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# Executive Function Outcomes at School Age in Children Born Moderate-to-Late Preterm

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**Objective** To compare executive function (EF) outcomes at school age between children born moderate-to-late preterm (MLP; 32–36 weeks' gestation) and term ( $\geq 37$  weeks' gestation) across subdomains of attentional control, cognitive flexibility, goal setting, and everyday executive behaviors.

**Study design** Two hundred one children born MLP and 201 born at term were recruited from the Royal Women's Hospital, Melbourne, Australia. Children completed EF measures at 9 years of corrected age. Group differences in mean or median outcome z-scores were estimated using linear or quantile regression. EF impairment risk ratios [RRs] between groups were estimated using generalized linear models. Analyses were adjusted for multiple birth and social risk.

**Results** One hundred fifty-nine children born MLP (79%) and 134 born at term (67%) were assessed. Compared with the term group, the MLP group performed poorer in goal setting (mean difference =  $-0.26$ , 95% CI =  $-0.50$ ,  $-0.03$ ,  $P = .03$ ) and cognitive flexibility (mean difference =  $-0.32$ , 95% CI =  $-0.59$ ,  $-0.05$ ,  $P = .02$ ). Children born MLP were at increased risk of behavioral executive dysfunction (RR = 1.86, 95% CI = 1.05, 3.27,  $P = .03$ ), impairments in cognitive flexibility (RR = 1.80, 95% CI = 1.05, 3.09,  $P = .03$ ), and goal setting (RR = 1.69, 95% CI = 1.08, 2.65,  $P = .02$ ).

**Conclusions** Children born MLP demonstrate a pattern of increased EF difficulties at school-age compared with term children, mostly within the goal setting subdomain. These difficulties are likely to affect other outcomes such as academic performance and social skills. (*J Pediatr* 2025;284:114634).

Research surrounding outcomes of preterm birth has historically focused on children born “extremely preterm” (<28 weeks of gestation) or “very preterm” (<32 weeks of gestation).<sup>1</sup> However, children born moderate-to-late preterm (MLP; 32-to-36 weeks of gestation) account for approximately 85% of preterm births and are increasingly reported to experience poorer neurodevelopmental outcomes compared with children born at term ( $\geq 37$  weeks' gestation).<sup>2–4</sup> Studies of individuals born MLP have typically focused on outcomes in infancy and preschool age.<sup>5,6</sup> More recently, poorer general cognitive ability at school-age has been reported in children born MLP compared with those born at term.<sup>6</sup> However, significant gaps in knowledge of performance on specific cognitive domains in this population remain. Such knowledge is necessary to determine the underlying neuropathologic mechanisms, and to structure surveillance and intervention programs.<sup>7</sup>

One cognitive domain of particular significance is executive function (EF), due to its importance to academic, vocational, social, emotional, and health outcomes.<sup>8–10</sup> Difficulties with EF are a feature of neurodevelopmental conditions such as attention-deficit disorder<sup>11</sup> and have been linked to worse childhood health behaviors, poorer mathematics performance and difficulties in social interactions.<sup>8–10,12</sup> EF encompasses a range of cognitive skills which support the execution of goal-directed behavior.<sup>13</sup> Although the exact parameters and organization of EF remain the subject of theoretical debate, several models offer useful frameworks for understanding these complex cognitive processes. Component-based models such as Miyake et al's<sup>14</sup> 3-part framework and Diamond's<sup>9</sup> hierarchical model identify core EF components such as working

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ADHD	Attention-deficit/hyperactivity disorder
ASD	Autism spectrum disorder
CNT	Contingency Naming Test
ECS	Executive Control System
EF	Executive function
MLP	Moderate-to-late preterm
RR	Risk ratio

memory, inhibition, and cognitive flexibility. However, Anderson's<sup>15</sup> model of EF, the Executive Control System (ECS) is established from a developmental lens. It provides a similar framework but is specifically designed for assessing EF in children. The ECS includes four subdomains: information processing (speed, efficiency and fluency of processing information), attentional control (ability to filter out distractors and focus on a specific task), cognitive flexibility (switching between tasks, shifting, and manipulating information in temporary storage), and goal setting (organization and planning, reasoning and problem solving).<sup>15</sup>

Our recent meta-analysis synthesizing the available data on EF outcomes in children born moderate-to-late preterm (MLP) found a paucity of high-quality studies.<sup>16</sup> Acknowledging marked methodologic variability in EF measurement and key cohort characteristics such as gestational age and social risk, we identified a small but clinically important difference in EF for children born MLP compared with children born at term.<sup>16</sup> Our meta-analysis concluded the need for further high-quality research.

The current study aimed to explore the impact of MLP birth on EF at 9 years of age. To conceptualize EF, we used the ECS framework, focusing on the attentional control, cognitive flexibility, and goal setting subdomains. We did not include the information processing subdomain as hierarchically we considered it a foundational cognitive domain facilitating EF efficiency rather than being a distinct EF subdomain.<sup>9</sup> EF behaviors in everyday settings were also assessed to take into account the broader ecological context.<sup>17</sup> We hypothesized that children born MLP would demonstrate poorer performance across all subdomains of EF compared with children born at term.

## Methods

The *LaPrem* study is a longitudinal cohort study of children born MLP ( $n = 201$ ) and at term ( $n = 201$ ; born  $\geq 37$  weeks' gestation, birthweight  $\geq 2500$  g), recruited in the neonatal period from the Royal Women's Hospital, Melbourne, Australia between December 2009 and November 2012. Children diagnosed with congenital abnormalities or genetic syndromes known to affect development were excluded. In addition, term children were ineligible if they were unwell at birth, received resuscitation, were admitted to the neonatal nursery, or were identified as having a condition affecting growth or development. This cohort has previously been assessed at 2 years of corrected age.<sup>18</sup>

Children were invited to attend a follow-up assessment at 9 years of corrected age, which included a neuropsychological assessment and parent questionnaires (for protocol see: Cheong et al, 2021<sup>19</sup>). Follow-up assessments were conducted between June 2019 and February 2024. Data collection was affected by state COVID-19 restrictions during 2020 and 2021, including the suspension of in-person research activities. Ethical approval was obtained from the Human Research Ethics Committees of the Royal Women's Hospital

(Project number: 09/38) and Royal Children's Hospital Melbourne (HREC 35187) for the original recruitment and 9-year follow up. Written informed consent was obtained from parents. This study followed the STROBE reporting guideline.

