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Abstract

Purpose: The purpose of this study was to examine the language, motor, and cognitive abilities of children born preterm in four categories: (a) healthy preterm infants, (b) infants of diabetic mothers, (c) infants with respiratory distress syndrome, and (d) infants with chronic lung disease when the children were 30 months, uncorrected age. Comorbidity of language, motor, and cognitive skills was examined, along with predictor variables.

Method: A total of 148 children who were born preterm participated and were assessed using bivariate tests and logistic regression on standardized assessment scores.

Results: Controlling for the children's gestational age (GA), overall language ability was significantly lower in the infants of diabetic mothers group compared to the healthy preterm infant group, and expressive language skills were significantly

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lower for the chronic lung disease group than the respiratory distress syndrome group. The children with language delays on at least one measure were significantly more likely to have cognitive, motor, or both delays. Lower maternal education was a significant predictor for language and cognitive delays, and younger GA was a significant predictor for language, motor, and cognitive delays.

Conclusion: Assessment of the preterm infant from a biosystems approach allows the speech-language pathologist to take into consideration maternal education, diagnosis at preterm birth, and GA, which were found to impact the language, motor, and cognitive outcomes of children born preterm. Our findings further reinforce the concept of the whole child in that children born preterm who display language delays should be screened for co-occurring motor and/or cognitive delays.

Speech-language pathologists (SLPs) are part of the specialized team responsible for the preterm infant in the neonatal intensive care unit (NICU). SLPs have many duties in their scope of practice in the NICU, including the evaluation and intervention of communication (American Speech-Language-Hearing Association, 2005). It is essential that the NICU SLP is knowledgeable about the neurodevelopmental outcomes of children born preterm in order to provide the best care to these infants and their families. In this study, we examine the language, cognitive, and motor outcomes of 30-month-old children born preterm. We describe the implications of these findings for SLPs working in the NICU and those who work in NICU follow-up clinics or with the broader birth-to-3 population.

Neurodevelopmental Outcomes of Children Born Preterm

Approximately 10% of children in the United States and worldwide are born before 37 weeks of gestation (Centers for Disease Control and Prevention, 2018). Preterm birth is defined as birth before 37 weeks of gestation (Blencowe et al., 2013). Children born preterm have been described in two ways: (a) by their gestational age (GA) or (b) by their birthweight (BW). Regarding GA, extremely preterm refers to infants born before 28 completed weeks. Very preterm is delegated for those born between 28 and 32 weeks, whereas moderate and late preterm is used for infants born between 32 and 37 weeks. Even children born outside the definition of preterm, at 38 and 39 weeks of gestation (i.e., early term), have been found to display higher risk of special educational needs compared to their full-term peers (MacKay et al., 2010).

In addition to GA, another way of describing populations of children born preterm in the research literature is by BW. Many, but not all, babies born preterm are smaller than a child born full term due to less time of growth in the womb. A full-term infant on average weighs 7 lb at birth. An infant born weighing 5 lb, 8 oz (or 2,500 g) is classified as low birthweight (LBW). Very low birthweight (VLBW) is the classification for infants born less than 1,500 g, or 3 lb, 9 oz. The smallest infant is one born at less than 1,000 g, or 2 lb 3 oz, and is classified as extremely LBW. Approximately 8% of babies in the United States are born with LBW, with a much lower incidence of VLBW infants (1.4%; J. A. Martin et al., 2018). Some infants born preterm are large for GA (LGA), with a BW greater than 90% of all babies with the same GA. Maternal diabetes is the most common reason for infants to be born LGA. Diabetes during pregnancy leads to an increase in blood glucose (i.e., sugar), and this is shared with the infant in the womb. The fetus' body produces insulin in response to the sugar (Nold & Georgieff, 2004). The additional glucose and insulin lead to excessive growth in utero. Similar to LBW infants, the incidence of LGA in infants is approximately 8% nationwide.

Regardless of whether a child is born early or weighs very little, children born preterm can be classified as "healthy preterm infants" (HPIs). These children have less neurological involvement, have more mature lung growth, and generally spend less time in the NICU compared to babies who need extensive ventilation or who are born to mothers with diabetes.

The neurodevelopmental literature concerning preterm birth is complex to interpret because of several biological complications that may accompany prematurity and potentially impact outcome, such as GA, BW, brain injury, seizures, feeding abilities, and other maternal or child comorbid factors (e.g., maternal diabetes or child illness occurring pre-, peri-, or postnatally). Many neurodevelopmental outcome studies conducted with children born preterm have combined children with a range of GA, BW, brain injury, and other comorbid factors. In this study, children in four groups of preterm diagnoses were studied: (a) HPIs, (b) infants of diabetic mothers (IDM), (c) infants with respiratory distress syndrome (RDS), (d) and infants with chronic lung disease (CLD).

Diagnostic Categories of Preterm Birth

The outcomes of infants born preterm who are considered “healthy infants” have not been documented in the literature. This group is described by neonatologists as not requiring supplemental oxygen for more than 5 days and no identified medical conditions.

IDM are a more recent group of infants that have been studied in the preterm literature, with only a handful of studies available to date. In 2017, approximately 16.2% of all births were associated with maternal diabetes (International Diabetes Federation, 2018). Because of uncontrolled glucose levels, the brain development of the fetus is at risk for abnormal development (Nold & Georgieff, 2004). Dionne et al. (2008) reported that IDM were 2.2 times more at risk for language impairment compared to a control group. These effects for negative impact on expressive language were present at 18, 30, 72, and 84 months of age. The children in the Dionne et al. study had a mean GA of 37 weeks and were not defined as preterm. In a study of children born preterm to mothers with diabetes who were also VLBW, Rehan et al. (2002) reported no differences in neurodevelopmental outcomes compared to children born preterm who were VLBW and not born to mothers with diabetes. Developmental outcomes were measured using the Revised Gesell Development Scales (Knobloch & Pasamanick, 1974) and a standard neurological examination at 6, 12, and 18 months of age. More recently, maternal diabetes has been linked with a greater risk of autism spectrum disorder (Xu et al., 2014). No further studies have been conducted to evaluate the impact of neurodevelopmental outcomes on these potentially vulnerable infants.

