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Declaration of Interest

None

Abstract

Background: Children born very preterm are at higher risk of adverse neurocognitive and educational outcomes. However, how low intelligence (IQ) and low executive function may each contribute to poorer academic outcomes at school age requires clarification.

Aim: To examine the associations between intelligence, executive function and academic achievement in children born very preterm.

Design/ methods: This cohort study assessed children born <30 weeks' gestation or <1500g at age 7 years using the Wechsler Intelligence Scale for Children, Fourth Edition (WISC-IV) for IQ, the Test of Everyday Attention for Children (TEA-Ch) and Behavior Rating Inventory of Executive Function (BRIEF) for executive function. Academic achievement was rated by teachers against curriculum standards.

Results: Of the 76 children (35 girls, 41 boys; mean age=7.2 year), 22 (28%) were rated below expected level for reading, 32 (42%) for writing and 38 (50%) for mathematics. After adjustment for sex and socioeconomic status, low IQ (OR's 9.0-12.3) and most low executive function measures (OR's 4.1-9.3) were associated with below-expected achievement. After further adjustment for IQ, low cognitive flexibility (OR=9.3, 95% CI=1.2-71.5) and teacher ratings of executive function (OR=5.3, 95% CI=1.4-20.2) were associated with below-expected achievement. Mediation analysis showed IQ had indirect effects on writing (b=1.5, 95% CI=0.6–3.1) via attentional control; and on reading (b=1.0, 95% CI=0.2–3.2) and writing (b=0.8, 95% CI=0.1–2.5) via cognitive flexibility.

Conclusions: Both low IQ and low executive function are associated with below-expected teacher-rated academic achievement in children born very preterm. IQ may influence academic achievement in part through executive function.

Abbreviations

VLBW	Very low birth weight
IQ	intelligence
WISC-IV	Wechsler Intelligence Scale for Children, Fourth Edition
TEA-Ch	Test of Everyday Attention for Children
BRIEF	Behavior Rating Inventory of Executive Function
GEC	Global Executive Composite

1. Introduction

Children born very preterm have been reported to have poorer neuro-cognitive and learning outcomes than their term-born peers [1-3]. A meta-analysis of 14 studies found that children aged > 5 years born very preterm (≤ 33 weeks) and/or very low birth weight (VLBW) had worse performance on achievement tests (0.60 SD lower for mathematics; 0.48 SD lower for reading; and 0.76 SD lower for spelling) than term born peers [4]. They were also more likely to be lagging behind grade level [5] and receiving special educational support in mainstream schools [1,6].

The underlying factors contributing to this poorer academic achievement of children born very preterm are not clear. Intelligence is a significant predictor of academic achievement in typically developing children [7]. Schneider et al found that children born very preterm on average had lower intelligence (IQ) than their term-born peers and IQ was an important predictor of academic success in these children [8].

Executive function has also been shown to play an important role in academic functioning in pre-school and school-aged children in a general population [9,10]. Children born very preterm and/or VLBW have been reported to have lower executive functions including verbal fluency, working memory, and cognitive flexibility [4]. Mulder et al found that processing speed and working memory were the factors underlying academic achievement in children at age 9–10 years born very preterm [1]. Furthermore, executive function was found to play a mediating role in the relationship between intelligence and mathematics performance in non-clinical samples [11]. Previous findings have demonstrated inter-relationships between IQ, executive function and academic achievement, but how and to what extent they are related in children born preterm has not been fully investigated.

We therefore investigated intelligence and executive function measures at 7 years of age in a cohort of children born very preterm, and in particular, the contributions of low intelligence and low executive function to below-expected teacher-rated academic achievement, and whether executive function may mediate the relationship between intelligence and academic achievement.

2. Methods

2.1. Participants

The PIANO (Protein, Insulin And Neonatal Outcomes) study was a follow-up study to assess the outcomes at 7 years of age in a cohort of children born < 1500g or < 30 weeks' gestation and admitted to the Auckland City Hospital Neonatal Intensive Care Unit from 2005 to 2008. Details have been published elsewhere [12]. Ethical approval was obtained from the Northern B Ethics Committee (NTY/12/05/035) and institutional approval from the Auckland District Health Board (ADHB 5486).

At 7 years' corrected age, children were invited to undergo a comprehensive assessment by trained assessors at the Liggins Institute, Auckland, New Zealand, or at a location convenient to parents. Parents provided written consent and children provided verbal assent for all assessments.