## Perinatal Factors and Social Risk

Perinatal characteristics were collected prospectively, via medical record review, including the collection of gestational age based on antenatal ultrasound. A social risk score was calculated using 6 variables captured at the 9-year follow-up including maternal age at birth of the child, employment status and occupation of the primary income earner, education of the primary caregiver, language spoken at home, and family structure.<sup>20</sup> These variables were scored as 0, 1, or 2, from lowest to highest risk and totaled to give an overall social risk score. The total score was dichotomized around the median as lower (total score  $< 2$ ) or higher (total score  $\geq 2$ ) social risk.<sup>21,22</sup>

## EF Measures

Neuropsychological assessments were administered by trained assessors, blind to group membership. The child's age was corrected for prematurity due to the systematic lowering of scores for preterm children if performance is based on chronological age.<sup>23</sup> The attentional control, cognitive flexibility, and goal setting subdomains were assessed using scales from the Wechsler Intelligence Scale for Children, Fifth Edition, Australia and New Zealand (WISC-5; Block Design, Matrix Reasoning and Digit Span Backwards subtests),<sup>24</sup> the Test of Everyday Attention for Children, Second Edition (TEA-Ch2; Hector Cancellation, the Troy Dual Task, and Reds, Blues, Bags and Shoes subtests),<sup>25</sup> the Contingency Naming Test (CNT),<sup>26,27</sup> and the Rey Complex Figure Test (RCFT).<sup>28,29</sup> EF behaviors were assessed using the Behavior Rating Inventory of Executive Function, Second Edition: Parent Report (BRIEF2; Behavior Regulation Index, Emotional Regulation Index, Cognitive Regulation Index and Global Executive Composite).<sup>30</sup>

Scores from cognitive measures were transformed into z-scores using the mean and SD of the term group to standardize the scale. Some cognitive scales were reverse-scored so that for all scales, higher z-scores indicated better performance (CNT trial 3 and 4: self-regulation score, and TEA-Ch2: reds, blues, bags and shoes). Subdomain composite scores were computed for attentional control, cognitive flexibility, and goal setting, with equal weighting applied to all measures within each composite score. Measures were selected to assess a range of skills within each subdomain.

Impairment on cognitive measures was classified as performing  $> 1$  SD below the mean of the term group. Impairment in EF behavior was classified as BRIEF2 T-scores  $\geq 65$ .<sup>30</sup> Parents disclosed a diagnosis of attention-deficit/hyperactivity disorder (ADHD), autism spectrum disorder (ASD), or other developmental disabilities such as cerebral palsy.

## Statistical Analysis

Data were analyzed using Stata 18 (StataCorp LLC).<sup>31</sup> Using descriptive statistics, participant characteristics were reported for the MLP and term children, as well as for those who did and did not undertake EF assessment at the 9-year follow-up.

Mean or median differences in EF performance at 9 years corrected age between MLP and term groups were estimated using linear regression (for symmetrically distributed outcomes) or quantile regression (for skewed outcomes). To investigate impairment in outcome measures, risk ratios and risk differences were estimated using generalized linear models with a binomial family (and log and identity link functions, respectively). Separate models were fitted for each EF measure and subdomain composite score (attentional control, cognitive flexibility and goal setting). Analyses were repeated excluding participants with a full-scale IQ < 80 (based on the WISC-5 Full Scale IQ composite score) to ensure findings were not driven by a small subgroup of low performing children.

Models were adjusted for multiple birth and social risk (see [Supplementary Figure 1](#); available at [www.jpeds.com](http://www.jpeds.com) for the directed acyclic graph which outlines the causal assumptions made). Generalized linear models (including linear regression models) were fitted using generalized estimating equations and robust standard errors to account for clustering of siblings from multiple births. Quantile regression models were fitted using cluster robust standard errors.

Multiple imputations by chained equations were used to account for missing data as the primary analysis. Multiple imputation was conducted separately for each outcome, with each imputation model including the outcome measure, as well as sex, birth group, birthweight, multiple birth, antenatal corticosteroid use, respiratory support at birth, social risk, and developmental delay at 2 years (cognitive, language or motor domain

scores of >1 SD below the mean of the children born at term on the Bayley-3, and/or cerebral palsy). Continuous outcomes were imputed using linear regression and binary outcomes were imputed using logistic regression. 40 imputed datasets were created, and Rubin rules were used to obtain estimates and standard errors.<sup>32</sup> [Supplementary Figure 1](#); available at [www.jpeds.com](http://www.jpeds.com) presents a missingness-directed acyclic graph that depicts our assumptions about the causes of missing data, including justification for using multiple imputations. Complete case analyses were performed for comparison. We did not adjust for multiple comparisons. We focused on the magnitude of effect sizes and overall patterns, rather than *P* value thresholds when interpreting our results.

## Results

Two hundred ninety-three participants attended the 9-year follow-up (159 MLP and 134 term children; [Figure 1](#)). Participant characteristics are outlined in [Table I](#). As expected, there were group differences in perinatal and neonatal characteristics. The MLP groups were more likely to be at higher social risk, to have repeated a school year, and had higher rates of ASD and ADHD compared with term controls. Demographic characteristics between those with and without EF data at the 9-year follow-up were largely comparable ([Supplementary Table 1](#); available at [www.jpeds.com](http://www.jpeds.com)), although MLP children assessed at 9 years were less likely to be male, of multiple birth, or have developmental delay at 2 years, compared with MLP children not assessed. Mothers of children assessed across both birth groups were 1.4–1.5 years older on average than mothers of children who were not assessed. In the term control group, the rate of assisted conception was higher for those who were assessed than those not assessed.

Moderate-late preterm		Term
Birth recruitment		
n = 201		n = 201
2-year follow up		
n = 198 (99%)		n = 183 (91%)
Overseas (n = 1) Not contactable (n = 2)		Overseas (n = 3) Not contactable (n = 14) Withdrew (n = 1)
9-year follow up: completion of neuropsychology assessment		
n = 159 (79%)		n = 134 (67%)
Not contactable (n = 7) Declined (n = 30) Withdrew (n = 5)		Overseas (n = 3) Not contactable (n = 9) Declined (n = 47) Withdrew (n = 5) Did not attend neuropsychology assessment (n = 3)

**Figure 1.** Participant recruitment and follow-up.

**Table I.** Demographic characteristics and outcome summaries presented by birth group (MLP or term). Statistics are number (%) unless stated otherwise

