Hand Function at 18-22 Months Is Associated with School-Age Manual Dexterity and Motor Performance in Children Born Extremely Preterm

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Objectives To determine associations between hand function at age 18-22 months (early) and scores on the Movement Assessment Battery for Children, 2nd edition (MABC) at 6-7 years of age (school age) in extremely preterm children.

Study design Prospective multicenter cohort of 313 extremely preterm children with early hand function assessment and school-age MABC testing. Early hand function was compared with "definite deficits" (MABC <5th percentile) and MABC standard scores. Early hand function was categorized as "no deficit" vs "any deficit." Mixed-effects regression models were used to evaluate the association of early hand function with MABC deficits, controlling for multiple demographic, neonatal, and childhood factors.

Results Children with early hand function deficits were more likely to have definite school-age deficits in all MABC subtests (Manual Dexterity, Aiming and Catching, and Balance) and to have received physical or occupational therapy (45% vs 26%; $P < .001$). Children with early hand function deficits had lower Manual Dexterity ($P = .006$), Balance ($P = .035$), and Total Test ($P = .039$) scores. Controlling for confounders, children with early hand function deficits had higher odds of definite school-age deficits in Manual Dexterity (aOR, 2.78; 95% CI, 1.36-5.68; $P = .005$) and lower Manual Dexterity ($P = .031$) and Balance ($P = .027$) scores. When excluding children with cerebral palsy and those with an IQ <70, hand function deficits remained significantly associated with manual dexterity.

Conclusion Hand function deficits at age 18-22 months are associated with manual dexterity deficits and motor difficulties at school age, independent of perinatal-neonatal factors and the use of occupational or physical therapy. This has significant implications for school success, intervention, and rehabilitative therapy development. *(J Pediatr 2020;225:51-7)*.

Children born extremely preterm (<28 weeks of gestation) are at high risk of significant motor deficits, including cerebral palsy (CP). However, milder motor impairments such as fine motor deficits are nearly 3 times more common than CP.[1] Fine motor function, or 'hand function', comprises the control and coordination of the musculature of the hands and fingers.[2] During early childhood, accurate, coordinated movement of the muscles of the fingers and hands is critical for environmental exploration and learning.

At school age, fine motor deficits may affect daily functioning and school success.[1] Successful participation in most kindergarten activities requires fine motor proficiency.[3] In typically developing children at school age and adulthood, early fine motor function has been associated with higher-order executive functioning skills, such as planning and working memory.[2,4,5] Connectivity between motor areas and other processing centers of the brain is essential for typical development of language.[6,7] Early fine motor skills require engagement from primary and secondary motor brain networks and are strong predictors of school readiness.[5-8] Despite the importance of fine motor function for future successes, studies of outcomes in extremely preterm children often assess only global motor function in early life, overlooking the impact of milder motor impairments or fine motor function.

Although fine motor functioning has been associated with neurodevelopment and school performance in typically developing children, the association between

CP	Cerebral palsy
MABC	Movement Assessment Battery for Children, 2nd edition
NICHD NRN	*Eunice Kennedy Shriver* National Institute of Child Health and Development Neonatal Research Network
NEURO	Neuroimaging and Neurodevelopmental Outcomes
OT	Occupational therapy
PT	Physical therapy

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early hand function and school-age outcomes is not well understood in children born extremely preterm. Should toddler-age hand function be predictive of school-age manual dexterity, it could present an opportunity for targeted and evidence-based early intervention. We therefore sought to determine associations between early hand function at 18-22 months and scores on the Movement Assessment Battery for Children, 2nd edition (MABC) at early school age (6-7 years) in children born extremely preterm. We hypothesized that early hand function would be positively associated with later performance on the Manual Dexterity subtest of the MABC assessment, and that hand function at 18-22 months would also be associated with MABC Total Test scores and with scores on the Aiming and Catching and Balance MABC subtests at school age.