RDS is a pulmonary disorder common in babies born preterm. It is characterized by need for supplemental oxygen greater than 5 days, but not extending beyond 36 weeks postmenstrual age (PMA). The respiratory distress occurs because the infant born preterm does not have lungs developed sufficiently, with enough surfactant to open their lungs completely. Approximately 10% of infants born preterm each year develop RDS. Complications such as brain injury may result from the lack of oxygen, bleeding, or side effects of treatment. To our knowledge, no studies have reported on the neurodevelopmental outcomes of children with diagnoses of RDS. However, it might be expected that children in the CLD group would perform more poorly than those in the RDS group and children in the RDS group would perform more poorly than those in the IDM and HPI groups, because the IDM and HPI groups did not experience difficulty with oxygen intake or lung scarring.

CLD has been used synonymously with the term "bronchopulmonary dysplasia" (BPD) in the research literature. However, Ho (2002) notes that, while both diagnoses are chronic pulmonary conditions and closely related, they differ in severity and diagnostic criteria. BPD can be diagnosed on Day 28 in infants who require supplemental oxygen, whereas CLD is present when the infant continues to require supplemental oxygen at 36 weeks of age. Children with a diagnosis of CLD, not BPD, as indicated by a neonatologist, were part of this study.

In general, the infants born the earliest are typically diagnosed with CLD based on oxygen requirement by the neonatologist. Infants with CLD require extensive ventilation due to their immature lung development. There is one study that indicates that, at 7 years of age, children born VLBW with CLD display poorer school performance compared to children born VLBW without CLD (Farel et al., 1998).

Associations and Comorbidity of Language, Cognitive, and Motor Disabilities in the Infant Born Preterm

Several studies conducted over the past two decades have provided extensive, converging evidence that children born preterm are at risk for delay and/or impairment in several neurodevelopmental areas regardless of level of prematurity (i.e., extremely, very, moderate, late, and early term; Allotey et al., 2017; Vohr, 2013). Most empirical studies have focused on one area of neurodevelopment, such as language, cognition, and/or motor skills in the child born preterm (e.g., Zimmerman, 2018). Some researchers have measured more than one neurodevelopmental area within the same group of children. For example, children born extremely preterm were found to have significantly lower motor, cognitive, and language scores compared to children born full term at 2.5 years of age (Månsson & Stjernqvist, 2014). Similarly, deJong et al. (2015) reported that children who were born moderately preterm when evaluated at 24 months of age, as a group, displayed language, cognitive, and motor scores that differed from a full-term birth comparison group.

Correlations between language, motor, and cognitive scores of the child born preterm and predictors associated with these areas have been reported in a handful of studies. Motor skills at 10–15 weeks using the score from the Test of Infant Motor Performance predicted language, cognitive, and motor outcomes when the children born preterm were assessed again at 18–24 months of age (Peyton et al., 2018). Significant correlations between fine motor scores, pointing and representational gestures, cognitive scores, and representational gestures have been found in infants born with extremely low gestational age (ELGA) when they were 12 months of age (Benassi et al., 2016). At 18 months of age, Ross et al. (2018) reported a significant relationship between cognitive, motor, and language development in a retrospective study of children born preterm who were VLBW. The children in this study ranged in neuromotor status, as determined by a clinical neuromotor exam, from normal to moderate–severe. Some of the sample included children with CLD, necrotizing enterocolitis (i.e., infection and inflammation of the intestine), and Grade III–IV intraventricular hemorrhage. The authors reported that cognition alone predicted receptive language skills and motor delays were related to expressive language development.

The previous studies indicate that there are deficits and correlations between motor, cognitive, and language skills in many children born preterm. There is less known about how many children display comorbidity of language, motor, and cognitive disability. However, a few studies shed light on this topic. Benassi et al. (2016) reported significant correlations between fine motor scores, pointing and representational gestures, cognitive scores, and representational gestures in a small sample of infants born at ELGA when they were 12 months of age. In a much larger group of infants (n = 399) born at ELGA, Månsson and Stjernqvist (2014) found that 20% of the children exhibited delays in only one area of cognition, receptive language, expressive language, fine motor, or gross motor subtests. Fourteen percent displayed delays on two subtests. Thirteen percent demonstrated delays on three subtests, and 12.5% displayed delays on three and five subtests, respectively. These two studies suggest that comorbidity is present from 12.5% to 20% of children born extremely preterm in the areas of language, cognition, and motor disabilities.

Biological and Environmental Factors Associated With Outcome in Preterm Neurodevelopment

Being born early places the infant at medical risk and at risk of later outcomes impacted by biological, social, and environmental factors (Loeb, 2014). In both the neuroconstructivist approach (D'Souza & Karmiloff-Smith, 2017) and the bioecological model of human development (Bronfenbrenner, 1977), the development of a child is viewed from biological and environmental factors. Each model would seek to identify risk and protective factors to guide assessment and intervention for the neurodevelopmental outcomes of the child born preterm.

Protective Factors

Koutra et al. (2012) studied the neurodevelopmental outcomes of Greek children born full term and born preterm by evaluating a variety of biological, social, and environmental factors and their impact when the children were 18 months of age. Approximately 13.1% of the children were born preterm. As a combined group, they found that female gender, higher maternal education, and maternal employment were positively associated with cognitive, language, motor, and social–emotional development. Infants who spent 6–10 hr a day with their mother had higher expressive language scores compared to mothers who spent less time with their children.