Variable	MLP group (n = 159)	Term group (n = 134)
<b>Perinatal characteristics</b>		
Maternal age (y), mean (SD)	34.3 (4.7)	33.7 (4.6)
Maternal pre-eclampsia	29 (18.2%)	2 (1.5%)
Assisted conception	31/156 (19.9%)	15 (11.2%)
Antenatal corticosteroid use	94 (59.1%)	4 (3.0%)
Antenatal magnesium sulfate	12 (7.6%)	0 (0.0%)
Multiple birth	55 (34.6%)	2 (1.5%)
Cesarean birth	110 (69.2%)	48 (35.8%)
<b>Neonatal characteristics</b>		
Male sex	72 (45.3%)	72 (53.7%)
Gestational age (wks), mean (SD)	34.3 (1.2)	39.8 (1.2)
Birthweight (g), mean (SD)	2155.9 (435.7)	3560.0 (454.1)
Birthweight z-score, mean (SD)	-0.3 (1.0)	0.2 (0.8)
Apgar score @ 5 minutes, median (IQR)	9 (8,9)	9 (9,9)
Any respiratory support	22 (13.8%)	0 (0.0%)
Brain injury*	0 (0)	0 (0)
Neonatal hospitalization (d), median (IQR)	19 (14,28)	2 (2,3)
Developmental delay at 2 y <sup>†</sup>	73 (45.9%)	36/128 (28.1%)
<b>9-y follow up</b>		
Corrected age at assessment (y), mean (SD)	9.7 (0.4)	9.8 (0.4)
Higher social risk	39 (24.5%)	23 (17.2%)
Autism spectrum disorder diagnosis	13/144 (9.0%)	8/129 (6.3%)
Attention-deficit/hyperactivity disorder or attention deficit disorder diagnosis	16/144 (11.1%)	7/129 (5.5%)
Repeated a school y	5/157 (3.2%)	0/132 (0%)
<b>Executive function outcome scores at 9 y</b>		
<b>Attentional control</b>		
CNT Trial 3 Self-regulation, median (IQR)	1 (0, 3)	1 (0, 3)
CNT Trial 4 Self-regulation, median (IQR)	3 (1, 6)	3 (1, 6)
TEA-Ch2 Hector Cancellation, mean (SD)	14.8 (2.4)	14.9 (2.5)
Attentional Control Composite Score (z-score)	-0.01 (0.73)	0.02 (0.63)
<b>Cognitive flexibility</b>		
WISC-5 Digit Span Backwards, mean (SD)	10.3 (2.9)	11.1 (2.5)
CNT Trial 3 Efficiency, mean (SD)	1.7 (0.5)	1.6 (0.6)
CNT Trial 4 Efficiency, mean (SD)	1.0 (0.5)	1.1 (0.4)
TEA-Ch2 Reds and Blues, Bags and Shoes, mean (SD)	1343.1 (375.0)	1386.0 (386.6)
TEA-Ch2 Troy Dual Task, mean (SD)	11.5 (2.6)	11.6 (2.7)
Cognitive Flexibility Composite Score (z-score)	-0.03 (0.62)	0.01 (0.63)
<b>Goal setting</b>		
WISC-5 Block Design, mean (SD)	9.7 (3.0)	11.1 (2.9)
WISC-5 Matrix Reasoning, mean (SD)	10.3 (2.5)	10.9 (2.6)
RCFT Accuracy, median (IQR)	24 (20, 28)	25.5 (21.5, 28.5)
RCFT Strategy, mean (SD)	4.1 (1.1)	4.2 (1.0)
Goal Setting Composite Score (z-score)	-0.27 (0.82)	0.00 (0.78)
<b>Behavioral executive function</b>		
BRIEF2 Parent Report, Behavior Regulation Index, median (IQR)	50 (44, 59)	48 (43, 55)
BRIEF2 Parent Report, Emotional Regulation Index, median (IQR)	52 (45, 63)	51 (45, 60)
BRIEF2 Parent Report, Cognitive Regulation Index, median (IQR)	50 (43, 58)	51 (43, 56)
BRIEF2 Parent Report, Global Executive Composite, median (IQR)	51 (45, 61)	50 (44, 58)

BRIEF2, Behavior Rating Inventory of Executive Function – Second Edition; CNT, Contingency Naming Test; IQR, interquartile range; MLP, moderate-to-late preterm; RCFT, Rey Complex Figure Test; SD, standard deviation; TEA-Ch2, Test of Everyday Attention for Children – Second Edition; WISC-5, Wechsler Intelligence Scale for Children – Fifth Edition.

\*Brain injury defined as any intraventricular hemorrhage or cystic periventricular leukomalacia diagnosed on cranial ultrasound, or brain magnetic resonance imaging.

†Developmental delay at 2 y defined as cognitive, language or motor domain scores of more than 1 SD below the mean of the children born at term on the Bayley-3, and/or cerebral palsy.

## EF Outcomes

Descriptive EF outcome summaries and measure descriptions by subgroup are outlined in **Tables I and II** respectively. Mean/median differences in EF outcome scores between the MLP and control groups, adjusted for social risk and multiple births, are presented in **Figure 2**.

Attentional control measures were similar between the 2 groups. For the cognitive flexibility subdomain, the MLP group performed less well on the working memory task (digit span backward; mean difference = -0.32, 95% CI = -0.59, -0.05,  $P = .02$ ) compared with term controls, but groups

performed similarly on the other tasks measuring shifting capacity. Performance was poorer for the MLP group for the goal setting composite (mean difference = -0.26, 95% CI = -0.50, -0.03,  $P = .03$ ), with the largest group difference observed on a measure of visual spatial reasoning and planning (Block Design; mean difference = -0.39, 95% CI = -0.68, -0.10,  $P = .01$ ). On average, parents of children born MLP reported more EF difficulties in everyday settings compared with parents of children born at term; however, precision of estimates was low. Exclusion of participants with Full Scale IQ < 80 did not alter conclusions.