Methods

This was a prospective observational cohort study of children enrolled in the support Neuroimaging and Neurodevelopmental Outcomes (NEURO) Study of extremely preterm infants born at <28 weeks of gestation. The support NEURO study was a secondary to the support study[9] and included neonatal neuroimaging as well as 18-22 month and 6-7 year neurodevelopmental assessments (ClinicalTrials.gov: NCT00063063 and NCT0000).[10,11] Children were eligible for inclusion in this study if they were enrolled in the support NEURO study, had complete hand function assessments on the 18- to 22-month neuromotor examination, and completed the Manual Dexterity subtest of the MABC at the 6- to 7-year visit. The NEURO study enrolled children between May 2005 and February 2009 at 15 Neonatal Research Network (NRN) centers nationwide. Informed consent was obtained for study participants, and the study was approved by the Institutional Review Boards of all participating centers and by the Institutional Review Board of RTI International, the Data Coordinating Center for the *Eunice Kennedy Shriver* National Institute of Child Health and Development Neonatal Research Network (NICHD NRN).

Measures

Early Hand Function. Pincer and grasp capacity, exaggerated hand preference, and ability to perform bimanual functions were assessed in detail at 18-22 months of corrected age using the "hand function," "upper limb function," and "hand preference" subsections of the standardized NRN neuromotor examination.[1] Clinicians trained and certified annually in this assessment perform this examination. The child is sitting comfortably with hands free during these portions of the examination. Pincer and grasp capacity are assessed in the "hand function" subsection of the examination. This requires presenting a Cheerio to the child at waist level on a flat, firm surface that is of contrasting color with the Cheerio. The hand function items are coded as (1) fine pincer grasp, (2) finger-thumb grasp, (3) more than one finger-thumb (rake) grasp, or (4) tries but unable to grasp. The ability to perform bimanual functions is determined in the "upper limb function" subsection. This is coded as (1) no apparent problem with bimanual tasks (the child is able to manipulate small toys and small objects with both hands and transfer from one hand to the other with both hands in midline position); (2) some difficulty using both hands together (the child is able to perform the task with a typical variation but with limitation and difficulty in the midline position on bimanual transfer); or (3) no functional bimanual task. Hand preference is coded as (1) no preference, (2) exaggerated right, or (3) exaggerated left. This is determined by the child's method of obtaining an offered object. If a child presented an object on the right side consistently reaches across midline to grab it with the left hand, this is considered "exaggerated left." An "exaggerated right" is when a child presented an object on the left side consistently reaches across midline to grab it with the right hand.

Three possible levels of hand function were attributed based on the assessments: normal, mild deficit, and severe deficit. Normal ("no deficit") in hand function was defined as (1) fine pincer or finger thumb grasp, (2) no hand preference, or (3) no apparent problem with bimanual tasks. Mild deficit was defined as (1) more than one finger-thumb (rake) grasp, (2) any hand preference, or (3) some difficulty using both hands together. Severe deficit was defined as (1) tries but unable to grasp, (2) any hand preference, or (3) no functional bimanual task. Because only 7 children had severe hand deficits, these children were combined with those with mild deficits, leaving 2 hand function categories used for analysis: (1) no deficit vs (2) any deficit. "Any deficit" in hand function was defined as any of the following: (1) any hand preference, (2) rake grasp, (3) some difficulty with using both hands together, (4) tries but unable to grasp, or (5) no ability to perform functional bimanual tasks. Where different values were found for the right hand vs the left hand, the worst score was assigned. NRN examiners assessing hand function were masked to hospital morbidities. The Motor scale of the Bayley Scales of Infant-Toddler Development, 3rd Edition was not part of the 18- to 22-month NRN assessment until after 2010 and was not available for the children included in this study.[1]

MABC. The MABC is a widely used motor assessment tool for identifying and characterizing motor and coordination impairments in children aged 3-17 years.[12,13] The youngest age band of the MABC was administered (3 years 0 months to 6 years 11 months) at the same time as a neurologic examination performed by a physician or other clinician who was trained and certified in the assessment. The MABC evaluates 3 scales: Manual Dexterity, Aiming and Catching, and Balance. Scaled MABC scores are obtained, along with percentiles. Scores ≤5th percentile demonstrate a significant movement difficulty ("definite deficit"); scores from the 6th-15th percentile indicate "at risk"; and scores ≥16th percentile are unlikely to indicate a movement difficulty ("no deficit").

