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The Relationship between Behavior Ratings and Concurrent and Subsequent Mental and Motor Performance in Toddlers Born at Extremely Low Birth Weight

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Abstract

When predicting child developmental outcomes, reliance on children's scores on measures of developmental functioning alone might mask more subtle behavioral difficulties especially in children with developmental risk factors. The current study examined predictors and stability of examiner behavior ratings and their association with concurrent and subsequent mental and motor performance in toddlers born at extremely low birth weight. Toddlers were evaluated using the Behavior Rating scale (BRS) and the mental and psychomotor indexes of the Bayley-II at 18 and 30 months corrected age. BRS total and factor scores showed moderate stability between 18 and 30 months. These scores also predicted 30-month Mental Scale and Psychomotor Scale scores above and beyond prior mental and motor performance. Our findings suggest that early behavior ratings are associated with child mental and motor performance; therefore, behavior ratings might be useful in identifying toddlers at developmental risk and who might benefit from early intervention.

Keywords

extremely low birth weight; Bayley; behavior ratings; performance

Child performance on standardized measures of developmental functioning is a relatively consistent predictor of subsequent performance in similar domains within the first three years of life. Among typically developing children, behavior observations made by trained examiners are associated with developmental test performance (Banergee & Tamis-LeMonda, 2007; Cardon & Fulker, 1991; DiLalla et al., 1990; Field, Dempsey, & Shuman, 1979; Glutting, Youngstrom, Oakland, & Watkins, 1996; Matheny, 1980; Yarrow, Morgan, Jennings, Harmon, & Gaiter, 1982). Less is known, however, about the extent to which early ratings of child behavior during testing situations predict subsequent developmental functioning. In this study, we examined the relationship between ratings of toddler behavior and subsequent performance in a sample of children born at extremely low birth weight (ELBW).

Children born at lower birth weight are at higher risk for behavioral and other impairments than other children (Anderson et al., 2003; Aylward, 2002; Constantinou et al., 2005; Lowe et al., 2005; Saigal et al., 2001; Sajaniemi, Hakamies-Blomqvist, Katainen, & von Wendt, 2001; Whitfield et al., 1997). Recent studies have documented mental and motor deficits of

18- and 30-month old toddlers who had been born at extremely low birth weight (≤ 1000g). These toddlers exhibited lower mean scores than their higher birth weight peers on standardized measures of mental and motor functioning (Aylward, 2002; Constantinou, Adamson-Macedo, Mirmiran, Ariagno, & Fleisher, 2005; Dezoete, MacArthur, & Tuck, 2003; Shankaran et al., 2004; Vohr et al., 2000; Vohr, Wright, Poole, & McDonald, 2005; Walsh et al., 2005). Recent studies have suggested that poor performance on these measures might be predicted by early deficits in behavior regulation including difficulty adapting to change, difficulty sustaining attention, increased activity level, increased need for examiner support, and decreased persistence in attempting to complete tasks (Anderson, Doyle, & Victorian Infant Collaborative Study Group, 2003; Saigal, Stoskopf, Streiner, & Burrows, 2001; Sajaniemi, et al., 2001; Weiss, St. Jonn-Seed, & Wilson, 2004; Whitfield, Eckstein Grunau, & Holsti, 1997).

While scores on assessments of developmental functioning might predict subsequent performance in children with very low birth weight (< 1500g; Dezoete, MacArthur, & Tuck, 2003) and children with ELBW (Burns, O'Callaghan, McDonell, & Rogers, 2004;; Sajaniemi et al., 2001), reliance on these scores alone might mask more subtle behavioral difficulties within these children (e.g., inattention; Aylward, 2002). However, the extent to which the behavioral characteristics of toddlers born at ELBW predict later developmental functioning is not clear. Some evidence suggests that negative emotionality is associated with poorer cognitive outcomes in children born at low birth weight (LBW, < 2500g;; Blair, 2002). For example, Emotional Regulation factor scores on the Behavior Rating scale (BRS) of the Bayley Scales of Infant Development, Second Edition (Bayley-II; Bayley, 1993) at 2 years are associated with concurrent Mental Developmental Index (MDI) scores on the Mental scale of the Bayley-II (Sajaniemi et al., 2001). Likewise, a decline in MDI scores between 8 and 18–22 months was reported in association with lower Emotional Regulation factor scores at the latter time point (Lowe, Woodward, & Papile, 2005). Determining the predictive validity of behavioral ratings in relation to later delays in the development of children born at ELBW is critical to identifying those children in need of early intervention services.

The BRS is an important supplement to Bayley-II index scores in that examiners rate infant behavior using a standardized scale within a relatively controlled setting. The objective of this study was to examine the association between ratings of infant behavior during the testing session and concurrent and future mental and motor performance in children with ELBW. We hypothesized that 18-month BRS scores would predict 30-month MDI scores, controlling for 18-month MDI scores. Similarly, we hypothesized that 18-month BRS scores would predict 30-month Psychomotor Developmental Index (PDI) scores derived from the Motor scale, controlling for 18-month PDI scores. We also examined the stability of the BRS scores between 18 and 30 months and determined how neonatal and sociodemographic risk factors were related to BRS scores in toddlers born at ELBW.

Methods

Participants

The primary study sample consisted of 539 toddlers born at ELBW who were evaluated at both 18- and 30-months corrected age. These children were born between October 1999 and September 2001 and admitted to the Neonatal Intensive Care Unit of 1 of 12 centers participating in a multi-site infant follow-up study under the auspices of the National Institutes of Child Health and Human Development (NICHD) Neonatal Research Network (Vohr et al, 2000; Vohr et al., 2005). Infants in the current sample participated in a clinical trial that found no evidence that glutamine supplementation decreased rates of infant sepsis or mortality (Poindexter et al., 2004). The study protocol was approved by the institutional review board at each study site and informed consent was obtained from a parent for each infant. The purpose of the current study was to examine the association between behavior ratings and mental and motor performance in this high-risk sample of infants.

Preliminary exclusion criteria included infants who had (a) one or more major congenital anomalies, (b) met criteria for a terminal illness (i.e., ph < 6.8 for 72 hours, persistent heart rate <100 associated with hypoxia > 2 hours), (c) suspected TORCH infection, (d) parental refusal of consent, or (e) determination of non-viability by an attending neonatologist. Infants also were excluded if they did not attend the follow-up assessments at 18- and 30-months of age, the focus of the current study. Two hundred and sixty-one toddlers were excluded from the present sample because they were seen at 18 months but not at 30 months. Toddlers not participating in follow-up had younger mothers ($p < .01$), mothers with lower income ($p < .05$), lower BRS total and factor scores ($p < .01$), lower PDI at 18 months ($p < .05$), and were more likely to be receiving early intervention services at 18 months ($p \leq .01$) than toddlers seen at 30 months. Toddlers not participating in follow-up also tended to have an increased likelihood of bronchopulmonary dysplasia (BPD; $p = .08$). The two groups were similar with respect to gestational age, birth weight, gender, maternal education, intraventricular hemorrhage/periventricular leukomalacia (IVH/PVL), necrotizing enterocolitis (NEC), late sepsis, and MDI scores at 18 months as shown in Table 1.

