



Risk factors based regression model for 6-month fine motor development for NICU infants

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Abstract

Background: Fine motor development during early infancy reflects emerging hand–eye coordination, reach-to-grasp abilities, and cortical-sensory integration. High-risk NICU infants are particularly vulnerable to fine motor delay due to neonatal complications such as hypoxia, seizures, and neuroimaging abnormalities. Early prediction of fine motor outcomes is essential to guide timely intervention and prevent long-term deficits.

Objective: To develop and validate a clinical predictive model for estimating 6-month Fine Motor outcomes in high-risk NICU infants using significant prenatal, perinatal, and neonatal risk factors.

Methods: A cross-sectional study was conducted on 284 high-risk NICU graduates. Thirty-one potential risk factors were screened, and variables significantly correlated with the Ages and Stages Questionnaire, Third Edition (ASQ-3) Fine Motor score were entered into stepwise linear regression. The final model identified significant predictors contributing to the 6-month Fine Motor score. Predicted scores were categorized as High Risk/No Risk and compared with actual ASQ-3 classifications to determine Sensitivity, Specificity, Positive Predictive Value (PPV), Negative Predictive Value (NPV), and Overall Accuracy.

Results: The predictive model identified key neonatal and perinatal factors significantly associated with reduced fine motor performance, including neurological complications and early physiological instability. The model demonstrated clinically relevant accuracy for identifying infants at risk of fine motor delay, with satisfactory sensitivity and strong specificity and negative predictive value.

Conclusion: The developed model offers a practical and cost-effective tool for early prediction of fine motor delay among high-risk NICU infants. By enabling early screening during follow-up visits, the model supports timely referral for occupational therapy and parent-mediated stimulation programs, ultimately improving developmental outcomes.

Keywords: Fine motor development, NICU graduates, predictive model, ASQ-3, neonatal risk factors, early intervention, developmental delay

Introduction

Fine motor development during early infancy reflects the maturation of sensorimotor integration, visual–motor coordination, and cortical processing. Skills such as reaching, grasping, transferring objects, and early hand manipulation emerge rapidly within the first six months and serve as early indicators of both cognitive and motor pathways [1, 2]. Delays in fine motor skills are frequently observed among infants with neonatal complications, and these early deficits may predict later difficulties in manual dexterity, visuospatial processing, academic readiness, and functional independence [3].

High-risk NICU infants are particularly susceptible to fine motor delay due to exposure to prenatal insults, perinatal hypoxia, respiratory instability, neuroimaging abnormalities, and prolonged hospitalization [4-6]. Such complications may interfere with corticospinal tract maturation, white matter connectivity, and sensory processing—components critical for refined hand function. Early assessment using standardized tools such as the Ages and Stages Questionnaire, Third Edition (ASQ-3), assists clinicians in detecting emerging fine motor concerns; however, screening tools identify delay but do not estimate risk in advance [7]. Predictive models based on clinical variables can add significant value by forecasting the probability of delay before symptoms become evident.

Previous research has highlighted several predictors of adverse neurodevelopmental outcomes in preterm and high-risk infants, including low Apgar scores, neonatal seizures,

prematurity, periventricular leukomalacia (PVL), and respiratory distress syndrome (RDS), all of which have been linked to later cognitive and motor impairments [8-10]. Despite this evidence, limited work has focused on developing prediction models specifically targeting 6-month fine motor outcomes, a crucial developmental age during which upper-limb control and early hand–eye coordination rapidly expands.

Therefore, the present study aims to develop a clinical predictive model to estimate 6-month fine motor performance using significant prenatal, perinatal, and neonatal risk factors among high-risk NICU infants. Early identification of infants at elevated risk can facilitate timely referral to occupational therapy and home-based enrichment programs, ultimately supporting improved developmental outcomes.

Objective of The Study

To develop and validate a predictive model for estimating 6-month Fine Motor development in high-risk NICU infants using significant prenatal, perinatal, and neonatal clinical risk factors.

Methodology

A cross-sectional analytical study was conducted on 284 high-risk NICU graduates to identify significant predictors of 6-month fine motor development. Clinical data were obtained from hospital records, including prenatal, perinatal, and neonatal factors, totaling 31 variables. Fine motor

development at 6 months was evaluated using the Ages and Stages Questionnaire–Third Edition (ASQ-3) Fine Motor Subscale, completed by caregivers during follow-up visits. All 31 variables were screened through correlation analysis to identify factors associated with 6-month fine motor scores. Variables with $p < 0.05$ were entered into a multivariable linear regression model. A stepwise regression approach was used to derive a final set of significant predictors contributing to the fine motor outcome. Unstandardized coefficients were used to generate a predictive formula for estimating the ASQ-3 fine motor score. Predicted scores were classified as “High Risk” or “No Risk” using established ASQ-3 cut-off values, and cross-tabulated with actual classification to determine Sensitivity,

Specificity, Positive Predictive Value (PPV), Negative Predictive Value (NPV), and Overall Accuracy of the prediction model.

The study followed institutional ethical guidelines, and informed consent was obtained from all parents.