In another study that focused on sociodemographic predictors of outcome, maternal education was the strongest predictor of neurodevelopmental outcomes of infants born preterm at 20 months of age (Patra et al., 2016). The authors reported that mothers with some college had children with greater language scores than those with no college; however, completion of graduate school was the best predictor of cognitive, language, and motor scores in 20-month-olds who were born extremely and very preterm.

Risk Factors

GA, child gender, BPD, maternal education, number of children in the family, and time spent with a caregiver have been found to contribute to negative neurodevelopmental outcomes. In addition, family history of language impairment can be a risk factor for language impairment in children born full term (Harrison & McLeod, 2010). In a study of over a million children born between 23 and 41 weeks of age, GA was found to be positively related to kindergarten readiness and achievement scores (Garfield et al., 2017). Although poorer performance was significantly related to lower GA, a number of the infants born close to the age of viability (i.e., 23–24 weeks) performed within age-level expectations and within the gifted category. Thus, GA alone does not appear to predict preterm outcome.

Both biological and environmental risk predictors are present at a very early age. Infants born preterm who spent less than an hour per day with their father had poorer receptive language (Koutra et al., 2012). These authors also reported that the more older siblings in a home, the lower the cognitive, language, motor, and social–emotional development outcomes at 18 months of age. Male gender, low maternal education, at 20 months of age in children born very preterm and extremely preterm were more likely to have poor language skills; however, only low maternal education and GA were predictors of low cognitive skills. Maternal education alone was correlated with low motor skills (Patra et al., 2016). Male gender, BPD, and low maternal education level were related to an increased risk for language delay at 24 months (Sansavini et al., 2011). Together, these studies indicate the presence of multiple risk and protective factors that may impact language, cognition, and motor skills in the child born preterm.

In this study, we compared the language, motor, and cognitive skills of children born preterm when they were 30 months of age. Given the findings of previous studies, we predicted that our sample would display language, cognitive, and motor delays (Foster-Cohen et al., 2010; Sansavini et al., 2010). The current study differs from previous studies in three important ways. First, rather than combining the children into one large group, four subgroups of children born preterm were studied: (a) IDM, (b) infants with RDS, (c) infants with CLD, and (d) HPIs. Most previous studies have combined these types of diagnostic categories, masking potential variables that may contribute to neurodevelopmental outcomes. Second, we report on all neurodevelopmental measures in a given child (i.e., language, motor, and cognitive skills). Previous studies have focused primarily on one or two of these variables. Third, in this study, we evaluate possible predictors associated with neurodevelopmental outcomes within the same children. Our specific research questions were as follows:

1. Is there a difference between the language, motor, and cognitive abilities at 30 months of age between children born preterm who are HPIs compared to IDM, infants with RDS, and infants with CLD?
2. Do children with language delays display cognitive delays and/or motor delays more often than children without language delays?
3. What are the predictors of language delay, motor delay, and/or cognitive delay in children born preterm?

For our first question, it was predicted that the children in the HPI group would have the best outcomes and that children in the CLD group would have the poorest outcomes for cognitive and language abilities based on previous literature. Infants with RDS were also predicted to fare less well than the HPI group, but better than the CLD group because their difficulty with oxygen would be for a shorter time span and their hospital stays may be shorter than those with CLD. Based on the limited data available, it was predicted that the IDM group may have poorer outcomes compared to the healthy children born preterm. Concerning the second question, it was predicted that children who had delays in language may be more likely to have cognitive and/or motor involvement. This prediction is based on the premise that the impact of early birth would likely negatively influence many brain functions, rather than specific areas of development. Regarding the third question, based on previous literature (Koutra et al., 2012; Patra et al., 2016; Sansavini et al., 2011), it was predicted that CLD, GA, maternal education, and child gender might contribute as multifaceted predictors to neurodevelopmental outcomes in the child born preterm.

Method

Study Design

This is a follow-up study, which originally included 223 infants who initially participated in a randomized blind trial of the NTrainer (Loeb et al., 2018). The University of Kansas Institutional Review Board approved the procedures for the follow-up research presented in this study.

Participants

At birth, the children were between 23 and 36 weeks of GA (*M* = 29.64, *SD* = 3.05), with BWs between 410 and 3,830 g (*M* = 1,390.96, *SD* = 626.02). A neonatologist assigned diagnostic categories to the children, which included children who were HPI, IDM, infants with CLD, and infants with RDS. The children with RDS were on extended supplementary oxygen up to 36 weeks PMA. PMA is the time elapsed between the first day of the last menstrual period and birth (GA) and the time elapsed after birth (chronological age). In contrast, the children diagnosed with CLD had supplementary oxygen beyond 36 weeks PMA. The children in each of the HPI and IDM groups had fewer than 5 days of supplemental oxygen. Head circumference was within the 10th to 90th percentiles, and a hearing examination in the NICU indicated no hearing impairment. Exclusion criteria included presence of nervous system anomalies, intracranial hemorrhage Grades III and IV, neonatal seizures, necrotizing enterocolitis, periventricular leukomalacia, cyanotic congenital heart disease, chromosomal anomalies or craniofacial malformation, sepsis, meningitis, omphalocele, gastroschisis, diaphragmatic hernia and/or other major gastrointestinal anomalies, or not ready for oral feeding.

A total of 148 of the 223 infants in the original NTrainer study participated in the follow-up study of neurodevelopmental outcomes at 30 months, uncorrected age. No significant difference was observed between study participants and the children who did not participate in the follow-up study in terms of medical diagnosis (i.e., CLD, HPI, RDS, or IDM; p = .09), GA (p = .43), and baseline weight (p = .76).