The final sample ($N = 539$) was 56% female and was ethnically diverse (African-American 45%; White 40%; Hispanic 13%; Other 2%). Mean birth weight was 792 grams and mean gestational age was 26 weeks. Birth weight was coded dichotomously (i.e., ≤ 750g, 751–1000g) as were IVH/PVL, BPD, NEC, late sepsis, and received early intervention by 18 months (i.e., yes/no). Maternal demographic information was collected at the child's 18-month assessment and coded categorically by income (i.e., low-income: < $20,000, mid-income: $20,000–$39,999, and high-income ≥ $40,000) and education (i.e., < HS diploma, HS diploma, some college).

Measures

The Mental and Motor scales of the Bayley-II were used to assess developmental functioning in the current sample. Mental scale measures a child's cognitive, language, and personal-social functioning and the Motor scale measures a child's control of gross and fine motor functions up to 42 months of age. Bayley-II MDI and PDI scores of 100 ± 15 represent the mean ± standard deviation (*SD*). MDI and PDI scores can be classified as Within Normal Limits (≥ 85), Mildly Delayed (70 to 84), or Significantly Delayed (< 70). Reliability of scores on both scales was demonstrated in the normative sample of children (i.e., internal consistency coefficients ranged from .78 to .93 for MDI and from .75 to .91 for PDI; Bayley, 1993). Test-retest score reliability in the normative sample was moderate to high for the age range in which we are reporting (i.e., $r = .91$ for MDI and $r = .79$ for PDI at 24 months of age).

The BRS is scored based on observations made by the examiner during Bayley-II administration. The BRS consists of three factors: Emotional Regulation, Motor Quality, and Orientation/Engagement. Emotional Regulation assesses task persistence, frustration tolerance, attention, activity level, and adaptation to change. Motor Quality considers the overall quality of muscle tone and fine and gross motor movements. Orientation/Engagement assesses the child's interest and initiative with test materials, interaction with the examiner, and levels of positive affect and energy. Each factor consists of individual items rated on a 5-point scale in which a higher score is more optimal. A total score is calculated from the sum of unduplicated subscale score items. Total raw scores and factor scores are then converted to percentile ranks. BRS scores can be categorized as Within Normal Limits (26^{th} percentile or above), Questionable (11^{th} to 25^{th} percentile), and Non-Optimal (at or below the 10^{th} percentile). Based on the Bayley-II validation sample, score reliability was moderate to high with internal consistency coefficients ranging from .73 to .90. For children 24 months of age, test-retest reliability coefficients for the three factor scale scores ranged from .61 to .71 (Bayley, 1993).

Procedures

At 18 and 30 months corrected age, the Mental scale, Motor scale, and BRS of the Bayley-II were administered by examiners who were trained to reliability and certified by a “gold standard” Bayley examiner. Gold standard examiners were experienced clinicians, specifically trained in the Bayley-II test procedures, who reviewed videotapes of trial assessments completed by examiners at each site. All examiners were recertified annually to administer this assessment.

Analyses

Pearson correlations were used to examine the relationship between BRS total scores and factor scores and to determine the stability of these scores over time. Pearson correlations also were used to examine the association between BRS scores and MDI and PDI scores at 18- and 30-months of age. Paired *t*-tests were computed to compare mean BRS scores at 18 and 30 months.

Linear regression models were run to predict child outcomes. The same set of covariates was entered simultaneously in all linear regression models: gestational age, birth weight, gender, maternal age, maternal income, maternal education, IVH/PVL, BPD, NEC, late sepsis, having received early intervention by 18 months, and research site. These covariates were not collinear. These covariates were first entered into separate regression models to predict 18-month and 30-month BRS total scores. Second, separate linear regression models were conducted using these covariates first to predict 30-month MDI scores and then to predict 30-month PDI scores. Next, a series of linear regression models were run using 18-month BRS total scores to predict 30-month MDI scores. Specifically, the first model used 18-month MDI scores and the covariates to predict 30-month MDI scores. The second model used 18-month BRS total scores and the covariates to predict 30-month MDI scores. Last, the third model used 18-month MDI scores, 18-month BRS total scores, and the covariates to predict 30-month MDI scores. Similar models were run using 18-month PDI scores, 18-month BRS total scores, and the covariates to predict 30-month PDI scores. To investigate the association of individual BRS factor scores (Emotional Regulation, Motor Quality, and Orientation/Engagement) with 30-month MDI and PDI outcomes, separate linear regression models were run for each BRS factor score using a similar format as described above. Finally, we conducted cumulative logistic regression models to examine the clinically pertinent association between the three categories of BRS total scores (i.e., Within Normal Limits, Questionable, and Non-Optimal) and the three categories of 30-month MDI and PDI scores.

Results

Descriptive Statistics

Scores on the MDI and PDI were generally within the low average to borderline range with a mean MDI of 83 ± 18 and a mean PDI of 85 ± 21 at 30 months of age (see Table 2). We examined the association between BRS total and factor scores and between BRS scores and MDI and PDI scores at the two assessment ages. BRS factors were intercorrelated (r = .39 to .68) and correlated with BRS total scores (r = .58 to .84). Toddlers' BRS factor and BRS total scores between 18 and 30 months also were correlated (r = .44 to .62). At 18 months, BRS total scores were correlated positively with MDI (r = .50) and PDI (r = .44) scores. At 30 months, BRS total scores also were correlated positively with MDI (r = .60) and PDI (r = .61) scores. The three BRS factors were also positively correlated with MDI and PDI scores at both ages. Results of paired *t*-tests indicated an increase in mean scores on BRS total, BRS factors and MDI between 18 and 30 months (see Table 2).

Predictors of Behavior Ratings

Regression models indicated that female gender and high-income (≥ $40,000) were predictive of higher BRS total scores at both 18 and 30 months (see Table 3). Absence of BPD was predictive of higher BRS total scores at 18 months only. Higher birth weight (751–1000 g) and higher maternal education (i.e., some college education) were predictive of higher BRS total scores at 30 months only. Gestational age, maternal age, IVH/PVL, NEC, late sepsis, and having received early intervention by 18 months were not predictive of 18- or 30-month BRS total scores.

Behavior Ratings as Predictors of Mental and Motor Performance

First, separate linear regression models were conducted to assess the variance in MDI and PDI scores that can be accounted for by the identified covariates alone. Thirty-seven percent of the variance in MDI scores was accounted for by these covariates. Results were parallel when predicting PDI scores ($R^2 = .37$ for each model). Next, a series of separate linear regression models were conducted using BRS total scores and then using each of the BRS factor scores to predict 30-month MDI and PDI scores. All predictors and covariates were entered simultaneously into each model. Type III Sums of Squares were used so that only the unique contribution of each variable is reported. Model 1 indicated that 18-month MDI scores positively predicted 30-month MDI scores after controlling for identified covariates ($R^2 = .62$; see Table 4). Thus, 18-month MDI scores explained an additional 25% of variance in 30-month MDI scores, after controlling for identified covariates. Model 2 indicated that 18-month BRS total scores positively predicted 30-month MDI scores explaining an additional 9% of variance, after controlling for identified covariates ($R^2 = .46$). When both variables were included in the model (Model 3), higher 18-month BRS total scores predicted higher 30-month MDI scores, controlling for prior MDI scores and identified covariates ($R^2 = .63$). Based on this full model, other significant predictors of higher 30-month MDI scores included higher birth weight (i.e., > 750 g) and higher maternal income (i.e., high-income and mid-income; p's ≤ .05).