**Table II. Measure characteristics**

Executive function subdomain	Measure and subtest	Measure description	Utilized score	Associated skill
Attentional control	Contingency Naming Test (CNT): Trial 3 (Shape Matching) <sup>26,27</sup>	Participants were presented with a sequence of 27 colored shapes which also included a smaller internal shape. They had to follow the rule of saying each figure's color if the inside and outside shape of the item matched or naming the outside shape, if the inside and outside shape did not match. The self-regulation score accounts for self-corrections and errors, with greater weighing on the number of errors made. A higher score represents poorer self-regulation.	Self-regulation score = (2xerrors) + self-corrections	Self-regulation and self-monitoring
	Contingency Naming Test (CNT): Trial 4 (Arrow Switching) <sup>26,27</sup>	Participants were presented with a sequence of 27 colored shapes. They had to follow the rule from Trial 3; however, if there was a backwards arrow above the item, the rule switched (eg, they named the shape instead of the color, or the color instead of the shape). The self-regulation score accounts for self-corrections and errors, with greater weighing on the number of errors made. A higher score represents poorer self-regulation.	Self-regulation score = (2xerrors) + self-corrections	Self-regulation and self-monitoring
	Test of Everyday Attention for Children, 2nd Edition (TEA-Ch2): Hector Cancellation <sup>25</sup>	Participants were instructed to complete a visual search task where they had to identify targets amongst an array of distractor items (in addition to 2 pages containing only target stimuli). Participants completed 6 trials and received a total score for the number of items identified, with higher scores indicating better performance.	Raw score	Selective attention
Cognitive flexibility	Wechsler Intelligence Scale for Children, 5th Edition (WISC-5): Digit Span Backwards <sup>24</sup>	Participants were required to recall a sequence of digits in reverse order. The sequence of digits increased in length from 2 to 8 digits. Raw scores were converted to age-standardized scaled scores with a mean of 10 and SD of 3.	Scaled score	Working memory
	Contingency Naming Test (CNT): Trial 3 (Shape Matching) <sup>26,27</sup>	Participants were presented with a sequence of 27 colored shapes which also included a smaller internal shape. They had to follow the rule of saying each figure's color if the inside and outside shape of the item matched or naming the outside shape, if the inside and outside shape did not match. The efficiency score accounts for time and errors, rewarding speed and accuracy. Higher scores represent efficient performance.	Efficiency score = $[(1/\text{time}) / \sqrt{(\text{errors}+1)}] \times 100$	Shifting
	Contingency Naming Test (CNT): Trial 4 (Arrow Switching) <sup>26,27</sup>	Participants were presented with a sequence of 27 colored shapes. They had to follow the rule from Trial 3; however, if there was a backward arrow above the item, the rule switched (eg, they named the shape instead of the color, or the color instead of the shape). The efficiency score accounts for time and errors, rewarding speed and accuracy. Higher scores represent efficient performance.	Efficiency score = $[(1/\text{time}) / \sqrt{(\text{errors}+1)}] \times 100$	Shifting
	Test of Everyday Attention for Children, 2nd Edition (TEA-Ch2): Reds and Blues, Bags and Shoes <sup>25</sup>	Participants were instructed to sort 4 items by color (red vs blue) or by category (bag vs shoe). Trial 1 involved sorting by category and trial 2 involved sorting by color. The final 2 trials involved switching between the 2 rules after every 5 trials. Scoring is based on reaction time and accuracy, where higher raw scores indicate poorer performance.	Raw score	Shifting
	Test of Everyday Attention for Children, 2nd Edition (TEA-Ch2): Troy Dual Task <sup>25</sup>	Participants were required to simultaneously complete 2 tasks: 1) auditory - instructed to listen and count target sounds; 2) visual search - identify target stimuli and ignore non-target distractors. Participants completed 4 trials and received a total score for the number of items identified, with higher scores indicating better performance.	Raw score	Divided attention

*(continued)*

Table II. Continued

Executive function subdomain	Measure and subtest	Measure description	Utilized score	Associated skill
Goal setting	Wechsler Intelligence Scale for Children, 5th Edition (WISC-5): Block Design <sup>24</sup>	Participants were provided with identical blocks with surfaces of red, white and half red, half white. They were instructed to recreate a pattern presented as a 2-dimensional picture, using these blocks. The number of blocks required to recreate the pattern and the complexity of the pattern increased across trials. Each item had a time limit. Raw scores were converted to age-standardized scaled scores with a mean of 10 and SD of 3.	Scaled score	Visual spatial reasoning and problem solving
	Wechsler Intelligence Scale for Children, 5th Edition (WISC-5): Matrix Reasoning <sup>24</sup>	Participants were presented with a series of incomplete matrices involving abstract patterns and asked to select which item from an array of options would best complete the matrix. The matrices increased in complexity across trials. Raw scores were converted to age-standardized scaled scores with a mean of 10 and SD of 3.	Scaled score	Visual spatial reasoning
	Rey Complex Figure Test (RCFT) <sup>28,29</sup>	Participants were instructed to accurately copy a complex figure made up of a large rectangle, 2 centerlines, 2 diagonals and a range of external and internal components. The accuracy score is based on 18 criteria (scored from 0 to 2) with a maximum score of 36. The organizational strategy score rates the drawing according to the level of the organizational strategy used, on a 7-point scale. Higher scores indicate a better organizational strategy used.	Accuracy score Organizational Strategy score	Organization and planning Organization and planning
Behavioral executive function	Behavior Rating Inventory of Executive Function, Second Edition (BRIEF2): Parent Report <sup>30</sup>	Parents or caregivers were asked to respond to 63 statements that described their child's behavior and indicate whether their child had experienced problems with this behavior in the past 6 months. Items were scored as 'never = 1', 'sometimes = 2' and 'often = 3'. Total scores were converted to T-scores where higher scores indicate higher parent-reported difficulties. T-scores ≥65 are in the "potentially clinically elevated" range and ≥70 falls within the 'clinically elevated' range. The BRI includes scores from the Inhibit and Self-Monitor scales. The ERI includes scores from the Shift and Emotional Control scales. The CRI includes scores from the Initiate, Working Memory, Plan/Organize, Task-Monitor, and Organization of Materials scales. The GEC includes the sum of the raw scores from the BRI, ERI and CRI.	Behavior Regulation Index (BRI) T-score Emotional Regulation Index (ERI) T-score Cognitive Regulation Index (CRI) T-score Global Executive Composite (GEC) T-score	Behavioral regulation Emotional regulation Cognitive regulation Global behavioral executive function