Statistical Analyses. We determined a priori that with the available sample size there was 90% power to detect medium-sized differences (d = 0.5) in mean MABC scale scores between the 2 hand function groups. Medical and psychosocial variables previously shown to adversely affect neurodevelopmental outcomes in at-risk children[14-20] were compared based on Manual Dexterity deficit category (none, at-risk, and definite) in bivariate analyses using the $\chi 2$ test (Table I). Then we compared performance on the MABC at school age for children with vs those without hand function deficits at 18-22 months corrected age. Frequencies, percentages, and $\chi 2$ values were computed for categorical variables and means, SDs, and the *t* test was used for continuous variables.

Medical and psychosocial variables were selected for inclusion as control variables in the regression models if they differed significantly at $P < .1$ for Manual Dexterity deficit in bivariate comparisons. Finally, linear mixed-effects regression models compared scores on the MABC tests based on hand function deficit, after controlling for demographic and medical characteristics and including NRN center as a random effect. A similar generalized linear mixed-effects model compared definite (vs none/at-risk) deficits in Manual Dexterity by early hand function deficit while controlling for other factors.

Results

A total of 313 children were included in the study sample. Figure 1 (available at www.jpeds.com) details the study sample selection process. We compared the demographic and neonatal characteristics (Table I) for the 313 children in the analysis with the 110 who were excluded owing to loss-to-follow-up or missing MABC standard scores. Those who were excluded from the analyses were more likely to have received postnatal steroids (13% vs 7%; $P = .049$); otherwise, there were no significant differences between the groups. There was no difference in rates of early hand function deficits between the children who were included and those who were lost to follow-up or missing MABC scores (13% vs 18%; $P = .224$).

School-Age Motor Performance

Overall, 35% of children had definite deficits on the MABC Manual Dexterity subtest, 10% had definite deficits in Balance, 6% had definite deficits in Aiming and Catching, and 17% had total MABC test scores in the “definite deficit” range. Table I presents the unadjusted comparison of demographic and medical characteristics based on deficits on the MABC Manual Dexterity subscale at school age. Children who were born at <26 weeks were significantly more likely to have definite Manual Dexterity deficits at school age than those born at 26-28 weeks ($P = .003$). Boys were more likely than girls to have school-age Manual Dexterity deficits ($P = .006$), and children who received physical therapy (PT) and/or occupational therapy (OT) at 18-22 months were more likely to have Manual Dexterity deficits at school age ($P < .001$). Children who received antenatal steroids were less likely to have definite Manual Dexterity deficits at school age ($P = .012$). There was no increase in Manual Dexterity deficits based on race/ethnicity.

School-Age Motor Function and Early Hand Function

The percentage of children in each hand function group at 18-22 months who had MABC deficits at 6-7 years is shown in Table II. Children with early hand function deficits were significantly more likely to have definite deficits (scores <5th percentile) in total MABC scores and in all MABC subtests at school age compared with those without early hand function deficits. Children with early hand function deficits also had lower mean Manual Dexterity, Balance, and Total Test scores ($P = .006$, .035, and .039, respectively; Table II). Mean scores on the Aiming and Catching subscale were not significantly different based on early hand function.

Regression Models of School-Age Motor Function by Early Hand Function

Results of regression models are shown in Figure 2 and Table III. Each model controlled for variables that were significantly associated with school-age Manual Dexterity in bivariate analyses at $P < .1$: OT/PT receipt at 18-22 months, gestational age, male sex, receipt of antenatal steroids, necrotizing enterocolitis, and patent ductus arteriosus. After controlling for these variables, children with hand function deficits at 18-22 months corrected age had nearly 3-fold greater odds of having a definite deficit (<5th percentile) on the MABC Manual Dexterity subtest at 6-7 years of age (Table III). Children who received OT/PT at 18-22 months had nearly double the odds of having a school-age definite deficit in Manual Dexterity. Children with higher gestational ages (26-28 weeks vs those born <26 weeks) as well as those children who received antenatal steroids had lower odds of having a definite Manual Dexterity deficit at school age. When mean MABC scores were considered (Figure 2), children with hand function deficits had significantly lower scores on the MABC Manual Dexterity ($P = .024$) and Balance ($P = .020$) subsets, as well as Total Test ($P = .036$) scores, compared with those without deficits after controlling for other factors (Figure 2), but these groups did not differ on the Aiming and Catching subtest.