A similar pattern emerged for PDI scores. Model 1 indicated that 18-month PDI scores positively predicted 30-month PDI scores, controlling for identified covariates ($R^2 = .56$). Thus, 18-month PDI scores explained an additional 19% of variance in 30-month PDI scores, after controlling for identified covariates. As shown by Model 2, 18-month BRS total scores predicted 30-month PDI scores explaining an additional 7% of variance, after controlling for identified covariates ($R^2 = .44$). Last, Model 3 indicated that higher 18-month BRS total scores predicted higher 30-month PDI scores, controlling for 18-month PDI scores and identified covariates ($R^2 = .56$). Based on the full model, other statistically significant predictors of higher 30-month PDI scores included higher birth weight, female gender, higher maternal income (i.e., mid-income), and higher maternal education (i.e., some college; p's ≤ .05).

Next, we examined the contribution of the three individual BRS factors (Emotional Regulation, Motor Quality, and Orientation/Engagement). Results of Model 1 are identical to those presented above for both MDI and PDI scores in that 18-month MDI scores predicted subsequent mental performance and 18-month PDI scores predicted subsequent motor performance, controlling for covariates ($R^2 = .62$ and .56, respectively). Eighteen-month Emotional Regulation positively predicted both 30-month MDI and PDI scores. In the partial model (Model 2), 18-month Emotional Regulation positively predicted 30-month MDI scores ($b = 0.18$, $p < .01$; $R^2 = .42$) explaining an additional 5% of variance, after controlling for identified covariates ($R^2 = .37$) used in prior multiple regressions. A similar pattern emerged for PDI scores ($b = 0.13$, $p < .01$; $R^2 = .40$) with 18-month Emotional Regulation explaining an additional 3% of variance in 30-month PDI scores, after controlling for identified covariates. In the full regression models (Model 3), 18-month Emotional Regulation predicted 30-month MDI scores ($b = 0.05$, $p = .04$; $R^2 = .62$) and PDI scores ($b = 0.06$, $p = .02$; $R^2 = .56$) after controlling for prior MDI and PDI scores and identified covariates. Other significant predictors of higher 30-month MDI scores in the full model included 18-month MDI scores (*b* = 0.58, *p* < .01), higher birth weight (*b* = 2.28, *p* = .05), and higher maternal income (high-income: *b* = 7.80, *p* < .001; mid-income: *b* = 5.50, *p* < .01). Presence of BPD was predictive of lower 30-month MDI scores (*b* = −2.30, *p* = .05). Other significant predictors of higher 30-month PDI scores in the full model included higher 18-month PDI scores (*b* = 0.56, *p* < .01), higher birth weight (*b* = 2.88, *p* = .05), higher maternal income (high-income: *b* = 3.76, *p* = .04; mid-income: *b* = 3.92, *p* = .01), and higher maternal education (some college: *b* = 4.49, *p* = .01).

Similarly, 18-month Motor Quality positively predicted both 30-month MDI and PDI scores. In the partial model, 18-month Motor Quality predicted 30-month MDI scores (*b* = 0.18, *p* < .01; R^2 = .44) explaining an additional 7% of variance in 30-month MDI scores, after controlling for identified covariates. A similar pattern emerged for PDI scores (*b* = 0.24, *p* < .01; R^2 = .47) with 18-month Motor Quality explaining an additional 10% of variance in 30-month PDI scores, after controlling for identified covariates. In the full regression models, 18-month Motor Quality remained predictive of both 30-month MDI (*b* = 0.06, *p* < .01; R^2 = .63) and PDI scores (*b* = 0.07, *p* = .01; R^2 = .56) after controlling for prior MDI and PDI scores and identified covariates. Other significant predictors of 30-month MDI scores in the full model included higher 18-month MDI scores (*b* = 0.57, *p* < .01), higher maternal income (high income: *b* = 7.77, *p* < .01; mid-income: *b* = 5.82, *p* < .01), and higher maternal education (some college: *b* = 3.23, *p* = .03). Other significant predictors of 30-month PDI scores in the full model included higher 18-month PDI scores (*b* = 0.50, *p* < .01), female gender (*b* = 2.63, *p* = .04), higher maternal income (high-income: *b* = 3.81, *p* = .04; mid-income: *b* = 4.31, *p* < .01), and higher maternal education (some college: *b* = 5.07, *p* < .01).

Finally, 18-month Orientation/Engagement also positively predicted both 30-month MDI and PDI scores. In the partial model, 18-month Orientation/Engagement predicted 30-month MDI scores (*b* = 0.18, *p* < .01; R^2 = .43) explaining an additional 6% of variance in 30-month MDI scores, after controlling for identified covariates. A similar pattern emerged for PDI scores (*b* = 0.15, *p* < .01; R^2 = .41) with 18-month Orientation/Engagement explaining an additional 4% of variance in 30-month PDI scores, after controlling for identified covariates. In the full regression models, 18-month Orientation/Engagement remained predictive of both 30-month MDI (*b* = 0.05, *p* = .02; R^2= .62) and PDI scores (*b* = 0.07, *p* < .01; R^2 = .56) after controlling for prior MDI and PDI scores and identified covariates. Other significant predictors of 30-month MDI scores in the full model included higher 18-month MDI scores (*b* = 0.58, *p* < .01), higher maternal income (high-income: *b* = 7.57, *p* < .01; mid-income: *b* = 5.33, *p* < .01). Presence of BPD predicted lower 30-month MDI scores (*b* = −2.26, *p* = .05). Other significant predictors of 30-month PDI in the full model included higher 18-month PDI scores (*b* = 0.55, *p* < .01), higher birth weight (*b* = 2.85, *p* =.05), female gender (*b* = 2.75, *p* = .03), higher maternal income (mid-income: *b* = 3.66, *p* =.02), and higher maternal education (some college: *b* = 4.30, *p* = .02).

Clinical Categorization of Behavior Ratings as Predictors of Mental and Motor Performance

To assess the clinical relevance of these findings we examined the association between the clinical categorization of toddlers on the BRS at 18 months (i.e., Within Normal Limits, Questionable, and Non-Optimal) and comparable categories of MDI performance at 30 months (i.e., Within Normal Limits, Mildly Delayed, and Significantly Delayed). Specifically, we developed a cumulative logistic regression model to predict higher 30-month MDI categorization (e.g., the highest category, >85, versus the other categories), controlling for 18-month MDI category (see Table 5 for the distribution of children within each of these categories). Compared to toddlers with BRS total scores at 18 months Within Normal Limits, toddlers with Non-Optimal BRS total scores [odds ratio (OR), 0.41; 95% confidence interval

(CI), 0.21–0.81; $p = .011$] and Questionable BRS total scores (OR, 0.53; 95% CI, 0.32– 0.87, $p = .011$) had significantly lower odds of scoring in the higher MDI categories at 30 months. Similar patterns emerged in parallel analyses predicting higher 30-month PDI category. Toddlers scoring in the lower BRS categories at 18 months (vs. Within Normal Limits) had lower odds of higher PDI scores at 30 months: Non-Optimal (OR, 0.30; 95% CI, 0.14–0.63; $p = .001$) and Questionable (OR, 0.30; 95% CI, 0.18–0.49; $p < .001$).

