Executive Function and Academic Outcomes in Children Who Were Extremely Preterm

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OBJECTIVES: Cognitive and behavioral impairments of children born extremely preterm (EP) (<28 weeks’ gestation) and extremely low birth weight (ELBW) (<1000 g) may change with age. We assessed the individual stability of behavioral executive function (EF) from 8 to 18 years of age in children born EP or ELBW and their academic outcomes.

METHODS: Participants comprised 180 children born EP or ELBW from a large geographic cohort. We investigated the frequency of 4 developmental groups (persistent, remitting, late-onset, and typical development) on the basis of dichotomized scores (typical versus elevated) at ages 8 and 18 years in 2 indices (the Behavioral Regulation Index [BRI] and the Metacognition Index [MCI]) of the parental form of the Behavior Rating Inventory of Executive Function. Adolescent academic outcomes were measured by using the word reading, spelling, and math computation subtests of the Wide Range Achievement Test, Fourth Edition.

RESULTS: Most participants had a typical EF (BRI 61%, MCI 53%), followed by persistent (BRI 15%, MCI 16%), late-onset (BRI 12%, MCI 19%), or remitting (BRI 12%, MCI 13%) executive difficulties. Groups with executive impairments at age 18 years (persistent and late onset) had poorer academic outcomes than the typical and remitting groups. Shifting impairment categories between 8 and 18 years old was relevant to later academic outcomes.

CONCLUSIONS: Most children showed stable and age-appropriate EF, although persistent and transient difficulties were observed and related to uneven academic outcomes. Studying the origins and consequences of the developmental stability of EF may contribute to the development of interventions to decrease the adverse neurodevelopmental outcomes of preterm birth.

WHAT'S KNOWN ON THIS SUBJECT: Children born extremely preterm are at risk for impairments in executive functioning (EF) and academics. The stability of executive impairments across childhood is not known, but it needs to be explored because developmental differences in EF may relate to academic outcomes.

WHAT THIS STUDY ADDS: Four distinct developmental groups from 8 to 18 years of age were described in children born extremely preterm. Academic performance in adolescence was related to EF stability, with those with typical and remitting EF profiles showing better outcomes.

Despite remarkable advances in medical care, children born extremely preterm (EP) (<28 weeks’ gestation) and extremely low birth weight (ELBW) (<1000 g) continue to be at risk for impairments in cognitive, social, behavioral, and educational functioning.\(^1\)\(^-\)\(^3\) However, the nature and severity of impairments may change with age, leading to uncertainty as to which developmental difficulties constitute a transient delay or a persistent deficit.\(^4\)\(^-\)\(^5\) Whereas transient impairments have been reported in cognition and behavior for preterm survivors,\(^6\)\(^7\) more severe and persistent difficulties may be seen in children born EP.\(^8\)\(^-\)\(^9\) It is also known that specific behavioral and cognitive problems, such as emotional regulation impairments, are unlikely to emerge until later in life.\(^10\)\(^-\)\(^12\)

Executive function (EF) refers to a set of cognitive control processes, such as working memory, inhibition, shifting and control of attention, planning, reasoning, problem-solving, and impulse control.\(^1\)\(^3\)\(^14\) These higher-order skills of executive control emerge early in life, with ongoing maturation continuing into adolescence and early adulthood.\(^1\)\(^5\) Compared with term-born controls, children born EP or ELBW are at increased risk for EF deficits throughout development,\(^1\)\(^6\)\(^-\)\(^16\)\(^17\) with a tendency to show slower age-related progress in both performance-based and questionnaire measures of EF.\(^1\)\(^1\)\(^2\)\(^1\)\(^2\) Difficulties in EF have been linked with reduced academic achievement of preterm survivors.\(^1\)\(^8\)\(^-\)\(^20\) However, research to date has not explored differential EF stability within individuals born preterm. For example, some individuals may have persistent difficulties, whereas others display improved or deteriorating functioning with time.\(^1\)\(^0\)\(^-\)\(^2\)\(^1\)\(^2\)\(^1\)\(^2\)\(^1\)\(^2\) Cognitive performance in individuals born preterm is markedly variable,\(^2\)\(^2\) yet most researchers will not differentiate those with a dysfunction from those with typical functioning. Disregard for individual differences may lead to an unbalanced focus on problematic development over the investigation of optimal human functioning.\(^2\)\(^3\)\(^2\)\(^3\) Importantly, it is also unknown whether distinct stability subgroups in EF are related to different outcomes in children born EP or ELBW.