2.2. Measures

General cognitive abilities of the children were assessed with the Wechsler Intelligence Scale for Children - Fourth Edition, Australian (WISC- IV) [13]. The WISC-IV has a mean score of 100 and a SD of 15. Low IQ was defined as Full Scale IQ (FSIQ) < 85. Both performance-based measures and rating scales were used to assess executive function. From the Test of Everyday Attention for Children (TEA-Ch) [14], Sky Search (attention score) and Score! (total correct) were used to assess children's attentional control. Sky Search requires participants to identify "target" spaceships among distracters. Both accuracy and speed are used to derive attention score. Score! asks participants to count the number of sounds they hear on a recording, with the number of correct items recorded. Creature Counting (Timing

Score) and Sky Search Dual Task (Decrement score) were used to assess cognitive flexibility. Creature counting requires children to switch between counting forward and counting backward repeatedly. Both time and accuracy are used to calculate the Timing score. In the Sky Search Dual Task, children are required to identify the "target" spaceships and keep a count of sounds simultaneously. The decrement score is the difference between scores on the Sky Search and the Sky Search Dual Task. All subtests of TEA-Ch have a mean of 10 and an SD of 3. Low performance was defined as scaled scores < 7. Scores on the TEA-Ch were reverse-coded in mediation analysis, as higher scores indicate lower executive function.

Both caregivers and teachers were asked to complete the Behavior Rating Inventory of Executive Function (BRIEF) [15]. BRIEF is a questionnaire to evaluate different aspects of executive function such as inhibition, shifting, initiate, and working memory manifested in school and home environments. The BRIEF yields an overall Global Executive Composite (GEC) score which has a mean of 50 and SD of 10. Higher scores indicate poorer executive functioning. Low executive function was defined as GEC ≥ 60.

The New Zealand (NZ) National Standards policy, now repealed, required teachers in Years 1 to 8 to make overall judgements of the child's progress in reading, writing, and mathematics against the expected curriculum standards for those years. These recorded judgements were used as measures of academic achievement [16] and were reported on a 4-point scale of Above, At, Below, or Well Below the expected standard for the child's year level. Below-expected achievement was defined as teacher ratings of Below or Well Below the standard.

Data on neonatal characteristics were obtained from medical records. Maternal ethnicity was self-defined and prioritised using the Ministry of Health Guidelines [17]. Socioeconomic status was derived from maternal address during pregnancy using the New Zealand Deprivation Index 2006, which is a decile scale ranging from 1 to 10, where 1 represents least deprivation and 10 the most [18], and divided above and below the cohort median of 7 for analysis (≥7 low; <7 high).

2.3. Statistical Analysis

Statistical analyses were performed using SPSS Version 25 (IBM Corp, Armonk, NY, USA). Descriptive data are presented as median (interquartile range), mean (standard deviation) or number (%). Independent group t-tests (for continuous variables) or chi-square tests (for categorical variables) were performed to compare the differences between neonatal and demographic characteristics of children with and without missing data on academic achievement and/or follow up assessment. Separate one sample *t*-tests and chi-square tests were used to compare performance on IQ, executive function and academic achievement of the study cohort with the normal values and to ascertain the effects of sex and socioeconomic status on these outcomes.

Logistic regression was used to examine the relationships between IQ, executive function and academic achievement, after adjusting for sex and socioeconomic status. The indirect effect of IQ on academic outcomes via executive function was determined using the bootstrapping method and the PROCESS macro for SPSS [20]. which provides more accurate confidence limits and greater statistical power than the normal theory method even with smaller sample sizes [21].

3. Results

Of the 129 children in the PIANO cohort, academic achievement data were available for 87. Of these, 11 were excluded: 6 (7%) had achievement data provided >1 year before or after the assessment, 3 (3%) had incomplete information and 2 (2%) were not assessed at age 7 years. Of the 76 included children, 55 (72%) were born at 25 to 28 weeks' gestation and 51 (67 %) were born <1000g (Table 1). Half the mothers were of New Zealand European ethnicity. There were no significant differences in neonatal and demographic characteristics of children who were and were not included (Table 1).

Overall, the study cohort had lower IQ than the normal values, with a 2-fold increased risk of IQ scores -1 SD below the mean (Table 2). The cohort also had more executive function difficulties than the normal values, with a 2-fold to 4-fold increased risk of performance-based scores below -1 SD. Furthermore, more executive function difficulties were reported by both parents and teachers, with 1.5-fold to 2-fold increased risk of low executive function in behavioural ratings (scores above +1 SD). Children in the study cohort were reported to have poorer academic achievement than national samples[19], with 1.5-fold and 2.5 fold increased risk of below-expected performance in writing and mathematics.

Sex and socioeconomic status were both related to IQ, executive function and teacher-rated achievement (Table 2). Boys had a lower scores for cognitive flexibility and a two-fold increased risk of below expected achievement in writing compared to girls. Children of lower socioeconomic status had a mean IQ 12 points lower than those of higher socioeconomic status, more parent and teacher-reported executive function difficulties and 2 to 3 –fold increased risk of below-expected teacher-rated academic achievement. We therefore included sex and socioeconomic status as covariates in the subsequent logistic regression models when testing the association of IQ and executive function with academic achievement.