Sensitivity Analyses

We reran bivariate comparisons for the MABC subtests excluding the following groups, one at a time: (1) children with any level of CP, (2) children with moderate/severe CP, and (3) children with a full-scale IQ <70. After excluding these groups, hand function deficits at 18-22 months remained significantly associated with school-age Manual Dexterity scores only (Table IV; available at www.jpeds.com).

Discussion

In this longitudinal study of >300 extremely preterm infants followed from preschool to school age, fine motor deficits at age 18-22 months were significantly associated with manual dexterity deficits and poorer balance at school age, independent of perinatal-neonatal factors and OT/PT receipt. In

Table I. Manual dexterity deficits at school age by demographic, perinatal, and neonatal characteristics and gross motor function

Variables	Number	Manual dexterity deficit* Definite, n (row %)	At-risk, n (row %)	None, n (row %)	P value
Demographic/perinatal/neonatal					
Birth weight, g					
<840	148	59 (40)	25 (17)	64 (43)	.255
840+	162	51 (31)	27 (17)	84 (52)	
Gestational age, wk					
<26	109	50 (46)	21 (19)	38 (35)	.003
26+	201	60 (30)	31 (15)	110 (55)	
Multiple gestation					
Yes	72	20 (28)	17 (24)	35 (49)	.123
No	238	90 (38)	35 (15)	113 (47)	
Race/ethnicity					
Non-Hispanic black	106	42 (40)	16 (15)	48 (45)	.318
Non-Hispanic white	127	45 (35)	17 (13)	65 (51)	
Hispanic	69	21 (30)	18 (26)	30 (43)	
Other	8	2 (25)	1 (13)	5 (63)	
Non-Hispanic white					
Yes	193	45 (35)	17 (13)	65 (51)	.367
No	117	65 (36)	35 (19)	83 (45)	
Maternal education					
Less than high school	79	30 (38)	13 (16)	36 (46)	.829
High school or more	225	77 (34)	38 (17)	110 (49)	
Sex					
Male	167	67 (40)	34 (20)	66 (40)	.006
Female	143	43 (30)	18 (13)	82 (57)	
Any antenatal steroids					
Yes	296	100 (34)	50 (17)	146 (49)	.012
No	14	10 (71)	2 (14)	2 (14)	
Cesarean delivery					
Yes	205	75 (37)	39 (19)	91 (44)	.178
No	105	35 (33)	13 (12)	57 (54)	
PDA diagnosed					
Yes	155	63 (41)	28 (18)	64 (41)	.069
No	155	47 (30)	24 (15)	84 (54)	
Early sepsis					
Yes	9	4 (44)	0 (0)	5 (56)	.390
No	301	106 (35)	52 (17)	143 (48)	
Late sepsis					
Yes	94	38 (40)	15 (16)	41 (44)	.481
No	216	72 (33)	37 (17)	107 (50)	
NEC					
Yes	20	6 (30)	0 (0)	14 (70)	.050
No	290	104 (36)	52 (18)	134 (46)	
Severe ROP					
Yes	30	14 (47)	5 (17)	11 (37)	.286
No	258	85 (33)	43 (17)	130 (50)	
Surgery for PDA, NEC, or ROP					
Yes	55	24 (44)	5 (9)	26 (47)	.165
No	255	86 (34)	47 (18)	122 (48)	
Postnatal steroids					
Yes	20	9 (45)	2 (10)	9 (45)	.540
No	287	99 (34)	50 (17)	138 (48)	
Brochopulmonary dysplasia					
Yes	115	47 (41)	16 (14)	52 (45)	.268
No	195	63 (32)	36 (18)	96 (49)	
PT (received or receiving)					
Yes	149	61 (41)	24 (16)	64 (43)	.158

(*continued*)