Our first aim in the current study was to assess the individual stability of behavioral EF from 8 to 18 years of age in a large geographic sample of children born EP or ELBW by assessing the frequency of the following 4 possible groups: persisting impairment, remitting impairment, late-onset impairment, and typical development. The second aim was to compare reading, spelling, and math computation at 18 years old among the different developmental subgroups, hypothesizing that children born EP or ELBW with persisting executive dysfunction would exhibit poorer academic achievement than those with remitting executive dysfunction.

**METHODS**

**Participants**

Participants comprised all infants born EP or ELBW in the state of Victoria, Australia, in 1991 and 1992. There were 298 survivors to 2 years of age and 297 survivors to 18 years of age, with follow-up assessments performed at ages 2, 5, 8, and 18 years and corrected for prematurity.\(^8\)\(^2\)\(^4\)\(^-\)\(^2\)\(^6\) The recruitment and follow-up assessments were approved by the Human Research Ethics Committees of all participating sites (The Royal Women’s Hospital, Mercy Hospital for Women, Monash Medical Centre, and The Royal Children’s Hospital, Melbourne, Australia). Only participants with complete parental reports of the Behavior Rating Inventory of Executive Function (BRIEF)\(^2\)\(^7\) at ages 8 and 18 years and who completed the Wide Range Achievement Test, Fourth Edition (WRAT4)\(^2\)\(^8\) at 18 years were included. No exclusion criteria other than not having complete data sets were applied. Participants older than 17 years and the parents of those younger than 18 years gave written, informed consent for participation.

**Measures**

**Behavioral EF**

The parental form of the BRIEF\(^2\)\(^7\) was used to assess everyday behavioral executive difficulties at 8 and 18 years of age. The BRIEF is valid, reliable,\(^2\)\(^7\)\(^2\)\(^9\) and is used extensively in research and clinical settings to assess executive dysfunction at home, school, and social situations.\(^2\)\(^9\) It consists of 86 items, which generate 8 clinical scales (Inhibit, Shift, Emotional Control, Initiate, Working Memory, Plan and Organize, Organization of Materials, and Monitor) and 2 broader indices (the Behavioral Regulation Index [BRI] and the Metacognition Index [MCI]). For this study, the 2 broad indices were used. The BRI is a composite of the Inhibit, Shift, and Emotional Control scales, whereas the MCI is a composite of the Initiate, Working Memory, Plan and Organize, Organization of Materials, and Monitor scales. Scores were age- and sex-normed to a t-distribution (a mean of 50 and SD of 10).\(^2\)\(^7\) Scores ≥60 (ie, 1 SD from the mean) were classified as “elevated executive difficulties.”

**Academic Achievement**

The WRAT4\(^2\)\(^7\) was used to measure participants’ single-word reading, spelling, and math computation performance at 18 years old. The raw scores were converted to age-standardized scores with a mean of 100 and SD of 15 by using the WRAT4 normative data.\(^2\)\(^7\) For descriptive purposes, we show the proportion of children in each group who were receiving special education support (eg, a regular school.
with an integration aide or other intervention) at 8 years old.

Medical and Social Characteristics

Perinatal and neonatal variables such as gestational age, birth weight, major brain injury on cranial ultrasound (grades 3 and 4 intraventricular hemorrhage or cystic periventricular leukomalacia), postnatal corticosteroid treatment, and major neonatal surgery were collected. Social characteristics were collected at the 8-year follow-up wave and included social class (categorized as lower if the major income earner in the family had an unskilled occupation or was unemployed), maternal age and education (classified as low if the mother reported <12 years of schooling), and multilingual status (the family spoke languages other than English at home).