Discussion

There is emerging evidence that deficits in behavior regulation might be associated with child performance on early measures of mental and motor functioning in high-risk populations (Anderson et al., 2003; Saigal et al., 2001; Sajaniemi et al., 2001; Whitfield et al., 1997). The current study examined the relationship between behavioral ratings and concurrent and future mental and motor functioning among toddlers born at ELBW. We found statistically significant and clinically substantive associations between early behavior ratings and later mental and motor performance.

The current sample generally scored within the low average to borderline range on the MDI and PDI at 30 months of age, consistent with previous evidence of suboptimal mental and motor performance in low birth weight populations (Aylward, 2002; Bayley, 1993; Constantinou et al., 2005; Dezoete et al., 2003; Shankaran et al., 2004; Vohr et al., 2000; Vohr et al., 2005; Walsh et al., 2005). However, an increase in MDI and BRS scores was observed with MDI scores increasing an average of two points and BRS scores increasing an average of four to five points between 18 and 30 months. In our sample of children with developmental risk factors, early intervention was prescribed based upon clinical need. More than half of the children in the current study received early intervention by 18 months; however, early intervention was not statistically associated with MDI, PDI, or BRS scores at either time point. While some studies have noted enhanced developmental performance among LBW infants and toddlers who receive early intervention, findings have generally been inconsistent given the heterogeneity of early intervention programs (Spittle, Orton, Doyle, & Boyd, 2007). More information is needed regarding the content, focus, and duration of early intervention services and supports received by these children and families to better assess the true association between early intervention and child developmental performance within the current sample. Early intervention effectiveness would be better assessed using randomized controlled trials. The general increase in scores possibly reflects a combination of factors, such as likelihood of early intervention referrals and developmental catch-up as medical complications alleviate with age (Koller, Lawson, Rose, Wallace, & McCarton, 1997; Ment et al., 2003). This increase also is consistent with test stability patterns reported in the Bayley-II manual (Bayley, 1993).

BRS total and factor scores showed moderate stability between 18 and 30 months and were positively correlated with MDI and PDI scores at both time points. As would be expected, all BRS factors were correlated with one another at both 18 and 30 months. Further, factors measuring state regulation and attention (Emotional Regulation and Orientation/Engagement) had stronger correlations with one another than with the Factor measuring motor movement quality and control (Motor Quality).

Approximately 20 to 40% of children born at LBW exhibit later behavioral problems, such as inattention, deficits in social skills, low self esteem, or symptoms of psychiatric disorders (e.g., attention deficit hyperactive disorders; Elgen, Sommerfelt, & Markestad, 2002; Gray, Indurkhya, & McCormick, 2004). The prevalence of later behavioral deficits in LBW populations underlines the importance of recognizing constellations of social and neonatal risk that put toddlers at particular risk for later problems (Elgen, Sommerfelt, & Markestad, 2002; Gray, Indurkhya, & McCormick, 2004). Toddler and maternal predictors of behavioral functioning were consistent with previous research. Female gender was associated with more optimal behavior ratings at both 18 and 30 months, consistent with previous associations reported in children born at ELBW (Sajaniemi et al., 2001). Gender differences might persist into later childhood as males are generally reported to have more behavior problems and more frequently require special education services than their female counterparts (Aylward, 2002). Higher income was associated with more optimal behavior ratings at both time points and higher maternal education was associated with more optimal ratings at 30 months of age, indicating the importance of socioeconomic factors in the developmental functioning of children born at ELBW (Dezoete et al., 2003; Lowe et al., 2005; Vohr et al., 2000; Vohr et al., 2005; Walsh et al., 2005).

With regard to neonatal risk factors, presence of BPD and being born at an especially low birth weight (≤ 750g) was associated with less optimal behavior ratings during the testing session at 18 months of age. BPD has been associated with later deficits in attention and fine motor skills, increased hyperactivity, and display of more internalizing behaviors (Farel, Hooper, Teplin, Henry, & Kraybill, 1998; Gray, O'Callaghan, & Poulsen, 2008; Majnemer et al., 2000); thus, results of the current study are consistent with previous evidence. However, BPD did not predict 30-month behavioral ratings, which might suggest that this condition has less impact on some toddlers born at ELBW as they continue to develop. Last, toddlers born at a birth weight ≤ 750g had lower behavior ratings than their heavier birth weight peers at 30 months of age. These findings are consistent with previous associations found between lower birth weights and subsequent behavioral ratings (Hack et al., 1994; Spiker, Ferguson, & Brooks-Gunn, 1993; Whitfield et al., 1997). Children born at such low birth weights are at increased risk for medical and developmental complications, which might in turn impact their behavior regulatory abilities during these first few years of life. Overall, practitioners need to take social and neonatal risk factors into account when assessing child developmental functioning and in making recommendations for intervention.

BRS total scores were not only associated with concurrent mental and motor functioning, but also with subsequent mental and motor functioning, even after controlling for toddler and maternal characteristics and earlier MDI and PDI scores, respectively. In other words, ratings of early difficulties in regulating emotion, controlling motor movement, and engaging with a relatively structured sequence of task demands predicted later difficulties in similar testing situations. Toddlers born at ELBW and who exhibit more disorganized behavior might be less able to profitably explore the physical environment and less able to elicit and profit from structured social stimulation (e.g., from parents and therapists) than toddlers born at ELBW who show more organized behavior (Brooks-Gunn, Klebanov, Liaw, & Spiker, 1993; Sajaniemi et al., 2001).

The association between 18-month behavior ratings and subsequent MDI and PDI scores continued when examining individual BRS factors. First, Emotional Regulation predicted 30-month MDI and PDI scores, controlling for 18-month MDI and PDI scores and identified covariates. Emotional Regulation is essentially a measure of task persistence and ability to regulate frustration, attention, and activity levels across various tasks. Difficulties in this area predicted toddlers' ability to complete appropriate motor tasks outlined in the PDI, which involve imitating examiner movements and coordinating movements in tasks such as stacking blocks. In separate analyses, Orientation/Engagement at 18 months predicted both MDI and PDI scores at 30 months. Toddlers who demonstrate cooperation with the examiner and who demonstrate interest and persistence in attempting to complete tasks are likely to score more optimally on later standardized developmental assessments. Unlike previous investigations (Lowe et al., 2005; Sajaniemi et al., 2001), the current study investigated Motor Quality, which predicted 30-month MDI and PDI scores. Early deficiencies in motor quality at 18 months (i.e., tone and control) appear to impact both mental (e.g., using materials to build something) and motor performance (e.g., ability to grasp objects or ability to maintain balance or walk) at 30 months. It is important to note that each of these factors does not necessarily have an independent association with 30-month outcome. Nevertheless, the findings suggest that all three BRS factors appear to be organizing features of behavioral functioning in toddlers born at ELBW that impact the acquisition of mental and motor milestones.