At follow-up testing, children were approximately 30 months, uncorrected age (*M* = 901.94 days, *SD* = 7.75 days) at the assessment. This age was selected to allow some time for development and yet to be early enough to detect difficulties in the neurodevelopmental areas studied. Approximately 57.4% were male, 86.5% were non-Hispanic, 80.4% were White, and 29.1% had family history of language impairment. About half of the mothers had a high school education (48.0%), followed by those with a bachelor's degree (27.7%) and those with a graduate degree (23.6%). There was no significant difference between the children's sex, ethnicity, race, family history, and maternal education across the diagnostic categories (all *p*s > .05; see Table 1). As a group, family history of language impairment was high at 29%, with no differences between diagnostic categories, $\chi^2(3) = 2.62$, $p < .453$, Cramer's $V = 0.135$. However, both GA and BW were significantly different. The means for both were the highest in the IDM group, followed by the HPI, RDS, and CLD groups (both *p*s < .001; see Table 2). Considering these differences and the high correlation between GA and BW ($r = .88$, $p < .001$), we incorporated GA as a control or predictor variable when analyzing neurodevelopmental outcomes in different diagnostic groups.

Assessment Procedure

For the purposes of this follow-up study, motor, language, cognitive, and hearing tests were administered. Each child was seen for a 1.5- to 2-hr session that included snack and play breaks in a quiet laboratory setting designed as a playroom. Breaks were taken if a child was showing fatigue. Assessments were administered by a doctoral student in speech-language pathology and supervised by a licensed and certified SLP. The graduate student and the SLP were blind to the child's diagnostic category (i.e., HPI, CLD, RDS, IDM). Language assessment included the Test of Early Language Development–Third Edition (TELD-3; Hresko et al., 1999), the Receptive One-Word Picture Vocabulary Test–Fourth Edition (ROWPVT-4; A. Martin & Brownell, 2011a), and the Expressive One-Word Picture Vocabulary Test–Fourth Edition (EOWPVT-4; A. Martin & Brownell, 2011b). Motor and cognitive skills were assessed using the Bayley Scales of Infant and Toddler Development–Third Edition (Bayley, 2005).

The TELD-3 was selected because it is one of the few psychometrically reliable and valid standardized tests for toddlers that includes parent report with observation and it provides receptive and expressive scores extending across language areas of semantics, syntax, and morphology. Psychometric properties reported in the TELD-3 manual indicate a sufficient normative sample size for 2-year-olds ($n = 226$) and that children with language delays were part of the sample.

Measures of reliability and validity were provided in the manual. Regarding reliability, internal consistent reliability as represented by the coefficient alpha and test–retest reliability were reported. The coefficient alphas ranged from .90 to .94, with .90 or above being the preferred level. Test–retest reliability for 2-, 3-, and 4-year-olds ranged between .87 and .95. Content validity, criterion prediction validity, and construct identification validity were assessed and reported to be supportive of a valid assessment tool. Construct validity yielded mean quotients across nine subgroups that were very supportive of the construct validity of the TELD-3.

Reliability. After test administration, raw scores and conversion to standardized test scores were computed by an independent scorer who did not conduct the testing. The tester and the scorer, two different individuals, were blind to the child's diagnostic assignment. There were two types of reliability conducted: (a) test scoring accuracy and (b) test score entry accuracy into a spreadsheet. Both types of reliability were conducted by additional, independent judges, blind to the child's diagnostic condition. The reliability for test scoring accuracy was 99.8% (1,330/1,332). The reliability for data entry was 1,326/1,332 or 99.5%. Any disagreements were resolved through consensus. Parents were asked to complete a questionnaire requesting family information and the child's developmental history. Families received a $100 gift card for their participation.

Statistical Analyses

Descriptive statistics and bivariate tests were utilized to summarize all measured variables within and between the four diagnostic categories. To address Research Question 1, general linear modeling was conducted to compare the four groups for the neurodevelopmental (language, motor, and cognitive) outcomes (i.e., standardized scores), adjusting for the children's GA. When an overall group difference was significant at .05 alpha level, adjusted means were pairwise compared at an alpha level corrected for possible Type I error inflation (i.e., .05/6 = .008). For Research Question 2, we identified delays among the children using the following criteria. Language delay was indicated by a standardized score of 85 or less on any of the TELD-3 measures (i.e., TELD-3 Receptive subtest, TELD-3 Expressive subtest, TELD-3 Overall

Language Quotient, which is a combination of the Receptive and the Expressive subtests) or the scores from the ROWPVT and the EOWPVT. Motor delays were determined by the presence of a standardized score of 85 or less on the Bayley Motor subtest. Finally, cognitive delay was indicated by a standardized score of 85 or less on the Bayley Cognition subtest. The means of these tests are 100, with an *SD* of 15; thus, children had to score 1 *SD* or more below their same-age peers. Because the children were over 2 years of age, their chronological ages were not corrected for their early birth.

A chi-square test of independence was performed to examine the associations between language, motor, and cognitive delays in the whole sample. Lastly, to answer Research Question 3, the following predictors were explored for each delay via logistic regression and expressed as odds ratios (*OR*s): sex, family history, maternal education, and GA.

Results

Research Question 1

As expected, the infants in the HPI group showed the highest level of language, motor, and cognitive skills, and those in the CLD group had the poorest outcomes, with only a few exceptions (see **Table 1** for raw means and **Table 2** for adjusted means).

General linear modeling adjusting for the children's GA indicated that language abilities were significantly different between the diagnostic groups for the TELD-3 Expressive score, $F(3, 132) = 4.36$, $p < .01$, partial $\eta^2 = .09$, and for the TELD-3 total score, $F(3, 132) = 4.79$, $p < .01$, partial $\eta^2 = .10$. General linear modeling adjusting for the children's GA also showed that cognitive ability significantly differed between the diagnostic groups for the composite score, $F(3, 132) = 3.63$, $p < .05$, partial $\eta^2 = .07$.