Table I. Continued

Variables	Number	Manual dexterity deficit* Definite, n (row %)	At-risk, n (row %)	None, n (row %)	P value
No	160	49 (31)	28 (18)	83 (52)	
OT (received or receiving)					
Yes	157	71 (45)	26 (17)	60 (38)	<.001
No	152	39 (26)	26 (17)	87 (57)	
Gross motor function					
Any CP					
Yes	7	4 (57)	1 (14)	2 (29)	.467
No	303	106 (35)	51 (17)	146 (48)	
Moderate/severe CP					
Yes	1	1 (100)	0 (0)	0 (0)	.402
No	309	109 (35)	52 (17)	148 (48)	
GMFCS level 2 or higher					
Yes	4	2 (50)	1 (25)	1 (25)	.656
No	306	108 (35)	51 (17)	147 (48)	

NEC, necrotizing enterocolitis; *PDA*, patent ductus arteriosus; *ROP*, retinopathy of prematurity; *GMFCS*, Gross Motor Function Classification System.
*Categories correspond to <5th percentile: definite deficit; 5th-15th percentiles: at risk; >15th percentile: no deficit.

sensitivity analyses excluding children with CP and IQ <70, hand function deficits at 18-22 months remained significantly associated with school-age Manual Dexterity scores. We also found that exposure to antenatal steroids was associated with lower rates of manual dexterity deficits at school age, which could be related to a number of confounders and intermediates influenced by steroid receipt.

Other researchers have found rates of CP of 7% to 11% in extremely preterm children.[21,22] Our finding that only 2% of

Table II. Hand function deficits at 18-22 months by MABC findings at school age

MABC-2 categories	Hand function deficit No deficit, n/N (col %)	Any deficit, n/N (col %)	P value
Manual Dexterity			
<5th percentile (definite deficit)	87/269 (32)	23/41 (56)	.012
6th-15th percentile (at-risk)	47/269 (17)	5/41 (12)	
>15th percentile (no deficit)	135/269 (50)	13/41 (32)	
Aiming and Catching			
<5th percentile (definite deficit)	12/270 (4)	7/42 (17)	.007
6th-15th percentile (at-risk)	31/270 (11)	3/42 (7)	
>15th percentile (no deficit)	227/270 (84)	32/42 (76)	
Balance			
<5th percentile (definite deficit)	21/266 (8)	9/42 (21)	.021
6th-15th percentile (at-risk)	45/266 (17)	7/42 (17)	
>15th percentile (no deficit)	200/266 (75)	26/42 (62)	
Total Test score			
<5th percentile (definite deficit)	38/264 (14)	14/41 (34)	.005
6th-15th percentile (at-risk)	63/264 (24)	10/41 (24)	
>15th percentile (no deficit)	163/264 (62)	17/41 (41)	
MABC-2 scores	**Mean (SD)**	**Mean (SD)**	
Manual Dexterity	6.89 (3.43)	5.27 (4.01)	.006
Aiming and Catching	9.55 (3.06)	9.05 (4.47)	.358
Balance	8.53 (2.98)	7.43 (4.03)	.035
Total Test Score	7.75 (3.23)	6.56 (4.42)	.039

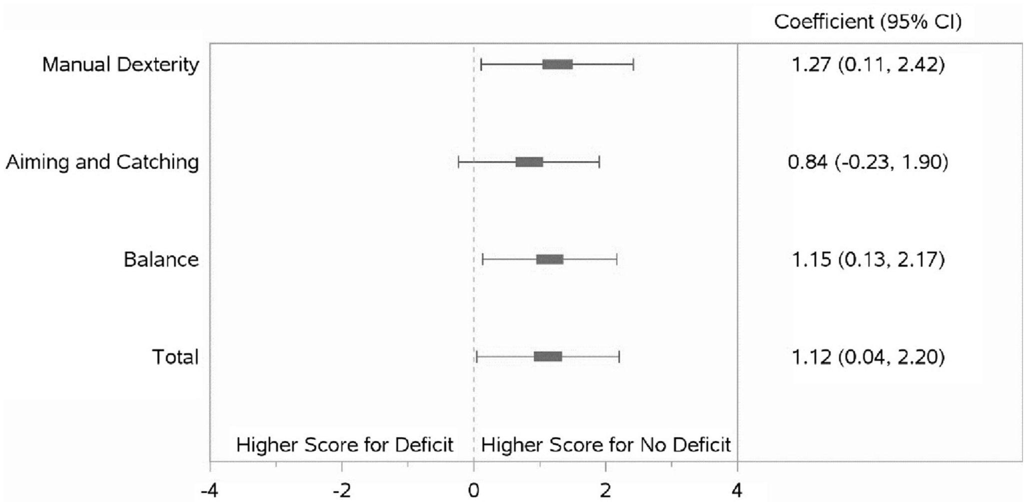

Figure 2. Linear regression models of school-age mean MABC-2 scores by early hand function. Coefficients are adjusted for site, receipt of OT/PT at 18-22 months, gestational age, male, antenatal steroid use, necrotizing enterocolitis, and patent ductus arteriosus.