Effect sizes were substantial for the full regression models using 18-month behavior scales to predict 30-month mental and psychomotor functioning with as much as 63% of variance in developmental functioning accounted for by these models; however, there was a considerable amount of shared variance in 30-month mental/psychomotor scores that was accounted for by earlier mental/psychomotor scores and behavior ratings. Although findings were statistically significant, the impact of behavior ratings alone was somewhat subtle after controlling for prior mental and psychomotor functioning. For example, 18-month BRS total scores accounted for an additional 1% of variance in 30-month MDI scores after controlling for 18-month MDI scores and neonatal and sociodemographic risk variables. To better understand the clinical relevance of the association between earlier behavior and later mental and psychomotor functioning, we conducted analyses using BRS categories (i.e., Within Normal Limits, Questionable, and Non-Optimal) at 18 months to predict higher 30-month MDI (or PDI) categories (e.g., ≥85 versus ≤84, *and* ≥70 versus <70). Based on clinical categorizations, toddlers performing in less optimal ranges on the BRS (i.e., the Non-Optimal or Questionable range) at 18 months were half as likely to score in a higher MDI category at 30 months than toddlers performing Within Normal Limits on the 18-month BRS. An even more striking pattern emerged for motor performance. Toddlers with less optimal BRS categorization were one third as likely to score in a higher PDI category at 30 months than toddlers with a normal 18-month BRS score. These predictive categorical associations indicate that poor behavioral performance at 1½ years forecasts poor mental and psychomotor performance at 2½ years of age.

Limitations

This study's results can only be generalized to toddlers born at ELBW who returned for a 30-month outcome visit. Loss to follow-up was associated with lower maternal age, lower maternal education, and increased participation in early intervention by 18 months. The toddlers lost to the 30-month follow-up had lower 18-month BRS total and factor scores than the infants examined in the current study. Although it is impossible to ascertain whether the associations documented in this study would be obtained in a sample with lower mean BRS scores, the relationship between BRS scores and child outcome might have been stronger in a sample of children that included greater variability in scores.

Another limitation to the current study is that examiner ratings of child behavior are limited to the testing environment. While test observations offer a standardized procedure for comparing the behaviors of toddlers born at ELBW in our sample, it is not clear the extent to which these behaviors generalize to the behaviors of these children within their natural environment. Glutting et al. (1996) suggest that examiner-observed deficits in children's behaviors during testing (e.g., excessive activity level, poor sustained attention) might provide complementary information to behavioral descriptions provided by parents or teachers. Evaluating examiner observations, scores on standardized developmental assessments, and parent- or teacher-reported behaviors would likely enhance diagnostic precision and intervention planning especially within this high-risk population.

It also is important to note that the Bayley-II has been revised since our administration of this assessment. The current Bayley-III (Bayley, 2006) expands upon the Bayley-II's utility in assessing the cognitive and motor functioning of infants and toddlers (Johnson & Marlow, 2006; Rhodes, D'Amato, & Rothlisberg, 2009) and assesses five developmental domains (i.e., cognitive, language, motor, socio-emotional, and adaptive behavior). Although the BRS has been replaced by two parent-report measures (the Social-Emotional scale and the Adaptive Behavior scale) in the Bayley-III, a brief behavioral observation measure also is included in the newer version to document examiners' impressions of child behavior during test administration. The Bayley-III Behavior Observation Inventory is intended for completion by the examiner to assess the child's behavior during the testing session and incorporates information regarding the child's behavior at home. Bayley (2006) argues that this inventory will aid in assessing the validity of behaviors observed in the testing session and in interpreting children's scores on the Bayley-III scales. Consequently, this might also aid practitioners in intervention planning.

Some evidence suggests that reliability and validity of the Bayley-III scores are consistent with previous versions (Bayley, 2006). Average internal consistency coefficients are high for the Cognitive and Motor scales (r = .91 and r = .92, respectively). Internal consistency also has been assessed in a large sample of children at high risk including children with Down syndrome, Pervasive Developmental Disorder, prenatal alcohol exposure, risk for developmental delay, language impairment, prematurity or low birth weight, small for gestational age, or asphyxiation at birth. Average reliability coefficients for this group were .96 for the Cognitive scale, .94 for the Fine Motor subscale, and .98 for the Gross Motor subscale (Bayley, 2006). Similar to the BayleyII, the author also reported a high degree of stability in Bayley-III scores over time with stability coefficients increasing slightly with increased age of the participant. Internal consistency coefficients also are moderate to high for the recently added Social-Emotional scale and Adaptive Behavior scale. Evidence suggests that children with known biological risk factors such as those listed above tend to score lower than matched controls on these measures (Bayley, 2006). The Bayley-III might be a useful assessment for incorporating measures of developmental functioning, examiner observations, and parent-reported behaviors to comprehensively assess developmental risk and aid in intervention planning for this high-risk population; however, future studies are necessary to confirm the utility of the Bayley-III for such purposes.

While the psychometric properties of the Bayley-III appear to be strong, it is not known whether examiner ratings of child behavior will predict subsequent cognitive and motor functioning using the new version of the Bayley or similar assessments. The BRS of the Bayley-II is just one example of how behavioral observations during testing might help clinicians predict child performance on measures of developmental functioning. Further, the additional information provided by behavioral observations might aid in identifying potential need for early intervention. As previously mentioned, there is considerable heterogeneity in the content, focus, methodology, and duration of early intervention programs. Clinical impressions of child behavioral deficits, such as frequent inattention or emotional dysregulation, might be useful in helping clinicians refer children to early intervention programs that best fit their developmental and behavioral needs. Future investigations, especially in high-risk populations, are required to determine the putative independent role of clinician ratings in predicting developmental outcome.

Conclusion

Standardized measures of developmental and behavioral functioning are not definitive predictors of developmental abilities; however, they are important indicators of future potential and functioning (Nellis & Gridley, 1994; Strauss, Sherman, & Spreen, 2006). It is generally advised that neurodevelopmental follow-up for premature populations be conducted within the first two years of life (British Association of Perinatal Medicine, 2001; Johnson & Marlow, 2006; National Perinatal Epidemiology Unit and Oxford Health Authority, 1994). While many clinics within multicenter networks (e.g., the Neonatal Research Network) conduct follow-up assessments as early as 18 to 24 months corrected age (Vohr, Wright, Hack, Aylward, & Hirtz, 2004), smaller pediatric clinics might not be equipped to conduct follow-up assessments as early or might conduct only portions of developmental assessments given limited resources or time restraints. The current study suggests that early behavioral characteristics, as indexed by examiner ratings, are important, complimentary indicators of subsequent mental and motor performance in toddlers born at ELBW.