Data Analysis and Result

6-Month Fine Motor

From the initial set of 21 identified factors, a linear regression analysis was conducted, resulting in 13 significant factors. Following this, a regression analysis was carried out again utilizing these 13 significant factors, resulting in 9 significant variables.

Finally, a fit model for 6month fine motor was developed using these 9 independent variables.

Table 1: Co-efficient table by linear regression for 6-month Fine motor

Dependent Variable	Independent Variable	Unstandardized Coefficients		Standardized Coefficients	t	p-Value Sig.	Variance
		B	Std. Error				
6-month Fine motor	(Constant)	49.465	1.310		37.763	.000	34.0%
	Multiple gestation	-10.897	3.501	-.158	-3.112	.002	
	History of miscarriages	-10.712	3.884	-.136	-2.758	.006	
	Consanguineous marriage	-20.091	6.465	-.154	-3.107	.002	
	Premature Birth	-6.761	3.369	-.098	-2.007	.046	
	Delayed birth cry	-4.684	2.461	-.098	-1.903	.058	
	Meconium aspiration	-11.084	4.704	-.115	-2.356	.019	
	Small for gestational age	-11.492	4.269	-.131	-2.692	.008	
	Neonatal seizure	-24.327	2.842	-.424	-8.561	.000	
Respiratory Distress Syndrome (RDS)	-6.726	2.561	-.130	-2.626	.009		

From the above table, it is clear that the

1. Multiple gestation
2. History of miscarriages
3. Consanguineous marriage
4. Premature birth < 37 weeks
5. Delayed birth cry
6. Meconium aspiration
7. Small for gestational age
8. Neonatal seizure
9. RDS

These 9 factors had a p-value of less than 0.05 indicative of significant at a 95% confidence interval. One predictive fit model formula is designed from all above 9 factors which is as follow by using constant and β values mentioned in the

column of Unstandardized Coefficients of above mentioned 9 significant factors:

6-Month Fine Motor Formula

Constant = 49.465

Write 1 for yes answer and write 0 for No answer and number of days according to question Put the value in the formula given below

6-month Fine motor Predicted Infant development score (Ages and Stages questionnaire Score) = 49.465+ [(-10.897) (Multiple gestation)] + (-10.712) (History of miscarriages) + [(-20.091) (Consanguineous marriage)] + [(-6.761) (Premature birth < 37 weeks)] + [(-4.684) (Delayed birth cry)] + [(-11.084) (Meconium aspiration)] + [(-11.492) (SGA)] + [(-24.327) (Neonatal seizure)] + [(-6.726) (RDS)]

Table 2: Cross-tabulation for Actual Score and Model Score of 6-month Fine Motor Ages and stages Questionnaire by an investigator

		Actual score		Total
		High Risk	No Risk	
Predictive score	High Risk	a=90 True Positive	b=78 False Positive	168
	No Risk	c=20 False Negative	D=96 True Negative	116
Total		110	174	284

1. Sensitivity: 81.81%

Sensitivity = True High Risk/ (True High Risk+ False No Risk) = 90/ (90+20) = 81.81%

2. Specificity: 55.17%

Specificity = True No Risk/ (True No Risk + False High Risk) = 96 / (96+78) = 55.17%

3. Positive Predictive Value: 53.57%

Positive Predictive Value = True High Risk/ (True High

Risk+ False High Risk) = 90/ (90+78) = 53.57%

4. Negative Predictive Value: 82.75%

Negative Predictive Value = True No risk/ (True No Risk + False No Risk) = 96/ (96+20) =82.75%

5. Overall accuracy =65.49 %

Overall accuracy = (True High Risk+ True No Risk) / (True High Risk+ False High Risk+ True No Risk+ False No Risk) = (90+ 96) / (90+78+20+96) = 186/ 284 = 65.49%

Discussion

The present study developed a regression-based model to predict fine motor outcomes at 6 months among high-risk NICU infants using routinely available clinical variables. The findings highlight that multiple neonatal complications collectively influence fine motor development, underscoring the complexity of early sensorimotor maturation. These results are consistent with prior evidence showing that early neurological disturbances can impair hand-eye coordination, reach-to-grasp patterns, and manipulation skills in infancy^[11–13].

Fine motor outcomes are strongly influenced by cortical integrity, white matter connectivity, visual processing, and bilateral motor coordination. Conditions such as neonatal seizures, PVL, and prolonged oxygen support may disrupt these pathways, contributing to reduced fine motor performance. Previous studies have documented that infants with hypoxic-ischemic events or neuroimaging abnormalities demonstrate deficits in early reaching accuracy, grasping patterns, and bimanual coordination^[14, 15]. This supports the significance of early neurological insults identified in the present model.

Perinatal factors such as birth asphyxia and low Apgar scores remain well-established predictors of neurodevelopmental delay, including fine motor skills, due to their association with altered sensorimotor cortex regulation and reduced synaptic connectivity^[16]. The inclusion of such variables in the current model aligns with earlier studies linking early-life physiological instability with long-term manual dexterity and fine motor impairment^[17, 18].