Pairwise comparisons further revealed that the adjusted means of the TELD-3 Expressive score were significantly higher for the RDS group ($M = 98.43$, $SE = 1.58$) compared to the CLD group ($M = 92.56$, $SE = 1.40$) with a moderate effect size (corrected $p < .05$, Cohen's $d = 0.65$). Furthermore, the HPI group ($M = 95.66$, $SE = 1.43$) scored

Table 1. Descriptive statistics.

	All (N = 148)			**HPI** (n = 46)			**IDM** (n = 24)			**RDS** (n = 20)			**CLD** (n = 58)		
Variable	n	M/%	SD	n	M/%	SD	n	M/%	SD	n	M/%	SD	n	M/%	SD
Sex															
Male	85	57.4%		24	52.2%		13	54.2%		14	70.0%		34	58.6%	
Female	63	42.6%		22	47.8%		11	45.8%		6	30.0%		24	41.4%	
Ethnicity															
Hispanic/Latino	12	8.1%		1	2.2%		0	0.0%		2	10.0%		9	15.5%	
Not Hispanic/Latino	128	86.5%		42	91.3%		24	100.0%		17	85.0%		45	77.6%	
Unknown	8	5.4%		3	6.5%		0	0.0%		1	5.0%		4	6.9%	
Race															
Asian	2	1.4%		1	2.2%		1	4.2%		0	0.0%		0	0.0%	
Black/African American	7	4.7%		0	0.0%		1	4.2%		0	0.0%		6	10.3%	
Multiple	20	13.5%		5	10.9%		3	12.5%		1	5.0%		11	19.0%	
White	119	80.4%		40	87.0%		19	79.2%		19	0.95		41	70.7%	
Family history															
Yes	43	29.1%		9	19.6%		7	29.2%		7	35.0%		20	34.5%	
No	100	67.6%		34	73.9%		16	66.7%		13	65.0%		37	63.8%	
Missing	3	6.5%		1	4.2%		0	95.0%		1	1.7%				
Maternal education															
High school	71	48.0%		17	37.0%		14	58.3%		12	60.0%		28	48.3%	
Bachelor's degree	41	27.7%		14	30.4%		4	16.7%		3	15.0%		20	34.5%	
Graduate degree	35	23.6%		14	30.4%		6	25.0%		5	25.0%		10	17.2%	
Missing	1	0.7%		1	30.4%		0	0.0%		0	0.0%		0	0.0%	
GA															
≤ 28 weeks	52	35.1%		1	2.2%		0	0.0%		2	10.0%		49	84.5%	
> 28 weeks	96	64.9%		45	97.8%		24	100.0%		18	90.0%		9	15.5%	
GA (day)	148	207.51	21.31	46	222.26	11.95	24	226.88	14.12	20	211.25	12.35	58	186.50	11.83
Birthweight (g)	147	1,390.96	626.02	46	1,733.89	419.80	24	1,974.79	710.78	20	1,421.25	464.64	57	857.75	258.77
TELD-3															
Receptive	137	90.39	11.41	43	94.00	15.83	23	89.70	7.67	19	89.95	7.77	52	87.88	8.76
Expressive	137	95.12	7.15	43	97.23	5.00	23	93.22	5.55	19	98.37	10.40	52	93.04	7.10
Total	137	91.72	8.41	43	96.00	7.15	23	89.74	6.53	19	92.95	8.54	52	88.62	8.64
ROWPVT-4	137	92.53	14.96	45	97.49	12.89	22	92.50	13.97	20	91.80	17.24	50	88.38	15.24
EOWPVT-4	131	90.62	18.04	44	97.41	13.40	21	88.05	14.96	19	93.58	16.30	47	84.21	21.40
Bayley															
Cognitive composite	147	90.58	9.61	46	94.46	6.52	24	90.42	9.20	20	94.25	6.93	57	86.23	10.91
Fine motor	147	9.02	2.29	46	9.72	2.05	24	9.54	2.28	20	9.70	1.49	57	8.00	2.37
Gross motor	147	8.48	2.35	46	9.13	2.58	24	8.58	1.56	20	9.45	2.37	57	7.58	2.16
Motor composite	147	92.03	13.95	46	96.61	11.28	24	94.46	9.85	20	93.55	22.02	57	86.77	12.31

The test scores are standard scores with the exception of the fine and gross motor scores, which are scaled scores. HPI = healthy preterm infants; IDM = infants of diabetic mothers; RDS = infants with respiratory distress syndrome; CLD = infants with chronic lung disease; GA = gestational age; TELD-3 = Test of Early Language Development–Third Edition; ROWPVT-4 = Receptive One-Word Picture Vocabulary Test–Fourth Edition; EOWPVT-4 = Expressive One-Word Picture Vocabulary Test–Fourth Edition.

Table 2. Standard scores adjusted for age.