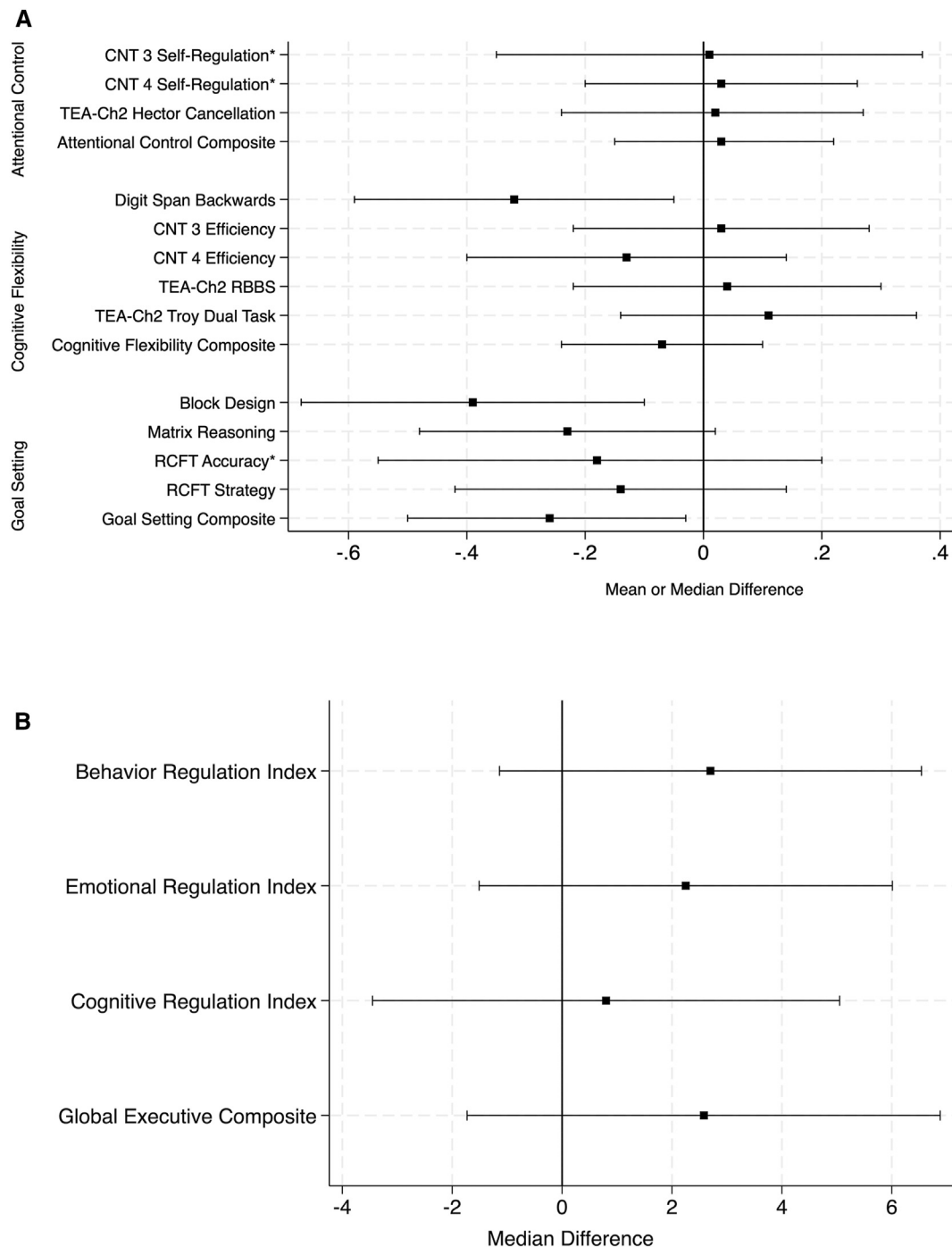
RRs and risk differences of impairment in EF outcomes between the MLP and control group, adjusted for social risk and multiple birth, are presented in **Table III**. The MLP group had a higher risk of impairment in working memory (Digit Span Backward) compared with controls. The risk of demonstrating impairment on a visual-spatial reasoning and planning task (Block Design subtest) was 15 percentage points higher in the MLP group compared with the control group (95% CI = 1.7, 28.2, *P* = .03). Children born MLP had a risk of scoring over the impairment cut-off on the GEC of the BRIEF2 that was 11 percentage points higher than controls (95% CI = 1.0, 20.9, *P* = .03). The risk of impairment for children born MLP was similar to the risk for children born at term for attentional control and cognitive flexibility tasks assessing switching capacity. Estimates from the complete case analyses were similar to the multiple imputation estimates.

## Discussion

Our prospective cohort study revealed a specific pattern of EF challenges for MLP children compared with their term

peers; namely poorer visual-spatial reasoning and problem-solving (goal setting subdomain) and working memory (cognitive flexibility subdomain). These findings largely mirror the pattern of group differences reported in our recent meta-analysis,<sup>16</sup> which found children born MLP to perform poorer in the goal setting and cognitive flexibility subdomains, with the latter largely driven by poorer working memory. Children born MLP were more likely to have elevated levels of parent-reported difficulties in executive behaviors in everyday settings, mostly related to challenges in cognitive regulation. For example, parents of MLP children were more likely to report that their child experienced difficulties with initiating, planning, monitoring and organizing tasks compared with parents of term children, similar to a previous study of everyday EF behaviors in children born MLP.<sup>33</sup> Of interest, this pattern of cognitive flexibility and goal setting vulnerabilities in MLP children mirrors the EF challenges observed in their more immature, very-preterm counterparts.<sup>34,35</sup>

The lack of group differences in the attentional control subdomain may reflect that the measures selected were not sufficiently complex to detect subtle deficits in the MLP group. Given that we assessed children only at one timepoint,



**Figure 2.** Mean or median differences in executive function outcome z-scores at 9 y between children born moderate-to-late preterm and term-born controls for **A**, the subdomains of attentional control, cognitive flexibility and goal setting and **B**, behavioral executive function. **A**, Scores less than 0 indicate poorer average performance in the moderate-to-late preterm participants than the term participants. All estimates are obtained using multiple imputations and adjusted for multiple birth and social risk.\*Median difference reported. CNT, Contingency Naming Test; RCFT, Rey Complex Figure Test; TEA-Ch2, Test of Everyday Attention for Children – Second Edition. **B**, Scores are presented as median difference in T-scores between groups. Points to the right of the line (positive) indicate more parent-reported difficulties for moderate-to-late preterm children comparative with term. All estimates are obtained using multiple imputations and adjusted for multiple birth and social risk.

it is possible that this cohort of children born MLP may have experienced early delays in attentional control and have either caught up to their peers or have developed

compensatory strategies.<sup>36,37</sup> It is also possible that the subtle deficits we identified in goal setting and working memory in the MLP group may reflect development delay and will

diminish with increasing age. Higher rates of ASD and ADHD in the MLP, compared with term-born children, as well as increased risk of behavioral difficulties in the broader 9-year follow-up study have also been reported.<sup>38</sup> These findings, in combination with elevated risk of behavioral EF difficulties on the BRIEF2 in the current study, suggest that direct neuropsychological assessment is less sensitive to the impacts being observed in daily life for MLP children. Whether subtle EF challenges underlie these broader functional difficulties should be explored, as well as whether EF difficulties are restricted to a select subgroup of children born MLP with a particular profile of risk factors.

Group differences within the magnitude of 0.2 to 0.4 SD and increased risk of impairment within the range of 10-15 percentage points were observed across some measures, reflecting small but clinically meaningful deficits. The magnitude of these findings may not translate to obvious functional impairments but rather reflect sub-clinical challenges in specific areas of EF. Though these EF challenges may be subtle, due to the substantial numbers of children born MLP each year, even minor increases in risk of impairment can have substantial effects on health and educational resources at a population level.<sup>39</sup>

In general, the mean group difference estimates had wide confidence intervals, likely reflecting significant variability in EF performance within the MLP sample. Future research with larger samples is needed to achieve more precise

estimates of differences in EF between MLP and term groups. We acknowledge the importance of not over-pathologizing the relatively small effects in this low-risk population. The vast majority of MLP children were performing within age-appropriate levels on our measures (Table I). However, there was a consistent pattern of subtle differences across multiple domains, coupled with increasing parent-reported concerns and higher prevalence of diagnosed conditions, indicating a small but meaningful shift in population-level risk that warrants attention from clinicians and educators.