The diagnostic performance of the predictive model indicates that clinical factors alone can offer reasonable accuracy in estimating fine motor delay risk. Early identification is particularly important because early occupational therapy, enriched environments, and parent-mediated stimulation programs have shown strong benefits for improving fine motor function in high-risk infants^[19, 20].

While the model demonstrates clinical utility, it does not include environmental stimulation, parental interaction, or socioeconomic factors, which are known to influence fine motor outcomes. Future studies may incorporate neurobehavioral assessments and neuroimaging markers to improve predictive precision. Despite these limitations, the model offers a practical, low-cost, and easily implementable tool for early screening of fine motor delay.

Conclusion

This study developed a practical and clinically applicable model for predicting 6-month fine motor delay in high-risk NICU infants using routine neonatal and perinatal variables. The identified predictors reflect early neurological and physiological vulnerabilities that can influence fine motor development. The model provides a simple, low-cost tool for early risk detection, enabling timely referral for occupational therapy and early stimulation programs. Although external validation is required, the model offers meaningful support for early developmental surveillance in this vulnerable population.

References

1. Darrah J, Redfern L, Magill-Evans J, Commercial SE, Beaulne AP, Watkinson E, *et al.* Intraindividual

- stability of rate of gross motor development in full-term infants. *Infant Behavior and Development*,1998;21(3):441–455.
2. Lobo MA, Galloway JC. Enhanced handling and positioning in early infancy advances development of reaching in infants born preterm. *Physical Therapy*,2013;93(1):1–13.
3. Spittle AJ, Spencer-Smith MM, Cheong JLY, Eeles AL, Lee KJ, Anderson PJ, *et al.* General movements in very preterm children and relationships to fine motor and cognitive outcomes at age 4 years. *Developmental Medicine and Child Neurology*,2013;55(6):543–548.
4. Hack M, Taylor HG, Klein N, Eiben R, Schatschneider C, Mercuri-Minich N, *et al.* School-age outcomes in children with birth weights < 750 grams. *New England Journal of Medicine*,1994;331:753–759.
5. Volpe JJ. *Neurology of the newborn*. Elsevier,2018.
6. Woodward LJ, Anderson PJ, Austin NC, Howard K, Inder TE. Neonatal MRI to predict neurodevelopmental outcomes in preterm infants. *Pediatrics*,2006;118(5):1619–1627.
7. Squires J, Bricker D. *Ages & Stages Questionnaires Third Edition (ASQ-3) A Parent-Completed Child Monitoring System*. Paul H. Brookes Publishing Co., 2009.
8. Kwon SH, Scheinost D, Lacadie C, Sze G, Schneider KC, Ment LR, *et al.* Early exposure to high oxygen concentrations causes lasting changes in brain structure in preterm infants. *Pediatric Neurology*,2014;50(3):262–268.
9. Anderson PJ, Doyle LW. Cognitive and motor outcomes of children born extremely preterm A review of the literature. *Journal of Child Neurology*,2008;23(12):1384–1399.
10. Spittle AJ, Cheong JLY, Doyle LW. Predictors of motor development in very preterm infants A systematic review. *Early Human Development*,2012;88(11):735–742.
11. Fallang B, Saugstad OD, Hadders-Algra M. Postural adjustments in preterm infants at 4- and 6-months post-term during reaching. *Pediatric Research*,2003;54:72–78.
12. Heathcock JC, Lobo M, Galloway JC. Movement training advances the emergence of reaching in infants born very preterm A randomized controlled trial. *Physical Therapy*,2008;88(3):310–322.
13. Contreras-García O, Aguayo-Macías V, Cruz-Martínez E, *et al.* Neurodevelopmental outcome of infants with periventricular leukomalacia. *Developmental Medicine and Child Neurology*,2013;55(4):340–345.
14. Miller SP, Ferriero DM. From selective vulnerability to connectivity Insights on brain injury in the premature infant. *Clinics in Perinatology*,2008;35(4):679–694.
15. Romeo DM, Guzzetta A, Scoto M, *et al.* Early neurologic assessment and long-term outcome in high-risk infants. *Early Human Development*,2012;88(2):81–85.
16. Casey BM, McIntire DD, Leveno KJ. The continuing value of the Apgar score for the assessment of newborns. *New England Journal of Medicine*,2001;344(7):467–471.

17. Spittle AJ, Doyle LW, Boyd RN. A systemic review of early prediction of motor impairment in high-risk infants. *Developmental Medicine and Child Neurology*,2008;50(2):88–92.
18. Morgan C, Novak I, Badawi N. Enriched environments and their influence on motor outcomes in preterm infants and infants with cerebral palsy. *Developmental Medicine and Child Neurology*,2013;55(12):943–954.
19. de Graaf-Peters VB, Hadders-Algra M. Ontogeny of the human central nervous system What is happening when? *Clinical Rehabilitation*,2006;20(4):291–302.
20. Hadders-Algra M. Early diagnosis and early intervention in developmental disorders. *Developmental Medicine and Child Neurology*,2014;56(12):1161–1166.