the current study's cohort had CP at age 6-7 years (considerably lower than the published prevalence rates for extremely preterm children) may indicate that children with CP were less likely to complete the MABC. Even within the context of fewer children with CP and potential severe impairments, 35% of our cohort still had fine motor (manual dexterity) deficits at school age. This finding thus supports published literature showing that milder motor impairments are significant contributors to functional impairment.[23,24] The foundations for the fine motor skills necessary for school success emerge in early infancy, and acquisition of these skills by school age is critical, given that up to two-thirds of daily kindergarten activities rely on fine motor skills.[3] Fine motor execution is fundamental to the development of handwriting skills[25] and is strongly associated with numerical manipulation ability and executive function competencies, such as processing speed and working memory.[2,26] We demonstrated that early hand function deficits at 18-22 months were associated with concurrent deficits in object permanence as a measure of early working memory in children born extremely preterm.[1] Given that deficiencies in graphomotor skills tend to cluster with deficits in attention and processing speed at school age,[27] the high rate of manual dexterity deficits in our cohort of extremely preterm children in early childhood and at school age is especially concerning. Our study was not designed to determine whether children with manual dexterity deficits also had higher rates of attention deficit problems, a common problem in children born extremely preterm.[28] Thus, at this time we are unable to speculate on the influence of deficient attentional networks on dexterity findings.

The rate of hand function deficits in the cohort increased from 16% at 18-22 months to 35% at school age. The results of a meta-analysis of studies of motor development in children born preterm and very low birth weight from birth to adolescence suggested that the differences in motor function between the preterm and very low birth weight children and those born at term decrease in the first years of life but increase later in development.[25] This may represent an increase in fine motor deficits as extremely preterm children age but is more likely a function of the increased complexity of manual dexterity demands in older age assessments such as the MABC.

The association between early fine motor skill and higher-order functioning noted by other researchers is likely related to the interplay between cognitive and motor regions in the brain during development. In infancy, movements are initially reflexive; increased cognitive control and ability is required, because more purposeful, complex movements are needed.[29] Therefore, movement drives cognition and higher-order functioning through engagement of motor skills in problem solving. The interconnection of motor and cognitive function is founded on the neural interconnections between brain regions previously thought to function primarily for cognition or movement, but not both. Fine motor function has also been demonstrated to mediate the visual memory and visuomotor integration deficiencies

Table III. Generalized linear regression models of MABC-2 Manual Dexterity <5th percentile (vs ≥5th percentile) by 18-22-month hand function

Variables	aOR (95% CI)*	*P* value
Hand function deficit	2.78 (1.36-5.68)	.005
Receipt of OT/PT†	1.93 (1.15-3.24)	.013
Gestational age	0.76 (0.59-0.97)	.030
Male sex	1.44 (0.87-2.39)	.154
Antenatal steroids	0.16 (0.04-0.57)	.005
NEC	0.68 (0.23-2.00)	.481
PDA	1.25 (0.75-2.08)	.400

*Center is included as a random effect.
†Recorded at the 18- to 22-month corrected age visit.

seen in preterm children,[30] and visual perceptive function is a factor underlying the IQ differences seen in preterm and term children.[31] Fine motor function requires visuomotor coordination and visual spatial integration[29] and is a critical component of visuomotor integration.[32] Our findings of increased manual dexterity deficits at school age may represent the inability of extremely preterm children to keep up with increasing manual dexterity demands as they age; this may be confounded by deficits in visuomotor skills, although we are unable to determine this within the current study.