Clinicians might find early behavior ratings, in conjunction with measures of mental and motor performance, helpful in determining which children are likely to achieve appropriate developmental milestones, identifying children who might need more frequent follow-up, and assessing the potential need for early intervention among children who display early behavioral deficits. Approximately 58% of this ELBW cohort received early intervention services by 18 months of age, similar to previous reports of children born at ELBW (Hintz, Kendrick, Vohr, Poole, & Higgins, 2008; Wang et al., 2009). Early intervention underenrollment is a significant concern among this population given the likelihood of heightened medical, social, and developmental risk associated with lower birth weights. Underenrollment might be attributed to multiple factors such as lack of family or program follow-up, access to health insurance, and deficits in clinical knowledge that might contribute to lower referral rates (Wang et al., 2009). Increased attention to specific behavioral characteristics of the toddler might be beneficial for practitioners in referring toddlers and families to early intervention services that target their specific needs. Targeting interventions to the specific developmental, behavioral, and sociodemographic needs of the toddler and family has important implications for increasing early intervention effectiveness and ultimately enhancing child developmental outcomes.

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References

Anderson PJ, Doyle LW, Victorian Infant Collaborative Study Group. Neurobehavioral outcomes of school-age children born extremely low birth weight or very preterm in the 1990s. JAMA 2003;289:3264–3272. [PubMed: 12824207]

Aylward GP. Cognitive and neuropsychological outcomes: More than IQ scores. Ment Retard Dev Disabil Res Rev 2002;8:234–240. [PubMed: 12454899]

Banerjee PN, Tamis-LeMonda CS. Infants' persistence and mothers' teaching as predictors of toddlers' cognitive development. Infant Behav Dev 2007;30:479–491. [PubMed: 17683756]

Bayley, N. Bayley Scales of Infant Development, Second Edition. Psychological Corporation; San Antonio, TX: 1993.

Bayley, N. Bayley Scales of Infant Development-III. The Psychological Corporation; San Antonio, TX: 2006.

Blair C. Early intervention for low birth weight preterm infants: The role of negative emotionality in the specification of effects. Dev Psychopathol 2002;14:311–332. [PubMed: 12030694]

British Association of Perinatal Medicine. Standards for hospitals providing intensive and high dependency care. British Association of Perinatal Medicine; London: 2001.

Brooks-Gunn J, Klebanov PK, Liaw F, Spiker D. Enhancing the development of low-birthweight premature infants: Changes in cognition and behavior over the first three years. Child Dev 1993;64:736–753. [PubMed: 7687948]

Burns Y, O'Callaghan MO, McDonell B, Rogers Y. Movement and motor development in ELBW infants at 1 year is related to cognitive and motor abilities at 4 years. Early Human Development 2004;80:19–29. [PubMed: 15363836]

Cardon LR, Fulker DW. Sources of continuity in infant predictors of later IQ. Intelligence 1991;15:279–293.

Constantinou JC, Adamson-Macedo EN, Mirmiran M, Ariagno RL, Fleisher BE. Neurobehavioral assessment predicts differential outcome between VLBW and ELBW preterm infants. J Perinat 2005;25:788–793.

Dezoete JA, MacArthur BA, Tuck B. Prediction of Bayley and Stanford-Binet scores with a group of very low birthweight children. Child Care Health Dev 2003;29:367–372. [PubMed: 12904244]

DiLalla LF, Thompson LA, Plomin R, Phillips K, Fagan J, Haith MM, et al. Infant predictors of preschool and adult IQ: A study of infant twins and their parents. Dev Psychol 1990;26:759–769.

Elgen I, Sommerfelt K, Markestad T. Population based, controlled study of behavioural problems and psychiatric disorders in low birthweight children at 11 years of age. Arch Dis Child 2002;87:128–132.

Farel AM, Hooper SR, Teplin SW, Henry MM, Kraybill EN. Very-low -birthweight infants at seven years: An assessment of the health and neurodevelopmental. J Learn Disabil 1998;31:118–126. [PubMed: 9529782]

Field T, Dempsey J, Shuman HH. Bayley behavioral ratings of normal and high-risk infants: The relationship to Bayley mental scores. J Pediatr Psychol 1979;4:277–283.

Glutting JJ, Youngstrom EA, Oakland T, Watkins MW. Situational specificity and generality of test behaviors for samples of normal and referred children. School Psych Rev 1996;25:94–107.

Gray PH, O'Callaghan MJ, Poulsen L. Behaviour and quality of life at school age of children who had bronchopulmonary dysplasia. Early Hum Dev 2008;84:1–8. [PubMed: 17317043]

Gray RF, Indurkhya A, McCormick MC. Prevalence, stability, and predictors of clinically significant behavior problems in low birth weight children at 3, 5, and 8 years of age. Pediatrics 2004;114:736–743. [PubMed: 15342847]

Hack M, Taylor HG, Klein N, Eiben R, Schatschneider C, Mercuri-Minich N. School age outcomes in children with birth weight under 750 gm. N Engl J Med 1994;331:753–759. [PubMed: 7520533]

Hintz SR, Kendrick DE, Vohr BR, Poole WK, Higgins RD. Community supports after surviving extremely low-birth-weight, extremely preterm birth: Special outpatient services in early childhood. *Archives of Pediatrics* & *Adolescent Medicine* 2008;162:748–755. [PubMed: 18678807]

Johnson S, Marlow N. Developmental screen or developmental testing? Early Hum Dev 2006;82:173–183. [PubMed: 16504424]

Koller H, Lawson K, Rose SA, Wallace I, McCarton C. Patterns of cognitive development in very low birth weight children during the first six years of life. Pediatrics 1997;99:383–389. [PubMed: 9041293]

Lowe J, Woodward B, Papile LA. Emotional regulation and its impact on development in extremely low birth weight infants. J Dev Behav Pediatr 2005;26:209–213. [PubMed: 15956871]

Majnemer A, Riley P, Shevell M, Birnbaum R, Greenstone H, Coates AL. Severe bronchopulmonary dysplasia increases risk for later neurological and motor sequelae in preterm survivors. Dev Med Child Neurol 2000;42:53–60. [PubMed: 10665976]

Matheny AP. Bayley's Infant Behavior Record: Behavioral components and twin analyses. Child Dev 1980;51:1157–1167. [PubMed: 7193557]

Ment LR, Vohr B, Allan W, Katz KH, Schneider KC, Westerveld M, et al. Change in cognitive function over time in very low-birth-weight infants. JAMA 2003;289:705–711. [PubMed: 12585948]

National Perinatal Epidemiology Unit and Oxford Health Authority. Report of two working groups. Disability and perinatal care: Measurement of health status at two years. Oxford: 1994.

Nellis L, Gridley BE. Review of the Bayley Scales of Infant Development-Second Edition. J Sch Psychol 1994;32:201–209.

Poindexter BB, Ehrenkranz RA, Stoll BJ, Wright LL, Poole WK, Oh W, et al. Parenteral glutamine supplementation does not reduce the risk of mortality or late-onset sepsis in extremely low birth weight infants. Pediatrics 2004;113:1209–1215. [PubMed: 15121931]

Rhodes, RL.; D'Amato, RC.; Rothlisberg, BA. Utilizing a neuropsychological paradigm for understanding common educational and psychological tests. In: Reynolds, CR.; Fletcher-Janzen, E., editors. Handbook of clinical child neuropsychology. 3rd ed.. Springer-Verlag; New York, NY: 2009. p. 332-333.