Alterations in brain structure and maturation in children born MLP at birth may assist in explaining the EF difficulties. Microstructural abnormalities in major white matter tracts, which are critical for executive skills, have been reported in children born MLP at term-equivalent age.<sup>40</sup> Alterations in cerebral structure and connectivity have also been reported in infants born MLP, which may negatively affect EF outcomes.<sup>41-43</sup>

The recruitment of MLP children and controls from the same birth hospital is a strength of the study. The comprehensive assessment of EF allowed us to thoroughly explore the profile of performance across specific subdomains. We controlled for confounders such as social risk and multiple birth in our analyses, and our findings were largely unaffected when we excluded participants with Full Scale IQ < 80. The combination of performance-based measures and parent-reported behaviors in everyday settings provided a more

**Table III. Impairment in executive function outcomes at 9 years, contrasted between children born moderate-to-late preterm and term-born controls. Statistics are number (%) unless stated otherwise**

Outcome	MLP Fraction (%)	Term Fraction (%)	Adjusted RR (95% CI), P value	Adjusted RD % (95% CI), P value
<b>Attentional control</b>				
CNT Trial 3 Self-regulation	21/154 (13.6%)	20/126 (15.9%)	0.81 (0.42, 1.55), .52	-2.3 (-11.5, 6.3), .56
CNT Trial 4 Self-regulation	24/151 (15.9%)	15/123 (12.2%)	1.12 (0.58, 2.15), .74	1.0 (-7.9, 9.9), .82
TEA-Ch2 Hector Cancellation	27/148 (18.4%)	23/120 (19.2%)	1.05 (0.62, 1.79), .84	0.7 (-9.3, 10.7), .89
Attentional Control Composite Score	14/144 (9.7%)	8/117 (6.8%)	1.17 (0.47, 2.87), .74	0.9 (-6.1, 7.9), .80
<b>Cognitive flexibility</b>				
WISC-5 Digit Span Backwards	34/153 (22.2%)	17/126 (13.5%)	<b>1.80 (1.05, 3.09), .03</b>	<b>11.4 (0.7, 22.0), .04*</b>
CNT trial 3 efficiency	21/154 (13.6%)	22/126 (17.5%)	0.77 (0.40, 1.50), .45	-3.6 (-13.3, 6.1), .47
CNT trial 4 efficiency	37/123 (24.5%)	18/151 (14.6%)	1.55 (0.92, 2.61), .10	8.0 (-1.7, 17.8), .11
TEA-Ch2 reds and blues, bags and shoes	13/147 (8.8%)	16/120 (13.3%)	0.90 (0.44, 1.85), .78	-1.2 (-9.7, 7.4), .79
TEA-Ch2 Troy Dual Task	21/147 (14.3%)	22/120 (18.3%)	0.69 (0.37, 1.30), .25	-6.0 (-15.5, 3.5), .21
Cognitive flexibility composite score	7/139 (5.0%)	6/115 (5.2%)	0.58 (0.15, 2.22), .43	-2.8 (-8.0, 3.4), .43*
<b>Goal setting</b>				
WISC-5 Block Design	44/118 (37.3%)	24/117 (20.5%)	<b>1.69 (1.08, 2.65), .002</b>	<b>14.9 (1.7, 28.2), .03</b>
WISC-5 Matrix Reasoning	39/157 (24.9%)	21/129 (16.3%)	1.51 (0.93, 2.46), .10	8.5 (-1.6, 18.5), 0.10
RCFT Accuracy	31/149 (20.8%)	18/121 (14.9%)	1.30 (0.71, 2.38), .39	5.0 (-5.2, 15.1), 0.34
RCFT Strategy	48/149 (32.2%)	30/121 (24.8%)	1.31 (0.86, 2.01), .21	7.8 (-3.8, 19.3), 0.19
Goal Setting Composite Score	23/118 (19.5%)	17/117 (14.5%)	1.47 (0.78, 2.76), .23	7.3 (-3.9, 18.5), .20
<b>Behavioral executive function</b>				
BRIEF2 Parent Report, Behavior Regulation Index	24/155 (15.5%)	16/131 (12.2%)	1.50 (0.84, 2.66), .17	6.4 (-2.5, 15.2), .16*
BRIEF2 Parent Report, Emotional Regulation Index	35/155 (22.6%)	25/131 (19.1%)	1.43 (0.89, 2.29), .14	7.8 (-2.5, 18.1), .14*
BRIEF2 Parent Report, cognitive regulation Index	24/155 (15.5%)	11/131 (8.4%)	<b>2.10 (1.04, 4.24), .04</b>	<b>10.1 (1.1, 19.1), .03*</b>
BRIEF2 Parent Report, Global Executive Composite	28/155 (18.1%)	17/131 (13.0%)	<b>1.86 (1.05, 3.27), .03</b>	<b>10.9 (1.0, 20.9), .03*</b>

BRIEF2, Behavior Rating Inventory of Executive Function – Second Edition; CNT, Contingency Naming Test; MLP, moderate-to-late preterm; RCFT, Rey Complex Figure Test; RR, risk ratio; RD, risk difference; TEA-Ch2, Test of Everyday Attention for Children – Second Edition; WISC-5, Wechsler Intelligence Scale for Children – Fifth Edition.

Generalized linear models were adjusted for social risk and multiple birth as informed by the Directed Acyclic Graph. RR and RD estimates are obtained using multiple imputations.

Bold values indicate P < .05.

\*Risk differences were estimated using generalized linear models with a Gaussian family.

complete evaluation. Research demonstrates that these 2 approaches are only modestly associated, with both providing unique and valuable information on functioning.<sup>44</sup>

Participants for this study were recruited from a single tertiary maternity hospital, which is a specialized facility equipped for high-risk pregnancies. Accordingly, this cohort of MLP infants may not be totally representative of the broader MLP population, which could limit generalizability of our findings. In addition, our follow-up rate was lower than anticipated, partly due to COVID-19 restrictions; however, any selection bias due to attrition was addressed by a missingness directed acyclic graph and multiple imputation. Further, there is some evidence to suggest that children born between 37 and 38 weeks' gestation may have increased risk for poorer neurodevelopmental outcomes compared with those born  $\geq 39$  weeks,<sup>45</sup> which may have narrowed the difference observed between groups.

In this study, school-aged children born MLP demonstrated subtle EF difficulties in the areas of goal setting and working memory compared with children born at term, consistent with their parents reporting more EF challenges in everyday settings. Although the magnitude of these difficulties was small, these differences may pose significant social and economic burdens at the population level due to the large percentage of children born MLP. Improved knowledge of the long-term outcomes of MLP birth is vital to informing the care, monitoring and support provided to these children, as well as improved obstetric decision-making practices.<sup>46</sup> Although clinical follow-up may not always be warranted or feasible for this population, greater levels of psychoeducation or screening facilitated with parents and educators could serve to better support these children as they develop.<sup>47</sup> Future research should focus on identifying specific neonatal risk factors which contribute to poorer EF, given the heterogeneity of outcomes in the MLP population. Distinguishing higher-risk subgroups would be valuable for increasing targeted support. Those who work in general pediatrics and neuropsychology should ensure consideration of gestational age at birth, as it may not be until school-age that EF difficulties become apparent. ■

### CRedit authorship contribution statement

**Lauren Rossetti:** Writing – review & editing, Writing – original draft, Investigation, Formal analysis, Data curation, Conceptualization. **Leona Pascoe:** Writing – review & editing, Supervision, Conceptualization. **Rheanna M. Mainzer:** Writing – review & editing, Supervision, Data curation. **Rachel Ellis:** Writing – review & editing, Investigation. **Joy E. Olsen:** Writing – review & editing, Data curation. **Alicia J. Spittle:** Writing – review & editing, Funding acquisition, Conceptualization. **Lex W. Doyle:** Writing – review & editing. **Jeanie L.Y. Cheong:** Writing – review & editing, Supervision, Resources, Methodology, Investigation, Funding acquisition, Data curation, Conceptualization. **Peter J. Anderson:** Writing – review & editing, Supervision, Funding acquisition, Conceptualization.