The impact of early fine motor ability on the development of later motor ability and higher-order functioning in extremely preterm children is not well studied. The early neural insults sustained by extremely preterm infants may result in abnormalities in critical brain circuits responsible for the visuoperceptual, motor coordination, and integration skills necessary for adequate fine motor function.[29] These neural abnormalities in turn may lead to abnormal visuomotor integration and may underlie not only the fine motor, balance, and coordination deficits, but also the abnormalities in many of the other neurodevelopmental domains associated with the poor school outcomes of many extremely preterm children. More likely, fine motor learning of advanced skills is driven by the brain's Bayesian computations of new movement, based on previous probability (experience) of movement.[33] Early deficits in hand function limit experience and decrease its quality, resulting in more faulty computations and poorer execution of movement, with the downstream effect of magnifying early fine motor deficits.

Early hand functioning was longitudinally assessed with school-age fine and gross motor function; however, the 2 measurement time points were remote. Thus, causation cannot be directly inferred between early hand function deficits and the school-age motor performance. The more global perinatal neural insults of extremely preterm infants may drive both proximal and distal motor functioning. Conversely, early hand function deficits may cumulatively affect school-age motor function via limitations in motor experiences, as has been shown in adults.[34] Either hypothesis could be supported from our study results, and future studies should longitudinally examine these connections with multiple time points and causal mediation analyses.

This study had several limitations. First, the MABC Manual Dexterity test focuses on the visuomotor coordination element of fine motor function and not the visual spatial integration element (eg, replicating an internally created representation of an image and creating it using the small muscles of the hand in an activity such as copying).[29] In addition, although the early fine motor assessment was extracted from the standardized NRN neuromotor examination, with highly monitored interrater reliability, the psychometric properties of this assessment have not been published. Although not feasible within the diverse NRN sites and resource constraints, the current study would have been bolstered by the inclusion of an early hand function assessment such as the Mini-Assisting Hand Assessment.[35] In addition, 7% of the children who were included in the 18- to 22-month assessment had impairment at school age that precluded completion of the MABC. This could have biased the results of the study, because loss of these children could have resulted in underestimation of school-age impairment. The lack of inclusion of 27% of the population studied at age 18-22 months in the school age assessment similarly could have resulted in unknown bias in the results. Conversely, the study is strengthened by the large sample size despite the losses, and by the measures of both early and school-age fine motor function.

The effect of poor fine motor skill on adaptive functioning early in life cannot be overstated. Early dysfunction impairs a child's ability to explore their environment, develop key communication skills (both nonverbal early on and written at school age), and is associated with decreased motor function, cognition, executive functioning, behavioral issues, and learning problems in older children.[14] The association of school-age fine motor deficits with early hand function deficits may not only provide a more granular ability to predict which extremely preterm children are most likely to develop issues at school age so as to allow for closer surveillance; this association also may indicate a target for earlier intervention (early hand function) that may allow clinicians to leverage early neuroplasticity to improve neurologic connections in the first 2 years of life and enhance outcomes across neuropsychological domains. In the extremely preterm population even more so than in term infants, fine motor skill characterization may be critical to rigorous intervention design to support early scholastic skills. Our finding that school-age manual dexterity and balance deficits remained despite receipt of PT/OT in the preschool years could be secondary to children with the poorest motor function being more likely to receive these therapies at an early age and also to have abnormalities at school age. This finding more likely points to the extreme heterogeneity in therapies delivered to the children resulting in no overall effect, as suggested by previous research.[36] However, evidence-based, standardized, and targeted early interventions improve outcomes[36-40] and are critically needed for this population.

In conclusion, longitudinal studies of fine motor development in extremely preterm infants offer opportunities to characterize the trajectory of fine motor outcomes through school age in extremely preterm children and identify early predictors of school-age outcomes. This study provides important longitudinal data toward that end. Our findings may have significant implications for school success and more complex constructs, such as later executive function. Further study is needed to elucidate the full phenotype of motor development in extremely preterm children to guide the development of effective interventions. ■