Additionally, adolescents’ full-scale IQ was estimated with the Wechsler Abbreviated Scale of Intelligence.30 These variables were shown to influence preterm outcomes, including academic performance.8

Data Analysis

For each BRIEF Index (ie, BRI and MCI) participants were classified into 1 of 4 possible subgroups according to their EF at 8 and 18 years old. The typical subgroup consisted of participants with T-scores <60 at both time points, whereas the persistent subgroup consisted of participants with T-scores ≥60 at both time points. The remitting group consisted of participants with an elevated score (≥60) at 8 years but not 18 years of age, whereas the late-onset difficulties group was characterized by a T-score ≥60 at 18 years old only.

Baseline characteristics were compared among participants and nonparticipants born EP or ELBW as well as among the EF stability subgroups. For categorical data, when an χ² test could not be performed because of the sample size, comparisons were made by using the Fisher’s exact test with a Monte Carlo approach (confidence level = 99%, K (number of samples) = 10 000). For continuous data, a multivariable analysis of variance was performed for parametric data and the Kruskal–Wallis test for nonparametric data.

Differences in academic performance at 18 years old among the groups were calculated through generalized estimating equations (GEE) with a linear regression model, robust estimators, and an exchangeable structure for working correlation matrices. This strategy was chosen to allow for nonindependence of siblings from multiple pregnancies. For the GEE parameter estimates, the academic variables were transformed into z scores by using the means and SDs of the sample to facilitate the interpretation of effect sizes. Secondary GEE analyses were performed by removing participants with an IQ ≤70 at 18 years old and adjusting for any significant differences in perinatal and sociodemographic characteristics. We acknowledge that there are multiple comparisons, and thus, we interpreted the results by the magnitude of the difference among groups rather than adjusting the P value by the number of tests performed. The larger the difference among groups, the higher the chance that the results are clinically meaningful.31 In the current study, effect sizes were interpreted by using Cohen’s conventions (small: d = 0.2, medium: d = 0.5, and large: d = 0.8).32 The analyses were performed in SPSS 22.0.33

RESULTS

Sample Progression From 8 to 18 Years of Age

As shown in Fig 1, 180 of the original 297 participants born EP or ELBW had complete data sets to be included in the analyses.

FIGURE 1 Flowchart of the study sample.

Perinatal and sociodemographic characteristics were similar among participants and nonparticipants (Table 1).

Developmental Stability of Behavioral EF in EP and ELBW Adolescents

For the BRI, the majority of participants (n = 110, 61%) were classified as typical at both time points, whereas 15% (n = 27) had persistently elevated scores, 12% (n = 22) had remitting difficulties, and 12% (n = 21) had late-onset difficulties. Thus, most participants had a stable EF performance, with only 24% changing categories between 8 and 18 years old. For the MCI groups, 53% (n = 94) were classified as typical at both time points, whereas 16% (n = 28) had persistent difficulties, 13% (n = 23) had remitting difficulties, and 19% (n = 34) had late-onset difficulties. Again, only a minority (32%) changed categories between 8 and 18 years old. These developmental groups are illustrated in Fig 2.

Demographic, biological (perinatal and neonatal variables), and social characteristics of the EF stability subgroups are presented in Table 2. There was evidence of group differences in sex, IQ, and social
class. In general, the typical group for both the BRI and MCI had a higher proportion of girls, families of higher social class, and higher mean IQ scores than the persistent, late-onset, and remitting groups. Regarding the percentage of participants receiving special education at 8 years of age, children with typical development were less likely to receive additional support, whereas children with persistent EF difficulties were more likely to have an integration aide or other intervention.