	HPI (n = 46)		IDM (n = 24)		RDS (n = 20)		CLD (n = 58)			
Variable	***M***	***SE***	***M***	***SE***	***M***	***SE***	***M***	***SE***	***p***	**Partial η^2**
TELD-3										
Receptive	92.66	2.04	87.85	2.79	89.68	2.58	89.91	2.28	.388	.023
Expressive	97.55	1.25	93.66	1.71	98.43	1.58	92.56	1.40	.006	.090
Total	95.66	1.43	89.27	1.96	92.88	1.81	89.13	1.60	.003	.098
ROWPVT-4	96.21	2.61	90.92	3.58	91.56	3.28	90.33	3.00	.387	.023
EOWPVT-4	94.81	3.07	84.80	4.28	92.92	3.97	88.36	3.62	.135	.043
Bayley										
Cognitive composite	93.87	1.59	89.64	2.17	94.10	2.02	87.08	1.75	.015	.071
Fine motor	9.40	0.38	9.12	0.52	9.62	0.48	8.46	0.42	.325	.024
Gross motor	8.95	0.40	8.34	0.55	9.40	0.51	7.84	0.44	.095	.044
Motor composite	95.34	2.38	92.79	3.25	93.23	3.01	88.61	2.62	.413	.020

HPI = healthy preterm infants; IDM = infants of diabetic mothers; RDS = infants with respiratory distress syndrome; CLD = infants with chronic lung disease; TELD-3 = Test of Early Language Development–Third Edition; ROWPVT-4 = Receptive One-Word Picture Vocabulary Test–Fourth Edition; EOWVPT-4 = Expressive One-Word Picture Vocabulary Test–Fourth Edition.

significantly higher than the IDM group (*M* = 89.27, *SE* = 1.96) in their overall (combined expressive and receptive language) scores on the TELD-3, and the difference was relatively large (corrected $p < .05$, Cohen's $d = 0.76$). The latter mean scores were all within normal limits. Pairwise comparisons for the vocabulary scores on the ROWPVT and the EOWPVT and cognitive ability did not yield statistical differences between the four groups of children. In addition, no statistically significant differences were present between the four groups with respect to their motor skills.

It should be noted that, although the means of the children born preterm were within normal limits on the language tests (between 85 and 115 standard score) and the Cognitive and Motor subtests (see Table 2), several children in each of the four diagnostic categories scored below 1 *SD* of the mean on at least one measure. Regarding language delay (i.e., defined as combined number of children performing below 85 on either the TELD-3, ROWPVT-4, or EOWPVT-4), 53.4% of participants displayed a delay. Delays were present for 21.6% of the children in the motor testing and 24.3 % in the cognitive testing. The means, standard deviations, and number of delays per diagnostic category are in **Table 3**.

Table 3. Means, standard deviation, number, and percentage of children displaying a delay.

Variable	HPI (n = 46)				IDM (n = 24)				RDS (n = 20)				CLD (n = 58)				p	Cramer's V
	%	n	M	SD	**%**	n	M	SD	**%**	n	M	SD	**%**	n	M	SD		
Language	32.6	15			62.5	15			55.0	11			65.5	38			.004	0.304
TELD-3 Receptive		3	60.00	43.30		6	82.33	1.97		3	81.33	6.35		20	80.80	2.65		
TELD-3 Expressive		0	—	—		1	79.00	—		0	—	—		5	81.00	2.65		
ROWPVT-4		6	74.67	11.11		7	76.14	5.93		8	75.75	9.88		21	73.19	7.18		
EOWPVT-4		8	76.13	7.95		7	70.71	9.11		6	75.00	10.92		24	68.04	16.69		
Cognition	8.7	4			29.2	7			0	0			43.1	25			< .001	0.409
Bayley Cognitive			83.75	2.50			80.00	7.07			—	—			76.40	8.84		
Motor	10.9	5			12.5	3			10.0	2			37.9	22			.001	0.325
Bayley Motor			76.00	7.65			77.00	7.55			45.00	52.33			75.05	10.93		

Em dashes indicate no data, because no data (this occurs when n = 1 or 0). The n, M, and SD on TELD Receptive, TELD Expressive, ROWPVT, and EOWPVT are for those who were delayed on the corresponding measure. The "n" column will not add to the total N because the total N in each diagnostic category only included a child once. For example, 15 children in the HPI group demonstrated a delay in language; however, the individual subtests total to 17 because two children showed delays on more than one subtest. HPI = healthy preterm infants; IDM = infants of diabetic mothers; RDS = infants with respiratory distress syndrome; CLD = infants with chronic lung disease; TELD-3 = Test of Early Language Development–Third Edition; ROWPVT-4 = Receptive One-Word Picture Vocabulary Test–Fourth Edition; EOWVPT-4 = Expressive One-Word Picture Vocabulary Test–Fourth Edition.

Research Question 2

Language delay, defined as a score of 85 or below on the TELD-3, the EOWPVT-4, or the ROWPVT-4, was significantly associated with motor delay (i.e., at least 1 *SD* below the mean), cognitive delay (i.e., at least 1 *SD* below the mean), and delay (i.e., at least 1 *SD* below the mean) in both motor and cognitive abilities, supporting our hypothesis. More specifically, the infants who displayed language delays on any language measure were 4.52 times more likely to have motor delay, $\chi^2(1) = 10.45$, $p < .001$, Cramer's $V = 0.27$, and 7.34 times more likely to have cognitive delay, $\chi^2(1) = 17.73$, $p < .001$, Cramer's $V = 0.35$, compared to those who did not have language delay. Also, the likelihood of having both motor and cognitive delays increased by 6.40 times when the infants had language delay, $\chi^2(1) = 10.07$, $p < .01$, Cramer's $V = 0.26$.

Research Question 3

The results of logistic regression are summarized separately for each area of delay in **Table 4**. Maternal education was a significant predictor of language delay and cognitive delay. Family history of language impairment was not determined to be a significant predictor of any area of language delay, $\chi^2(1) = 3.44$, $p < .064$; however, there was a trend in the direction of it being a predictor. When controlling for the infants' sex, family history, and GA, those whose mothers had a high school education were 2.94 times more likely to have language delay ($OR = 2.94$, $p < .05$) and 5.75 times more likely to have cognitive delay ($OR = 5.75$, $p < .05$) compared to those whose mother had a graduate degree. In addition, GA was a significant predictor of all language, motor, and cognitive delays. The likelihood of having language, motor, and cognitive delays increased by 2.2% ($[1 / OR - 1] \times 100 = 2.25$, $p < .05$), 3.6% ($[1 / OR - 1] \times 100 = 3.63$, $p < .01$), and 3.5% ($[1 / \text{OR} - 1] \times 100 = 3.52$, $p < .01$) per each 1-day increase in GA, respectively controlling for the infants' sex, family history, and maternal education.