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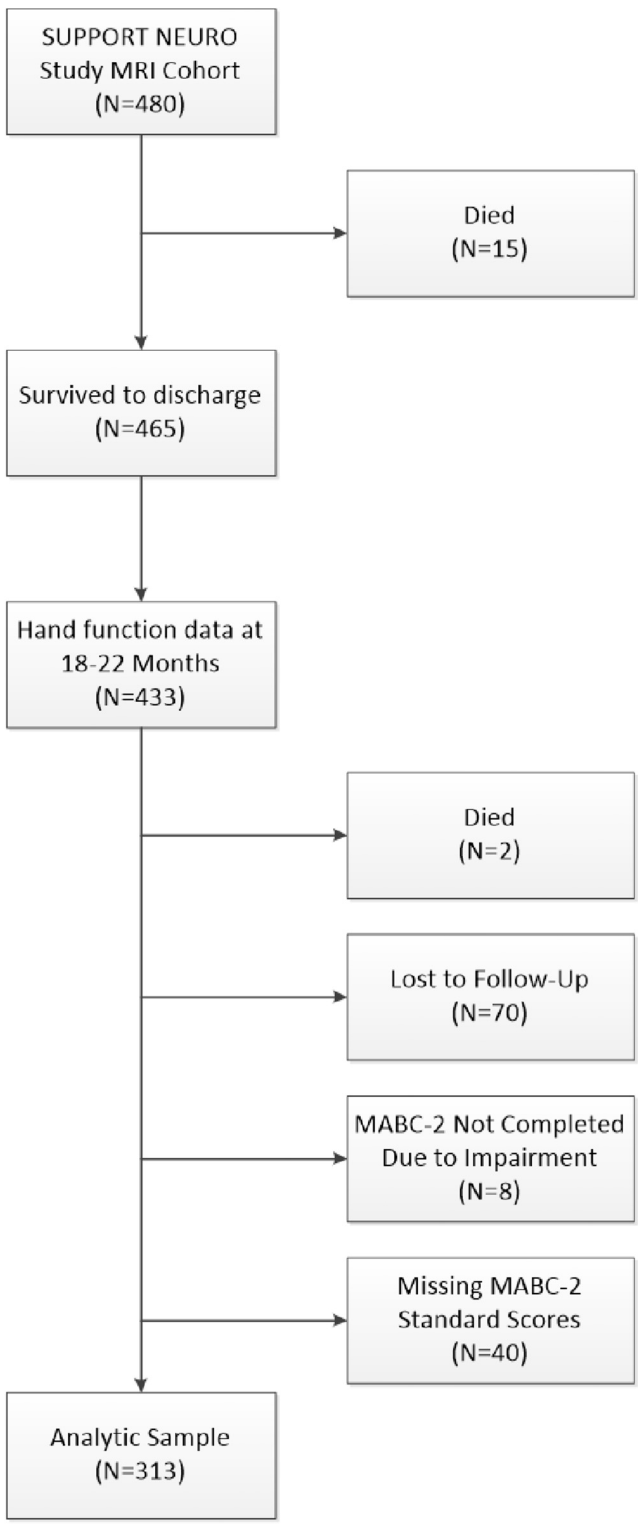

Figure 1. Sample selection flowchart.

Table IV. Sensitivity analyses

Variables	Patients	Hand function deficit: No deficit, mean (SD)	Hand function deficit: Any deficit, mean (SD)	*P* value
Excluding children with any CP				
Manual Dexterity (standard score)	303	6.90 (3.43)	5.55 (4.02)	.027
Aiming and Catching (standard score)	304	9.57 (3.05)	9.79 (4.01)	.688
Balance (standard score)	300	8.57 (2.97)	8.00 (3.76)	.288
Total Composite (standard score)	298	7.78 (3.23)	7.00 (4.29)	.187
Excluding children with moderate/severe CP				
Manual Dexterity (standard score)	309	6.89 (3.43)	5.33 (4.05)	.009
Aiming and Catching (standard score)	311	9.55 (3.06)	9.20 (4.42)	.520
Balance (standard score)	307	8.53 (2.98)	7.59 (3.94)	.071
Total Composite (standard score)	304	7.75 (3.23)	6.70 (4.38)	.071
Excluding children with full-scale IQ <70				
Manual Dexterity (standard score)	281	7.20 (3.38)	5.80 (4.05)	.027
Aiming and Catching (standard score)	282	9.69 (3.11)	9.58 (4.43)	.855
Balance (standard score)	280	8.84 (2.83)	7.97 (3.90)	.106
Total Composite (standard score)	278	8.04 (3.16)	7.26 (4.33)	.195