**EF Stability and Academic Performance**

Reading, spelling, and math computation means and SDs for the EF development groups are displayed in Table 2, and Fig 3 shows comparisons among the groups. Adjusted results exclude participants with an IQ ≤70 at 18 years old and include significant confounders (eg, lower social class for the BRI and lower maternal education and multilingualism for the MCI). There was evidence of differences between some of the BRI and MCI stability subgroups, but not all of them (Fig 3). For both the BRI and MCI, the typical subgroup outperformed the persistent and late-onset subgroups for all academic outcomes. For the BRI, the persistent subgroup performed poorer than the remitting difficulties subgroup for all academic outcomes, and the remitting subgroup performed better than the late-onset subgroup in reading and spelling in the adjusted analyses. For the MCI, the persistent subgroup had lower spelling scores than those with remitting difficulties.

**DISCUSSION**

We observed that most participants born EP or ELBW in this study had a stable development in parent-reported EF from 8 to 18 years of age. Importantly, more than half of our participants born EP or ELBW had an age-appropriate EF based on parental reports at 8 and 18 years, and by late adolescence, only 27% had elevated BRI scores, and 35% had elevated MCI scores. Only 12% to 13% of children had persisting problems, whereas 24% to 32% had transient difficulties. Thus, although it is well established that children born EP are at risk for executive dysfunction,11,12,16,17 based on parental reports, the rates of children with persisting issues were low.

Previous studies investigating parent-reported EF in the population born EP have reported significantly increased risk for behavioral problems.34–36 Behavioral and emotional regulation have been suggested to be a special concern for parents,18,37 although in our sample, a slightly higher proportion of parents reported MCI difficulties compared with BRI problems. Researchers in other studies using the BRIEF have also noted MCI problems, although the patterns are not identical. For example, Luu et al36 found that adolescents born with low birth weight were at risk for behavioral problems comprised in the MCI but not in the BRI, and Ritter et al38 reported significant differences between children born very preterm and controls only in the Working Memory subscale and not in BRI scales, such as Inhibition and Shift. Recently, we reported

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**TABLE 1 Characteristics of Participants and Nonparticipants**

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Included (n = 180)</th>
<th>Not Included (n = 118)</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age 8 y, mean (SD)</td>
<td>8.7 (0.3)</td>
<td>8.7 (0.4)*</td>
<td>.12</td>
</tr>
<tr>
<td>Age 18 y, mean (SD)</td>
<td>18.2 (0.8)</td>
<td>18.2 (0.8)</td>
<td>.71</td>
</tr>
<tr>
<td>Boys, n (%)</td>
<td>80 (44)</td>
<td>58 (49)</td>
<td>.43</td>
</tr>
<tr>
<td>Gestational age (wk), mean (SD)</td>
<td>26.7 (2.0)</td>
<td>26.7 (1.8)</td>
<td>.65</td>
</tr>
<tr>
<td>Birth weight (g), mean (SD)</td>
<td>866 (163)</td>
<td>890 (158)</td>
<td>.76</td>
</tr>
<tr>
<td>Major neonatal brain injury, n (%)</td>
<td>16 (9)</td>
<td>16 (14)</td>
<td>.20</td>
</tr>
<tr>
<td>Small for gestational age, n (%)</td>
<td>30 (17)</td>
<td>16 (14)</td>
<td>.47</td>
</tr>
<tr>
<td>Postnatal corticosteroids, n (%)</td>
<td>56 (31)</td>
<td>42 (36)</td>
<td>.42</td>
</tr>
<tr>
<td>Neonatal surgery, n (%)</td>
<td>48 (27)</td>
<td>29 (25)</td>
<td>.69</td>
</tr>
<tr>
<td>Maternal age (y), mean (SD)</td>
<td>29.0 (5.82)</td>
<td>27.8 (5.7)</td>
<td>.07</td>
</tr>
<tr>
<td>Lower maternal education, n/N (%)</td>
<td>91/179 (51)</td>
<td>49/90 (54)</td>
<td>.58</td>
</tr>
<tr>
<td>Lower social class, n/N (%)</td>
<td>71/177 (40)</td>
<td>46/92 (50)</td>
<td>.12</td>
</tr>
<tr>
<td>Multilingual family, n/N (%)</td>
<td>26/180 (14)</td>
<td>24/103 (23)</td>
<td>.06</td>
</tr>
</tbody>
</table>

*Age at assessment is corrected for prematurity. Ns vary because of missing data.