Table 4. Results of logistic regression predicting language, motor, and cognitive delays.

DV = language delay	**Estimate**	*SE*	*p*	*OR*	*p*
Intercept	3.91	1.89	.039	50.04	
Sex					.537
Male	0.23	0.37	.537	1.26	
Female (ref.)	—	—	—	—	
Family history					
Yes	0.76	0.41	.064	2.14	.064
No (ref.)	—	—	—	—	
Maternal education					.015
High school	1.08	0.46	.019	2.94	
Bachelor's degree	0.00	0.50	.994	1.00	
Graduate degree (ref.)	—	—	—	—	
Birth GA	−0.02	0.01	.012	0.98	.012
Max-rescaled R^2 = .17					
BIC = 204.53					
AUC = .71					
DV = motor delay	***Estimate***	*SE*	*p*	*OR*	*p*
Intercept	5.65	2.27	.013	284.16	
Sex					.708
Male	0.17	0.44	.708	1.18	
Female (ref.)	—	—	—	—	
Family history					
Yes	0.19	0.46	.685	1.21	.685
No (ref.)	—	—	—	—	
Maternal education	.866				
High school	0.21	0.57	.711	1.23	
Bachelor's degree	0.34	0.63	.593	1.40	
Graduate degree (ref.)	—	—	—	—	
Birth GA	−0.04	0.01	.001	0.97	.001
Max-rescaled R^2 = .14					
BIC = 162.96					
AUC = .71					
DV = cognitive delay	**Estimate**	*SE*	*p*	*OR*	*p*
Intercept	4.72	2.25	.037	111.73	
Sex					.725
Male	−0.15	0.43	.725	0.86	
Female (ref.)	—	—	—	—	
Family history					
Yes	0.00	0.46	.999	1.00	.999
No (ref.)	—	—	—	—	
Maternal education	.017				
High school	1.75	0.68	.010	5.75	
Bachelor's degree	0.85	0.76	.267	2.34	
Graduate degree (ref.)	—	—	—	—	
Birth GA	−0.03	0.01	.002	0.97	.002
Max-rescaled R^2 = .21					
BIC = 164.31					
AUC = .74					

Em dashes indicate no number is provided because it is a reference number. DV = dependent variable; ref. = reference; GA = gestational age; BIC = Bayesian Information Criteria; AUC = area under the curve.

Discussion

Clinical Relevance of Preterm Diagnostic Categories

The literature is replete with studies of the neurodevelopmental outcomes of children born preterm, especially within the past 5 years. Up-to-date studies are needed because new medical advances in the care for the infants born preterm have the potential to lead to improved or decreased outcomes. Our study of toddlers who were born preterm provides additional evidence that some of these children will display language, motor, and cognitive delays early in development (Allotey et al., 2017). Our results differ from past studies in that we are able to better elucidate the contributions of the diagnostic category related to the child's medical condition and their neurodevelopmental outcomes. Whereas previous researchers have combined groups of children with various diagnostic categories, we compared four diagnostic groups with one another. This led to the increased understanding that children born preterm who were of a healthy infant status are more likely to have a better outcome for language skills; though standard score means for cognitive and motor skills did not vary across the four populations. This finding makes some sense given that the HPI will likely have the shortest stay in the NICU and the fewest medical complications.

The means of the children born preterm as a group were within normal limits. In addition, many of the mean scores of children with expressive language delays were mild delays. The mean data provide important, yet limited, insight into those in the preterm population who exhibit delays. In contrast, the percentage of children who scored below 1 *SD* (see Table 3) provide compelling evidence that a substantial number of these children have delayed language, motor, and cognitive skills. Several previous studies have reported mean scores of the group of children born preterm as being within normal limits on standardized tests; however, despite this, they still score significantly lower than their full-term counterparts, and 25%–40% of children in those studies have standardized scores indicative of a delay (i.e., 1 *SD* or more below the mean; Foster-Cohen et al., 2010). In comparison, in our sample, over 50% of the children who were in the IDM, RDS, and CLD groups displayed a language delay in one or more areas of language testing. All but one of the children who had difficulty with the TELD-3 Expressive subtest were from the CLD group. Furthermore, 43.1% of the children in the CLD group exhibited delays in cognition, and 37.9% exhibited delays in motor skills. Children in the CLD group also had the lowest GA and BW. These results are consistent with previous research in younger and older children with CLD born very preterm and extremely preterm (Sriram et al., 2018). This may occur because children with CLD are more likely to be longer in the NICU and may not have the same, early interactive experiences with caregivers. There may also be a biological factor contributing to children with CLD due to the exposure to prolonged supplemental oxygen. Because our results indicate that children with a CLD diagnosis may be the most vulnerable for future neurodevelopmental delays, SLPs and other professionals may view these infants at high risk and justify the provision of services as early as possible.

Previous researchers of children born preterm (Nguyen et al., 2018) have reported deficits in receptive language compared to a full-term group. In our study, we did not find diagnostic category group differences on receptive language measures. Unlike these previous studies, we did not have a full-term comparison group. Inclusion of such a group would clarify the extent that these infants differ from the full-term population. Based on our findings, we would recommend that SLPs assess both receptive and expressive language in children born preterm. Given our results, it is likely that children with CLD will display expressive delays more often than children in the other diagnostic categories.

Morgan et al. (2016) found that children with expressive language delays at 24 months of age are likely to continue to need language intervention. Because children born very preterm and moderate-to-late preterm display consistent language abilities from 20 months of age to 8 years of age, it is recommended that language intervention is initiated as early as possible (Putnick et al., 2017). A watch and- see approach may not be the best approach for children born preterm, especially those with CLD, RDS, or who are IDM, given what we now know about their outcomes.