Saigal S, Stoskopf BL, Streiner DL, Burrows E. Physical growth and current health status of infants who were extremely low birth weight and controls at adolescence. Pediatrics 2001;108:407–415. [PubMed: 11483807]

Sajaniemi N, Hakamies-Blomqvist L, Katainen S, von Wendt L. Early cognitive and behavioral predictors of later performance: A follow-up study of ELBW children from ages 2 to 4. Early Child Res Q 2001;16:343–361.

Sajaniemi N, Makela J, Salokorpi T, von Wendt L, Hamalainen T, Hakamies-Blomqvist L. Cognitive performance and attachment patterns at four years of age in extremely low birthweight infants after early intervention. Eur Child Adolesc Psychiatry 2001;10:122–129. [PubMed: 11469284]

Shankaran S, Johnson Y, Langer JC, Vohr BR, Fanaroff AA, Wright LL, et al. Outcome of extremely low birth weight infants at highest risk: Gestational age ≤ 24 weeks, birth weight ≤ 750g and 1 minute Apgar ≤ 3. Am J Obstet Gynecol 2004;191:1084–1091. [PubMed: 15507925]

Spiker D, Ferguson J, Brooks-Gunn J. Enhancing maternal interactive behavior and child social competence in low birth weight, premature infants. Child Dev 1993;64:754–768. [PubMed: 8339693]

Spittle A, Orton J, Doyle LW, Boyd R. Early developmental intervention programs post hospital discharge to prevent motor and cognitive impairments in preterm infants. Cochrane Database of Systematic Reviews. 2007;(Issue 2)

Strauss, E.; Sherman, EMS.; Spreen, O. A compendium of neuropsychological tests: Administration, norms, and commentary. 3rd ed.. Oxford University Press; NY: 2006.

Vohr BR, Wright LL, Dusick AM, Mele L, Verter J, Steichen JJ, et al. Neurodevelopmental and functional outcomes of extremely low birth weight infants in the National Institute of Child Health and Human Development Neonatal Research Network, 1993–1994. Pediatrics 2000;105:1216–1226. [PubMed: 10835060]

Vohr B, Wright LL, Hack M, Aylward GP, Hirtz DE. Follow-up care of high risk infants. Pediatrics 2004;114:1377–1397.

Vohr BR, Wright LL, Poole WK, McDonald SA. Neurodevelopmental outcomes of extremely low birth weight infants <32 weeks' gestation between 1993 and 1998. Pediatrics 2005;116:635–643. [PubMed: 16143580]

Walsh MC, Morris BH, Wrage L, Vohr BR, Poole WK, Tyson JE, et al. Extremely low birthweight neonates with protracted ventilation: Mortality and 18-month neurodevelopmental outcomes. J Pediatr 2005;146:798–804. [PubMed: 15973322]

Wang CJ, Elliott MN, Rogowski J, Lim N, Ratner JA, Schuster MA. Factors influencing the enrollment of eligible extremely-low-birth-weight children in the Part C early intervention program. Academic Pediatrics 2009;9:283–287. [PubMed: 19482532]

Weiss SJ, St. Jonn-Seed M, Wilson P. The temperament of pre-term, low birth weight infants and its biological substrates. Res Nurs Health 2004;27:392–402. [PubMed: 15514956]

Whitfield MF, Eckstein Grunau RV, Holsti L. Extremely premature (<= 800 g) schoolchildren: Multiple areas of hidden disability. Arch Dis Child 1997;77:85–90.

Yarrow LJ, Morgan GA, Jennings KD, Harmon RJ, Gaiter JL. Infants' persistence at tasks: Relationships to cognitive functioning and early experience. Infant Behav Dev 1982;5:131–141.

Table 1

Infant and Mother Characteristics

Variable	Final Sample-Attended 18 and 30 months (*N* = 539)	Infants Attending 18 months only (*n* = 261)	P
Gestational age, *M (SD)*	26 (2)	26 (2)	.718
Birthweight, *M (SD)*	792 (130)	787 (136)	.652
Male, % (*n*)	44 (239)	45 (117)	.914
Maternal Age, *M (SD)*	28 (7)	26 (7)	.004
Maternal income, % (*n*)			
≥ $40,000	31 (165)	23 (61)	.041
$20,000−$39,999	26 (139)	33 (85)	
< $20,000	44 (235)	41 (106)	
Maternal education, % (*n*)			
Some college	47 (251)	38 (100)	.096
HS graduate	28 (151)	28 (73)	
< HS graduate	25 (137)	31 (81)	
IVH/PVL, % (*n*)	14 (74)	13 (34)	.809
BPD, % (*n*)	44 (239)	51 (133)	.083
NEC, % (*n*)	8 (43)	6 (16)	.345
Late sepsis, % (*n*)	39 (211)	35 (92)	.301
Early intervention by 18 months, % (*n*)	58 (311)	66 (173)	.012
Bayley scores at 18 months, *M (SD)*			
MDI	81 (17)	78 (16)	.110
PDI	86 (18)	83 (16)	.044
BRS total	57 (31)	42 (29)	< .001
BRS Emotional Regulation	57 (28)	45 (28)	< .001
BRS Motor Quality	52 (35)	41 (31)	< .001
BRS Orientation/Engagement	57 (30)	47 (28)	< .001

Note: IVH = intraventricular hemorrhage; PVL = periventricular leukomalacia; BPD = bronchopulmonary dysplasia; NEC = necrotizing enterocolitis. All percentage categories sum to 100%.

Table 2

Correlations of BRS Scales

Scale	BRS total	Emotional Regulation	Motor Quality	Orientation/ Engagement
18 Months (*r*)				
BRS total	1.00			
Emotional Regulation	0.84	1.00		
Motor Quality	0.58	0.40	1.00	
Orientation/Engagement	0.84	0.68	0.39	1.00
MDI	0.50	0.44	0.48	0.44
PDI	0.44	0.26	0.63	0.32
30 Months (*r*)				
BRS total	1.00			
Emotional Regulation	0.85	1.00		
Motor Quality	0.68	0.51	1.00	
Orientation/Engagement	0.82	0.64	0.42	1.00
MDI	0.60	0.51	0.50	0.45
PDI	0.61	0.46	0.67	0.42
18 and 30 months (*r*)	0.53	0.45	0.62	0.44

	18 months	30 months	18 vs. 30 months MI
	M (SD)	M (SD)	P
BRS total	57 (31)	61 (31)	0.001
Emotional Regulation	57 (28)	61 (30)	< .001
Motor Quality	52 (35)	56 (36)	0.002
Orientation/Engagement	57 (30)	62 (30)	0.001
MDI	81 (17)	83 (18)	< .001
PDI	86 (18)	85 (21)	0.494

Note: $N = 539$. All correlations were statistically significant at $p < .001$; *p*-values for comparisons of mean scores over time are based on paired t-tests.