Low IQ and most measures of low executive function were associated with below-expected achievement on reading, writing and mathematics on logistic analysis after adjustment for sex and socioeconomic status (Table 3). Children with low IQ were 9 to 12 times more likely to have below-expected performance on academic achievement than children with normal IQ. On the performance-based measures of executive function, children with low attentional control, assessed by Score! as well as low cognitive flexibility, assessed by Creature Counting and Sky Search Dual Task, were 4 to 9 times more likely to have below-expected academic performance. Children with low teacher reported executive function were more likely to have below-expected reading and writing. However, low parent reported executive function was not significantly associated with below-expected learning outcomes.

After further adjusting for IQ, children with low cognitive flexibility, as measured by Sky Search Dual Task, were 9 times more likely to have below-expected writing (Table 3). However, the association between other performance-based measures of executive function and academic performance were not statistically significant after adjusting for IQ. Teacher, but not parent ratings, (BRIEF) were also associated with below-expected achievement only for reading.

Further mediation analyses were performed to ascertain whether IQ had an indirect influence on academic achievement through executive function. Three out of the 18 analyses were statistically significant. Low IQ was associated with poorer attentional control and cognitive flexibility and in turn, increased the risk of below-expected reading and writing. The effects of IQ on academic achievement were mediated by attentional control, measured by Score! for reading ($b = 1.48$, $SE = .67$, 95% CI 0.58–3.09) and by cognitive flexibility, measured by Creature Counting for reading ($b = 1.00$, $SE = 2.10$, 95% CI 0.22–3.24) and writing ($b = 0.78$, $SE = 2.06$, 95% CI 0.13–2.53). In the mediation models, the direct effect of IQ was statistically significant for writing ($b = 1.64$, $SE = 0.68$, 95% CI 0.31–2.97) with cognitive flexibility as the mediator, and the coefficients were similar, although not meeting conventional statistical significance, for reading with cognitive flexibility as the mediator, and for writing with attentional control as the mediator (Fig. 1).

4. Discussion

In this cohort of infants born very preterm or VLBW, performance on IQ, executive function testing and academic achievement were significantly lower than the normal values. Both IQ and executive function were independently associated with teacher-reported academic achievement at age 7 years after adjustment for sex and socioeconomic status. Furthermore, after adjustment for IQ, low cognitive flexibility and low teacher-reported executive function were independently associated with poorer academic achievement.

Previous meta-analyses reported that both sex and socioeconomic status have impacts on academic achievement. Girls tended to do better academically than boys [22] and higher socioeconomic status was associated with better academic achievement [23]. Similarly, we found that boys and children of lower socioeconomic status were at greater risk of below-expected teacher-rated achievement. These variables were therefore treated as covariates in the regression models in this study.

General cognitive ability is a major predictor of academic outcomes in children born extremely or very preterm [8] In a review of 15 case-control studies, children born preterm had lower IQ at school age than their term-born counterparts (weighted mean difference 10.9; 95% CI, 9.2-12.5) [24]. Consistent with those findings, we also found the mean IQ score of this cohort was 10 points lower than the normal values, and twice as many children had low IQ compared to the normative sample.

Intelligence refers to abilities in understanding complex concepts, adapting to the environment, learning from experience, reasoning and solving problems [25] These are the fundamental skills in classroom learning and are strongly correlated (r = 0.81) with educational attainment [26]. Hence, children with low IQ have a greater risk of below-expected learning outcomes than those with normal IQ, and this also applies to children born very preterm. Children born preterm show difficulties in cognitive processing which may have negative impacts on learning [8].

Children in our study cohort had lower scores on performance-based measures of attentional control and cognitive flexibility and were reported by parents and teachers to have more difficulties in executive function in comparison with normal values. Others have reported that children born very preterm were at greater risk for having difficulties in executive function

[27] with underlying neuropathology related to white matter abnormalities [28]. A review of 12 studies reported a decrement of 0.57 SD for verbal fluency, 0.36 SD for working memory, and 0.49 SD for cognitive flexibility among children born very preterm and/or VLBW compared with controls [4] compared with decrements on the performance-based measures of attentional control and cognitive flexibility of >1 SD in our study cohort.

Executive function is another important factor related to academic achievement in clinical populations [29]. Impaired executive function may affect children's abilities to follow classroom instructions and regulate learning related behaviour such as sitting still and attending to instructions, which may result in lower learning performance. There is a growing interest in the unique contribution of executive function to learning, with some studies suggesting that executive function predicts learning outcomes better than IQ [30], although findings are inconsistent [7]. We found that most measures of executive function were associated with academic outcomes. However, compared to IQ (OR's 9.00 - 12.30), executive function had a weaker relationship (OR's 4.14 - 9.27) with academic outcomes in our cohort. Results of previous meta-analyses reported that the correlation between IQ and academic achievement ($r = 0.44$) [31] was slightly higher than that between executive function and academic achievement ($r = 0.37$) [32]. Peng and Kievit suggested that this may reflect higher reasoning abilities promoting the use of analogies and abstract schema which, in turn, help organising and consolidating learning [33]. The relations between non-verbal IQ, but not executive function, and reading or mathematics increased with age, suggesting that relative to executive function, intelligence seemed to be more related to the skills relevant to learning over time.