Cognitive and Motor Skills Implications

It is clear from the previous meta-analyses that children born preterm will exhibit cognitive (Brydges et al., 2018) and motor skill impairments (Allotey et al., 2017). Our results were similar to those of Kherkheulidze et al. (2016), who found lower cognitive and motor scores in children with CLD born preterm compared to other children born preterm; however, in our study and the Kherkheulidze et al. study, these differences did not reach levels of significance. Laughon et al. (2009) report that the more severe the CLD, the greater the likelihood of developmental delay. The clinical implication of these results for SLPs is that motor and cognitive skills need to be evaluated with the preterm population.

Clinical Relevance of Comorbidity of Neurodevelopmental Disorders

Our findings support previous research that language, motor, and cognitive delays may be present at an early age within the same child when the child is born preterm (Benassi et al., 2016; Månsson & Stjernqvist, 2014). These previous studies found comorbidity in children born extremely preterm. Comorbidity of neurodevelopmental disorders in children born extremely preterm is also evident when children are older, at 10 years of age (Hirschberger et al., 2018). Of the 30% of children born preterm who displayed impairments in their study, approximately 40% had multiple diagnoses (i.e., cognitive impairment, cerebral palsy, autism spectrum disorder, and/or epilepsy). Our findings and those of others indicate that SLPs might expect to encounter comorbidity of language, motor, and cognitive delays in the same child born preterm. Referral to and collaboration with physical therapists, occupational therapists, and special educators may be of special importance with many of these children. Furthermore, working with children born preterm may result in valuable interprofessional experiences for students training to become SLPs.

Clinical Implications of Predictors of Language Impairment

The existing literature strongly supports that children born preterm are at risk for neurodevelopmental delays (Aylward, 2014). However, not all children born preterm will have language, cognitive, and/or motor delays. This is supported in our findings that indicate group means to be within normal limits across diagnostic categories. Even so, many children within each subgroup displayed language, motor, and cognitive delays. Given this, how does the SLP know which factors might lead to a negative outcome? By better understanding the predictors of outcome, the SLP can be better informed with regard to identification and assessment of these children. Our study found that maternal education was a significant predictor of language delay and cognitive delay. In addition, GA was a significant predictor of all language, motor, and cognitive delays. Both these findings are supported by converging evidence (Agarwal et al., 2018; ElHassan et al., 2018). Family history of language impairment was not found to be a predictor, as it has been previously in children born full term; however, there was a trend toward significance. Knowledge of these predictors can inform a child's eligibility for services (Loeb, 2014). SLPs can use this information about maternal education in two ways. First, SLPs might note the maternal education on the case history and view it as a potential risk or protective factor. Second, education level may also lead the SLP to provide consistent and systematic education to the caregiver regarding communication development, ways to facilitate conversations and language, indicators of concern, how to interpret and respond to communicative intent, and other areas critical for language, speech, and communication development. Early intervention involves both child and family goals. Utilizing risk and protective factors to assist in developing family and child goals seems a logical step in bridging our empirical data with clinical practice.

Some children born preterm are not only medically fragile; they also are apart from their families during a critical period of bonding. Recent research in attachment theory includes a concept known as "mind-mindedness," which is the caregiver's view and treatment of the child as an individual with emotions, thoughts, and desires. As part of mind-mindedness, caregivers reflect the child's mental states with their child during interactions (Meins, 2013). Mind-mindedness has been found to be related to language growth between 14, 24, and 36 months in both children born preterm and full term; however, it had a stronger impact on the language of children born preterm (Costantini et al., 2017). Constantini et al. suggest that mind-mindedness input may serve as a protective factor in the language development of infants born preterm. It has been found that mind-mindedness interactions can mediate internal and externalizing behaviors in children in low socioeconomic homes (Meins et al., 2013). In addition, toddlers' expressive vocabulary has been documented to be significantly correlated with maternal mind-mindedness (Laranjo & Bernier, 2013). Future studies of this type of talk with infants born preterm may benefit early intervention services.

Limitations of the Study

The results of this study are limited by the small number of children in each diagnostic category, in particular those in the IDM and RDS groups. Significant differences may have been more apparent with larger samples. Further studies of these diagnostic groups are needed to provide continued insight to the needs of these populations. The lack of healthy infant full-term control also limits our understanding of the extent to which the children born preterm differ from the full-term population. Furthermore, the exclusion of children with nervous system anomalies, intracranial hemorrhage, and seizures limits the generalization of our results to the higher incidence level of the preterm population. Additional studies of the neurodevelopmental outcomes of children born preterm with various medical diagnoses and levels of brain injury need to be conducted that assess motor, cognition, and language in the same child. One final limitation of this study is the use of standardized testing alone to assess children born preterm. Most studies, to date, with children born preterm have been conducted using standardized tests. This methodology needs to evolve. Recently, Imgrund et al. (2019) report that preschoolers born preterm did not differ significantly from full-term peers on a standardized assessment tool but did display language delay when language sampling was utilized. In the current study, we may have under identified children in our study due to not using language sampling. More extensive study of the early language development of young children born preterm is needed to fully characterize their language abilities.

Conclusions

Children born too soon begin life precariously. The SLP who works in the NICU and/or with the birth-to-3 population can utilize the results of this study to identify and intervene earlier with these vulnerable infants. As SLPs, we are in the unique position to identify and provide intervention to this population. Furthermore, many of these children continue to have language, motor, and cognitive difficulties throughout the school years (Joseph et al., 2016; Luu et al., 2017) and have a lower quality of life at adulthood (Baumann et al., 2016). These children will continue to need the support of the SLP in academic environments.

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