-R compared to infants without problems. The gestational age range in our study encompasses a large group. Analyses were not performed according to severe USG findings, and the recently revised MOS-R was used. Therefore, according to the results of the current study, infants with young gestational age and a problem on USG may have lower MOS-R and thus, may have higher risk of poor

neurodevelopmental outcomes.

In very preterm infants, neurodevelopmental outcomes may be associated with diverse variables such as gender and gestational age; however, these variables alone cannot explain poorer motor or cognitive function.[1] The MOS-R is a predictive tool. Additionally, developments in technology and care conditions as well as all medical and rehabilitation applications within the scope of early intervention have positive effects on the neurodevelopment of infants. The fact that all these interventions are associated with mortality and morbidity rates may have resulted in the lower-than-expected effect of the perinatal factors on MOS-R in the study.

The lack of equal numbers of infants included in the groups during analysis (twin-singleton, etc.) is a limitation of the study. Additionally, it may be important to follow up long term, and to reach higher numbers of infants to be able to clarify the results.

In conclusion, the weak positive relationship between gestational age and early motor repertoire is affected by birth weight, which is a mediator variable, and multiple pregnancy, gender, and USG findings, which are moderator variables. Infants with younger gestational age or lower birth weight, male infants, and infants with problems on cranial USG may have poorer early motor repertoire. The potential of these perinatal characteristics to impact the infant's neurodevelopmental outcome may be determined by evaluating the infant's early motor repertoire. Subsequently, it is possible to start early intervention at a very young age.

Ethical approval

This study was approved by Hacettepe University, non-interventional clinical research ethics committee (GO 21/895). Informed voluntary consent forms were signed by the families of infants included in the study.

Author contribution

The authors confirm contribution to the paper as follows: study conception and design: AK, AA, GÖT, AL; data collection: AA, GÖT; analysis and interpretation of results: AK, AA, SE, AL; draft manuscript preparation: AK, AA, GÖT, AL. All authors reviewed the results and approved the final version of the manuscript.

Source of funding

The authors declare the study received no funding.

Conflict of interest

The authors declare that there is no conflict of interest.

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