* N = 95.

* N = 42.

* Major neonatal brain injury: grades 3 and 4 intraventricular hemorrhage and/or cystic periventricular leukomalacia.

* Small for gestational age: birth weight ≥2 SD below the mean for gestational age and sex.

* Lower maternal education: <12 years of schooling.

* Lower social class: major income earner in the family has an unskilled occupation or unemployed.

* Multilingual family: speaks languages other than English at home.

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**FIGURE 2**

Level of behavioral executive dysfunction from 8 to 18 years old according to developmental stability. A, the means and 95% confidence intervals for the BRI. B, the means and 95% confidence intervals for the MCI.
<table>
<thead>
<tr>
<th></th>
<th>BRI</th>
<th>MCI</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Typical (n = 110)</td>
<td>Persistent (n = 27)</td>
</tr>
<tr>
<td></td>
<td>Remitting (n = 22)</td>
<td>Late Onset (n = 21)</td>
</tr>
<tr>
<td></td>
<td>P</td>
<td>Typical (n = 94)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Persistent (n = 28)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Remitting (n = 23)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Late Onset (n = 34)</td>
</tr>
<tr>
<td><strong>Demographic</strong></td>
<td></td>
<td><strong>P</strong></td>
</tr>
<tr>
<td>Age 8 y, mean (SD)</td>
<td>8.7 (0.3)</td>
<td>8.7 (0.3)</td>
</tr>
<tr>
<td>Age 18 y, mean (SD)</td>
<td>18.2 (0.8)</td>
<td>18.4 (0.7)</td>
</tr>
<tr>
<td>Boys, n (%)</td>
<td>42 (38)</td>
<td>17 (63)</td>
</tr>
<tr>
<td>Major disability at 18 y</td>
<td></td>
<td><strong>P</strong></td>
</tr>
<tr>
<td>Full-scale IQ, mean (SD)</td>
<td>99.7 (15.2)</td>
<td>85.6 (13.2)</td>
</tr>
<tr>
<td>Full-scale IQ &lt; 70, n (%)</td>
<td>2/110 (2)</td>
<td>2/27 (7)</td>
</tr>
<tr>
<td>Biological</td>
<td></td>
<td><strong>P</strong></td>
</tr>
<tr>
<td>Gestational age (wk), mean (SD)</td>
<td>26.8 (2.0)</td>
<td>26.7 (2.8)</td>
</tr>
<tr>
<td>Birth weight (g), mean (SD)</td>
<td>886 (177)</td>
<td>854 (139)</td>
</tr>
<tr>
<td>Major neonatal brain injury, n (%)</td>
<td>7 (8)</td>
<td>6 (22)</td>
</tr>
<tr>
<td>Small for gestational age, n (%)</td>
<td>21 (19)</td>
<td>6 (22)</td>
</tr>
<tr>
<td>Postnatal corticosteroids, n (%)</td>
<td>32 (29)</td>
<td>13 (48)</td>
</tr>
<tr>
<td>Neonatal surgery, n (%)</td>
<td>27 (25)</td>
<td>11 (41)</td>
</tr>
<tr>
<td>Social</td>
<td></td>
<td><strong>P</strong></td>
</tr>
<tr>
<td>Maternal age (y), mean (SD)</td>
<td>29.5 (5.5)</td>
<td>27.4 (6.0)</td>
</tr>
<tr>
<td>Lower maternal education, n (%)</td>
<td>48 (44)</td>
<td>16 (59)</td>
</tr>
<tr>
<td>Lower social class, n (%)</td>
<td>36/109 (33)</td>
<td>13 (48)</td>
</tr>
<tr>
<td>Multilingual family, n (%)</td>
<td>19 (17)</td>
<td>1 (4)</td>
</tr>
<tr>
<td>Academic performance</td>
<td></td>
<td><strong>P</strong></td>
</tr>
<tr>
<td>Special education at 8 y, n (%)</td>
<td>15/106 (12)</td>
<td>10/27 (37)</td>
</tr>
<tr>
<td>Reading at 18 y, mean (SD)</td>
<td>98.5 (13.3)</td>
<td>87.8 (13.2)</td>
</tr>
<tr>
<td>Spelling at 18 y, mean (SD)</td>
<td>101.4 (14.9)</td>
<td>89.3 (14.4)</td>
</tr>
<tr>
<td>Math computation at 18 y, mean (SD)</td>
<td>89.2 (13.8)</td>
<td>77.3 (9.9)</td>
</tr>
</tbody>
</table>