### Declaration of Competing Interest

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### References

- Kallioinen M, Eadon H, Murphy MS, Baird G, Guideline Committee. Developmental follow-up of children and young people born preterm: summary of NICE guidance. *BMJ* 2017;10;j3514. <https://doi.org/10.1136/bmj.j3514>
- Ohuma EO, Moller AB, Bradley E, Chakwera S, Hussain-Alkhateeb L, Lewin A, et al. National, regional, and global estimates of preterm birth in 2020, with trends from 2010: a systematic analysis. *The Lancet* 2023;402:1261-71. [https://doi.org/10.1016/S0140-6736\(23\)00878-4](https://doi.org/10.1016/S0140-6736(23)00878-4)
- Blencowe H, Cousens S, Oestergaard MZ, Chou D, Moller AB, Narwal R, et al. National, regional, and worldwide estimates of preterm birth rates in the year 2010 with time trends since 1990 for selected countries: a systematic analysis and implications. *The Lancet* 2012;379:2162-72. [https://doi.org/10.1016/S0140-6736\(12\)60820-4](https://doi.org/10.1016/S0140-6736(12)60820-4)
- Woythaler M. Neurodevelopmental outcomes of the late preterm infant. *Semin Fetal Neonatal Med* 2019;24:54-9. <https://doi.org/10.1016/j.siny.2018.10.002>
- Martínez-Nadal S, Bosch L. Cognitive and Learning outcomes in late preterm infants at school age: a systematic review. *IJERPH* 2020;18:74. <https://doi.org/10.3390/ijerph18010074>
- Chan E, Leong P, Malouf R, Quigley MA. Long-term cognitive and school outcomes of late-preterm and early-term births: a systematic review. *Child Care Health Development* 2016;42:297-312. <https://doi.org/10.1111/cch.12320>
- Anderson PJ. Neuropsychological outcomes of children born very preterm. *Semin Fetal Neonatal Med* 2014;19:90-6. <https://doi.org/10.1016/j.siny.2013.11.012>
- Aarnoudse-Moens CSH, Weisglas-Kuperus N, Duivenvoorden HJ, van Goudoever JB, Oosterlaan J. Executive function and IQ Predict mathematical and attention problems in very preterm children. *PLoS One* 2013;8:e55994. <https://doi.org/10.1371/journal.pone.0055994>
- Diamond A. Executive functions. *Annu Rev Psychol* 2013;64:135-68. <https://doi.org/10.1146/annurev-psych-113011-143750>
- Riggs N, Chou CP, Spruijt-Metz D, Pentz MA. Executive cognitive function as a correlate and predictor of child food intake and physical activity. *Child Neuropsychol* 2010;16:279-92. <https://doi.org/10.1080/09297041003601488>
- Diamond A. Attention-deficit disorder (attention-deficit/hyperactivity disorder without hyperactivity): a neurobiologically and behaviorally distinct disorder from attention-deficit/hyperactivity disorder (with hyperactivity). *Dev Psychopathol* 2005;17:807-25. <https://doi.org/10.1017/S0954579405050388>
- Riggs NR, Jahromi LB, Razza RP, Dillworth-Bart JE, Mueller U. Executive function and the promotion of social-emotional competence. *J Appl*