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Table 3

Regression Coefficients of Predictors of BRS Total at 18 and 30 Months

Variable	18 Months			30 Months		
	B	SE	β	B	SE	β
Gestational age	−0.10	0.67	−0.01	0.41	0.66	0.02
Birth weight > 750g	−0.89	2.55	−0.01	5.00*	2.49	0.08
Female	6.94**	2.26	0.11	4.96*	2.20	0.08
Maternal age	−0.14	0.18	−0.03	−0.16	0.17	−0.04
Maternal income						
≥ $40,000	9.18**	3.23	0.14	7.81*	3.16	0.11
$20,000–$39,999	4.46	2.88	0.06	5.29	2.82	0.07
Maternal education						
Some college	1.55	3.24	0.03	6.56*	3.17	0.10
HS graduate	1.07	3.28	0.02	2.76	3.21	0.04
IVH/PVL	−1.97	3.28	−0.02	−4.27	3.20	−0.05
BPD	−5.62*	2.51	−0.09	−4.27	2.46	−0.07
NEC	−2.06	4.11	−0.02	−0.18	4.02	0.00
Late sepsis	0.93	2.45	0.01	0.65	2.40	0.01
Early intervention by 18 months	−4.52	2.44	−0.07	−3.32	2.38	−0.05

Note: N = 539; B = unstandardized coefficient; SE = standard error coefficient; β = standardized coefficient.

All variables were entered simultaneously and each model controls for study site. Reference categories are male, birth weight ≤ 750g, mother income < $20,000, mother does not have a HS diploma, no IVH/PVL, no BPD, no NEC, no late sepsis, and had not received early intervention by 18 months of age.

* $p \leq .05$

** $p > .01$

*** $p < .001$.

Table 4

Regression Coefficients of Models Predicting 30-Month MDI and PDI Scores by 18-Month BRS Total Scores

Variable	Model 1: 18-Month MDI/PDI			Model 2: 18-Month BRS			Model 3: MDI/PDI and BRS		
	B	SE	β	B	SE	β	B	SE	β
MDI									
Gestational age	−0.52	0.31	−0.05	−0.47	0.37	−0.05	−0.51	0.31	−0.05
Birth weight > 750g	2.10	1.17	0.06	4.98***	1.39	0.13	2.40*	1.17	0.06
Female	1.85	1.06	0.05	4.43***	1.24	0.12	1.70	1.05	0.05
Maternal age	0.13	0.08	0.05	0.09	0.10	0.03	0.13	0.08	0.05
Maternal income									
≥ $40,000	7.84***	1.50	0.20	10.73***	1.78	0.27	7.60***	1.49	0.19
$20,000–$39,999	5.51***	1.32	0.13	6.25***	1.58	0.15	5.34***	1.31	0.13
Maternal education									
Some college	2.63	1.49	0.07	4.52*	1.77	0.12	2.71	1.47	0.07
HS graduate	1.26	1.50	0.03	1.26	1.79	0.03	1.20	1.49	0.03
IVH/PVL	−2.19	1.51	−0.04	−5.33**	1.79	−0.10	−2.35	1.50	−0.04
BPD	−2.33*	1.15	−0.06	−2.64	1.38	−0.07	−2.05	1.15	−0.06
NEC	−0.01	1.89	0.00	−2.93	2.24	−0.04	−0.15	1.87	0.00
Late sepsis	−0.27	1.12	−0.01	−0.98	1.34	−0.03	−0.38	1.11	−0.01
Early intervention by 18 months	−1.74	1.12	−0.05	−2.45	1.34	−0.07	−1.56	1.11	−0.04
MDI at 18 months	0.61***	0.03	0.58				0.56***	0.04	0.53
BRS total score				0.22***	0.02	0.38	0.07**	0.02	0.12
Model R^2	0.62			0.46			0.63		
PDI									
Gestational age	−0.38	0.38	−0.03	−0.78	0.43	−0.07	−0.41	0.38	−0.04
Birth weight > 750g	2.72	1.44	0.06	5.30**	1.61	0.12	3.01*	1.43	0.07
Female	2.85*	1.28	0.07	4.37***	1.44	0.10	2.53*	1.28	0.06
Maternal age	−0.03	0.10	−0.01	−0.06	0.11	−0.02	−0.02	0.10	−0.01
Maternal income									
≥ $40,000	4.03*	1.82	0.09	4.10*	2.06	0.09	3.43	1.81	0.08

Variable	Model 1: 18-Month MDI/PDI			Model 2: 18-Month BRS			Model 3: MDI/PDI and BRS		
	B	SE	β	B	SE	β	B	SE	β
$20,000–$39,999	4.02*	1.62	0.08	3.73*	1.83	0.08	3.70*	1.61	0.08
Maternal education									
Some college	4.62*	1.82	0.11	3.80	2.05	0.09	4.45*	1.81	0.11
HS graduate	3.07	1.85	0.07	1.55	2.08	0.03	2.87	1.83	0.06
IVH/PVL	−1.23	1.87	−0.02	−5.42**	2.07	−0.09	−1.48	1.85	−0.02
BPD	−1.25	1.43	−0.03	−3.48*	1.60	−0.08	−1.08	1.42	−0.03
NEC	0.24	2.31	0.00	−1.19	2.60	−0.02	0.24	2.29	0.00
Late sepsis	0.29	1.38	0.01	−0.14	1.55	0.00	0.19	1.37	0.00
Early intervention by 18 months	−2.18	1.39	−0.05	−4.93**	1.55	−0.12	−2.13	1.38	−0.05
PDI at 18 months	0.58**	0.04	0.50				0.53***	0.04	0.45
BRS total score				0.21***	0.03	0.31	0.08**	0.03	0.13
Model R^2	0.56			0.44			0.56		

Note: $N = 539$.

Each model controls for study site. Reference categories are male, birth weight ≥ 750g, mother income < $20,000, mother does not have a HS diploma, no IVH/PVL, no BPD, no NEC, no late sepsis, and had not received early intervention by 18 months of age.

* $p \geq .05$

** $p < .01$

*** $p < .001$

Table 5

Toddlers Born at ELBW by BRS Clinical Categories at 18 Months and MDI and PDI Clinical Categories at 18 and 30 Months

Variable	MDI at 30 months, *n*			Variable	PDI at 30 months, *n*		
	< 70	70–84	≥85		< 70	70–84	≥85
MDI at 18 months, **< 70**				**PDI at 18 months**, **< 70**			
BRS total at 18 months				BRS total at 18 months			
Non-Optimal	27	8	2	Non-Optimal	22	4	1
Questionable	22	10	3	Questionable	17	2	0
Normal	34	28	14	Normal	24	7	7
MDI at 18 monthsM, **70–84**				**PDI at 18 months**, **70–84**			
BRS total at 18 months				BRS total at 18 months			
Non-Optimal	0	2	4	Non-Optimal	5	3	2
Questionable	7	14	14	Questionable	16	9	10
Normal	12	53	64	Normal	15	30	42
MDI at 18 months, **≥ 85**				**PDI at 18 months**, **≥ 85**			
BRS total at 18 months				BRS total at 18 months			
Non-Optimal	0	1	0	Non-Optimal	1	3	3
Questionable	1	2	6	Questionable	6	6	13
Normal	7	37	167	Normal	25	36	230

Note: $N = 539$. Regardless of 18-month MDI category, toddlers with a Normal rather than a Questionable or Non-optimal BRS total score at 18 months obtained a more optimal MDI categorization at 30 months. A similar pattern was evident for PDI scores.