Age at assessment is corrected for prematurity. As vary because of missing data.

- a Major neonatal brain injury: grades 3 and 4 intraventricular hemorrhage and/or cystic periventricular leukomalacia.
- b Small for gestational age: birth weight ≥ 2 SD below the mean for gestational age and sex.
- c Lower maternal education: < 12 years of schooling.
- d Lower social class: major income earner in the family has an unskilled occupation or unemployed.
- e Multilingual family: speaks languages other than English at home.
- f WRAT4.
differences between children born EP and ELBW and children born at term in both the BRI and MCI, but the differences were stronger in the MCI domain for school-aged children. However, none of these previous studies examined developmental stability within individuals. Different responsiveness to environmental or biological risks might cause distinct behavioral courses and influence academic outcomes.

Executive problems are thought to be related to academic achievement and learning skills, and the current study provides additional evidence supporting this proposed relationship. In general, groups with executive difficulties at age 18 years tended to have poorer academic outcomes than those without concurrent executive difficulties. Our typical and remitting groups performed within 0.5 SD of the normative mean for the literacy measures but performed poorer on the math computation subtest. Mathematics is an area of particular vulnerability for preterm children. However, it is important to note that the reading and spelling subtests used in this study rely more on basic abilities of single-word recognition and coding, which are usually mature by late adolescence, whereas the math computation subtest includes complex arithmetic problems. The influence of core EFs, such as working memory, may decrease with time for reading but increase for mathematics. For the BRI, shifting categories between 8 and 18 years of age was of extreme relevance for academic performance at 18 years old. Individuals with remitting difficulties performed comparably with individuals in the typical group, but in contrast, the late-onset group exhibited lower scores in all domains. Interestingly, for the MCI, the groups that changed categories between 8 and 18 years old (ie, the remitting and late-onset groups) performed similarly on academic measures, intermediate between the typical and the persistent groups. As hypothesized, we observed that adolescents with remitting behavioral regulation difficulties performed better in all academic domains investigated when compared with adolescents with persistent behavioral problems. However, the same phenomenon was not as noticeable for the MCI, suggesting that early metacognitive difficulties may have a more lasting impact on later academic outcomes.

Importantly, for some children born EP, executive difficulties are transient. Understanding the factors associated with improved functioning over time may inform intervention and management strategies for children with early EF difficulties. However, we also observed that for other children born EP, EF difficulties do not

![Figure 3](https://doi.org/10.1542/peds.2017-0257)

**Figure 3**

Standardized mean differences (SD) and 95% confidence intervals among the developmental subgroups in academic domains. Adjusted results are from models excluding participants with an IQ \(\leq 70\) at 18 years old. A, includes lower social class for the BRI groups’ comparison. B, includes lower maternal education and multilingual family for the MCI groups’ comparison. *Significant at \(P \leq .05\); **Significant at \(P \leq .001\).
emerge until later in development, highlighting the need to monitor this population throughout childhood. Executive dysfunction is a common characteristic of several behavioral and emotional disorders,\textsuperscript{11,13} with the clinical expression of many of these disorders changing during adolescence,\textsuperscript{11} and the late-onset group may help us understand the role of emerging EF problems on the adolescent onset of developmental disturbances such as emotional disorders.