- Developmental Psychol 2006;27:300-9. <https://doi.org/10.1016/j.app-dev.2006.04.002>
13. Lezak MD, Howieson DB, Bigler ED, Trane D. *Neuropsychological assessment*. 5th ed. Oxford, NY: Oxford University Press; 2012.
  14. Miyake A, Friedman NP, Emerson MJ, Witzki AH, Howerter A, Wager TD. The unity and diversity of executive functions and their contributions to complex “Frontal Lobe” tasks: a latent variable analysis. *Cogn Psychol* 2000;41:49-100. <https://doi.org/10.1006/cogp.1999.0734>
  15. Anderson PJ. Assessment and development of executive function (EF) during childhood. *Child Neuropsychol* 2002;8:71-82. <https://doi.org/10.1076/chin.8.2.71.8724>
  16. Rossetti L, Pascoe L, Piazza C, Mills T, Stedall P, Cheong JLY, et al. Executive function in children born moderate-to-late preterm: a meta-analysis. *Pediatrics* 2024;154:e2024067382. <https://doi.org/10.1542/peds.2024-067382>
  17. Doebel S, Müller U. The Future of research on executive function and its development: an introduction to the special issue. *J Cogn Development* 2023;24:161-71. <https://doi.org/10.1080/15248372.2023.2188946>
  18. Cheong J, Doyle LW, Burnett AC, Lee KJ, Walsh JM, Potter CR, et al. Association between moderate and late preterm birth and neurodevelopment and social-emotional development at age 2 Years. *JAMA Pediatr* 2017;171:e164805. <https://doi.org/10.1001/jamapediatrics.2016.4805>
  19. Cheong J, Cameron KLI, Thompson D, Anderson PJ, Ranganathan S, Clark R, et al. Impact of moderate and late preterm birth on neurodevelopment, brain development and respiratory health at school age: protocol for a longitudinal cohort study (LaPrem study). *BMJ Open* 2021;11:e044491. <https://doi.org/10.1136/bmjopen-2020-044491>
  20. Roberts G, Howard K, Spittle AJ, Brown NC, Anderson PJ, Doyle LW. Rates of early intervention services in very preterm children with developmental disabilities at age 2 years. *J Paediatrics Child Health* 2008;44:276-80. <https://doi.org/10.1111/j.1440-1754.2007.01251.x>
  21. Spittle AJ, Treyvaud K, Lee KJ, Anderson PJ, Doyle LW. The role of social risk in an early preventative care programme for infants born very preterm: a randomized controlled trial. *Dev Med Child Neurol* 2018;60:54-62. <https://doi.org/10.1111/dmcn.13594>
  22. Pace CC, Spittle AJ, Molesworth CML, Lee KJ, Northam EA, Cheong JLY, et al. Evolution of depression and anxiety symptoms in parents of very preterm infants during the newborn period. *JAMA Pediatr* 2016;170:863-70. <https://doi.org/10.1001/jamapediatrics.2016.0810>
  23. Wilson-Ching M, Pascoe L, Doyle LW, Anderson PJ. Effects of correcting for prematurity on cognitive test scores in childhood. *J Paediatr Child Health* 2014;50:182-8. <https://doi.org/10.1111/jpc.12475>
  24. Wechsler D. *Wechsler Intelligence scale for children, Australian and New Zealand Standardised edition (WISC-V A&NZ)*. Fifth Edition. Clinical Australia & New Zealand: Pearson; 2016. Accessed October 31, 2021. <https://www.pearsonclinical.com.au/products/view/579>
  25. Manly T, Anderson V, Crawford J, George M, Robertson IH. *Test of everyday attention for children*. 2nd Edition. Clinical Australia & New Zealand: Pearson; 2016 (TEA-Ch2). Accessed October 31, 2021. <https://www.pearsonclinical.com.au/products/view/593>
  26. Taylor HG, Albo VC, Phebus CK, Sachs BR, Bierl PG. Postirradiation treatment outcomes for children with acute lymphocytic leukemia: clarification of risks. *J Pediatr Psychol* 1987;12:395-411. <https://doi.org/10.1093/jpepsy/12.3.395>
  27. Anderson P, Anderson V, Northam E, Taylor HG. Standardization of the contingency naming test (CNT) for school-aged children: a measure of Reactive flexibility. *Clin Neuropsychological Assess* 2000;247-273.
  28. Rey A. L'examen psychologique dans les cas d'encéphalopathie traumatique. (Les problems.). [The psychological examination in cases of traumatic encephalopathy. Problems.]. *Arch de Psychol* 1941;28:215-85.
  29. Osterrieth PA. Le test de copie d'une figure complexe; contribution à l'étude de la perception et de la mémoire. [Test of copying a complex figure; contribution to the study of perception and memory.]. *Arch de Psychol* 1944;30:206-356.
  30. Gioia GA, Isquith PK, Guy SC, Kenworthy L. *BRIEF: behavior rating Inventory of executive function*. Lutz, FL: Psychological Assessment Resources; 2015.
  31. StataCorp. *Stata Statistical Software: Release 18*. College Station, TX: StataCorp LLC; 2023.
  32. Rubin DB. *Multiple imputation for nonresponse in surveys*. 1st ed. New York: Wiley; 1987. <https://doi.org/10.1002/9780470316696>
  33. Cserjesi R, Van Braeckel KNJA, Butcher PR, Kerstjens JM, Reijneveld SA, Bouma A, et al. Functioning of 7-year-Old children born at 32 to 35 Weeks' gestational age. *Pediatrics* 2012;130:e838-46. <https://doi.org/10.1542/peds.2011-2079>
  34. Pascoe L, Burnett AC, Anderson PJ. Cognitive and academic outcomes of children born extremely preterm. *Semin Perinatol* 2021;45:151480. <https://doi.org/10.1016/j.semperi.2021.151480>
  35. Haebich KM, Willmott C, Ellis R, Burnett AC, Scratch SE, Pascoe L, et al. Goal setting deficits at 13 Years in very preterm born children. *J Int Neuropsychol Soc* 2018;24:372-81. <https://doi.org/10.1017/S1355617717001138>
  36. Reijneveld SA, Hornman J, Boelema SR, de Winter AF. Stability of executive functioning of moderately-late preterm and full-term born children at ages 11 and 19: the trails cohort study. *Int J Environ Res Public Health* 2021;18:4161. <https://doi.org/10.3390/ijerph18084161>
  37. Ment LR, Constable RT. Injury and recovery in the developing brain: evidence from functional MRI studies of prematurely born children. *Nat Clin Pract Neurol* 2007;3:558-71. <https://doi.org/10.1038/ncpneuro0616>
  38. Cheong JLY, Mainzer RM, Doyle LW, Olsen JE, Ellis R, FitzGerald TL, et al. Neurodevelopment at age 9 Years Among children born at 32 to 36 Weeks' gestation. *JAMA Netw Open* 2024;7:e2445629. <https://doi.org/10.1001/jamanetworkopen.2024.45629>
  39. Chawanpaiboon S, Vogel JP, Moller AB, Lumbiganon P, Petzold M, Hogan D, et al. Global, regional, and national estimates of levels of preterm birth in 2014: a systematic review and modelling analysis. *The Lancet Global Health* 2019;7:e37-46. [https://doi.org/10.1016/S2214-109X\(18\)30451-0](https://doi.org/10.1016/S2214-109X(18)30451-0)
  40. Kelly CE, Cheong JLY, Gabra Fam L, et al. Moderate and late preterm infants exhibit widespread brain white matter microstructure alterations at term-equivalent age relative to term-born controls. *Brain Imaging Behavior* 2016;10:41-9. <https://doi.org/10.1007/s11682-015-9361-0>
  41. Kelly CE, Thompson DK, Spittle AJ, Chen J, Seal ML, Anderson PJ, et al. Regional brain volumes, microstructure and neurodevelopment in moderate-late preterm children. *Arch Dis Child Fetal Neonatal Ed* 2020;105:593-9. <https://doi.org/10.1136/archdischild-2019-317941>
  42. Walsh JM, Doyle LW, Anderson PJ, Lee KJ, Cheong JLY. Moderate and late preterm birth: effect on brain size and maturation at term-equivalent age. *Radiology* 2014;273:232-40. <https://doi.org/10.1148/radiol.14132410>
  43. Cheong J, Thompson DK, Spittle AJ, Potter CR, Walsh JM, Burnett AC, et al. Brain volumes at term-equivalent age are associated with 2-year neurodevelopment in moderate and late preterm children. *The J Pediatr* 2016;174:91-7.e1. <https://doi.org/10.1016/j.jpeds.2016.04.002>
  44. Mcauley T, Chen S, Goos L, Schachar R, Crosbie J. Is the behavior rating inventory of executive function more strongly associated with measures of impairment or executive function? *J Int Neuropsychological Soc* 2010;16:495-505. <https://doi.org/10.1017/S1355617710000093>
  45. Nielsen TM, Pedersen MV, Milidou I, Glavind J, Henriksen TB. Long-term cognition and behavior in children born at early term gestation: a systematic review. *Acta Obstet Gynecol Scand* 2019;98:1227-34. <https://doi.org/10.1111/aogs.13644>
  46. Baron IS, Weiss BA, Baker R, Khoury A, Remsburg I, Thermolice JW, et al. Subtle adverse effects of late preterm birth: a cautionary note. *Neuropsychology* 2014;28:11-8. <https://doi.org/10.1037/neu0000018>
  47. Pettinger KJ, Copper C, Boyle E, Blower S, Hewitt C, Fraser L. Risk of developmental disorders in children born at 32 to 38 Weeks' gestation: a meta-analysis. *Pediatrics* 2023;152:e2023061878. <https://doi.org/10.1542/peds.2023-061878>