Among the perinatal and sociodemographic variables investigated in the current study, differences in social background including maternal education, social class, and being in a multilingual family were observed among the developmental groups. Social disparities have a known effect on cognitive development,\textsuperscript{34–46} and in the population born preterm, socioeconomic factors seem to have an increasing influence over time.\textsuperscript{25,67,68} We were unable to investigate this issue further in our sample because of a lack of statistical power. However, future studies are required to understand the factors influencing the variability of behavioral EF stability in children born preterm. The identification of individuals at risk, those who are particularly vulnerable to adversity, represents an opportunity to introduce targeted and timely interventions to ameliorate future outcomes.\textsuperscript{23} Interventions facilitating child physiologic regulation, improving parent–child attachment, parenting style, maternal mental health, as well as elementary school programs enhancing self-regulation and planning skills, and working memory training are associated with higher levels of EF in children born preterm, particularly with early identification.\textsuperscript{49} Nevertheless, variation in the effects of formal interventions is ubiquitous, and to acknowledge and understand factors related to individual differences in development is of utmost importance for determining for whom and how specific interventions will work.\textsuperscript{23}

This study was limited to participants born EP or ELBW. Although this is a group particularly at risk for developmental impairments, research extending the spectrum of gestational age and birth weight is necessary. Cognitive and behavioral outcomes are inversely associated with the degree of prematurity.\textsuperscript{50} Therefore, it is reasonable to expect different rates of developmental stability according to the degree of prematurity. For example, the rate of persistent emotional and behavioral problems may be higher for children born EP, whereas the rate of children with remitting problems may be higher among those born moderately preterm.\textsuperscript{10} In fact, little is known about individual changes of behavioral EF even for children with typical development. Cross-sectional studies have shown a decrease in reported EF problems with increasing age.\textsuperscript{51,52} A previous longitudinal study of our group showed a slight increase with age of BRI scores for children born preterm but not for term controls.\textsuperscript{1}

Another limitation of our study is that we only used parental reports of behavioral EF. However, the demand for EFs varies according to environmental contexts (eg, home and school).\textsuperscript{18,37} Also, cognitive (performance-based) and behavioral measures of EF are probably covering distinct aspects of EF.\textsuperscript{53} For example, the association of the BRIEF with performance-based measures is generally modest.\textsuperscript{54} Cognitive measures of EF may uniquely explain a higher proportion of children’s academic performance, but behavioral measures of EF are complementary.\textsuperscript{53,55} We did not consider cognitive, educational, and behavioral interventions that the participants may have received during childhood, which is a potential limitation because it has been proposed that EF can benefit from interventions targeting cognitive and behavioral enhancement.\textsuperscript{13} At any rate, we observed that children with persistent EF difficulties were more likely to receive additional academic support at 8 years old. Strengths of the study include a geographically selected sample born EP or ELBW, with no significant differences between participants and nonparticipants (eg, children lost to follow-up) with regard to perinatal and sociodemographic characteristics. Moreover, the follow-up period of ∼10 years is associated with remarkable changes in human development related to self-control.\textsuperscript{56}

There is an undeniable heterogeneity in individual responses to adversity,\textsuperscript{35} and outcomes after preterm birth are also characterized by interindividual variability. In this study, we have demonstrated 4 stability subgroups for EF in children born EP or ELBW, which were associated with different academic outcomes in adolescence. Studying the origins and consequences of the distinct stability groups of children born preterm may contribute to the development of efficient interventions to decrease the adverse neurodevelopmental outcomes of preterm birth.

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Children Who Were Extremely Preterm

Executive Function and Academic Outcomes in

Costa et al

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ABBREVIATIONS

BRI: Behavioral Regulation Index
BRIEF: Behavior Rating Inventory of Executive Function
EF: executive function
ELBW: extremely low birth weight
EP: extremely preterm
GEE: generalized estimating equations
MCI: Metacognition Index
WRAT4: Wide Range Achievement Test: Fourth Edition

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