We also found an association between cognitive flexibility, as measured by Sky Search Dual task, and writing achievement after adjustment for IQ and individual-level covariates. Balioussis et al found that cognitive flexibility predicted the complexity of persuasive writing in a group of children age 8-9 years [34]. Although the focus on writing in New Zealand for the age level of this cohort is to construct texts showing awareness of purpose and audience as well as to express ideas and information, which is different from persuasive writing [35], they both involve the skills to monitor and inhibit their own ideas intentionally and shift to another perspective flexibly. However, the association between cognitive flexibility and academic achievement after adjustment for IQ has been unclear. One study found that the association between cognitive flexibility and academic achievement was no longer significant after controlling for verbal intelligence [36], but another study found that cognitive flexibility remained a significant predictor of learning outcome after controlling for verbal intelligence [37].

Consistent with previous findings on typically developing children, we found that teacher reported executive function, but not parent reported, was associated with academic performance. Dekker et al found that cognitive performance and teachers' ratings of working memory and shifting explained differences in spelling achievement. However, parents' ratings of executive function could not explain further variance in academic outcomes [38]. Results of meta-analyses suggested that the overall level of consistency between parents' and teachers' reports of emotional and behavioural problems was low (r = 0.27), perhaps because of situational specificity of target behaviour (behaviour different from one situation to another) [39]. Situational specificity may also affect the executive function observed by parents and teachers. The executive function reported by teachers referred to the behaviours manifested in a learning context, which may be most relevant to children's academic achievement. This is consistent with our findings that teacher reported executive function was significantly associated with academic outcomes.

Our study suggests that both attentional control and cognitive flexibility may play a mediating role between IQ and teacher-rated academic achievement in reading and writing, but not mathematics. The lack of relationship with achievement in mathematics was perhaps suprising, given previous reports that working memory mediated the relationship between fluid intelligence and number production and mental calculus, while shifting mediated the relationship between both crystallised and fluid intelligence and arithmetical problem solving [11]. Among the various components of executive function, working memory is reported to make a unique contribution to achievement in mathematics [40]. However, working memory was not separately included in our mediation analysis, but was incorporated as one of the four components of full-scale IQ. Thus, its influence on academic achievement may have been reflected in the direct effect of IQ. Furthermore, previous research suggested that executive function mediated the relationship between IQ and specific mathematics skills such as mental calculus and arithmetical problem solving [11]. The outcome analysed in our study was teachers' overall judgement of mathematics performance, which is different from specific mathematics skills.

Strengths of the present study include using multiple modes of assessment (performance-based measures and rating scales) and involving multiple informants (parents and teachers) to assess children's executive function. However, one of the limitations of our study is the measurement of academic achievement. The National Standards relied on teachers' overall judgement of children's achievements. Unlike standardised attainment tests, teachers' judgements are based on a range of data from informal (i.e. observation) and formal assessment in addition to their own and children's views in evaluating children's learning progress against the standard [16]. Meissel et al found that the correlations between standardised achievement results and teacher judgement in a NZ large study was only slightly greater than 0.70 for both reading and writing [41]. Marginalised learners such as students with special needs were being assigned lower teacher judgments even when standardised achievement was the same. The underestimation of performance by teachers' judgement highlighted the need for a consistent and standardised way to evaluate children's academic achievement. Other limitations of our study are limited sample size, which was limited by the number of children in the inception cohort, and that we only addressed two components of executive function (attentional control and cognitive flexibility). There is a need to include more components of executive function such as working memory in order to develop a more comprehensive understanding of how specific executive functions relate to learning.

Our study has several implications for practice and research. Firstly, our findings highlight the importance of identifying the needs of and providing special educational support where required for children born very preterm, as they are at high risk of exhibiting learning difficulties. Secondly, our study shows the importance of incorporating teachers' views when assessing executive function and learning outcomes of school age children, as they can provide unique information on children's functioning in the school context. It would be useful in future research to investigate whether teacher reported executive function relates to other aspects of school functioning such as learning motivation, peer relationship and involvement in extra-curricular activities. Thirdly, executive function may serve as a potential target for intervention in the school setting in children born very preterm. Various interventions such as computerised training, school curricula, and exercises have been shown to improve executive function in school age children [42]. As we found that executive function was independently related to academic achievement, developing children's executive function may help ameliorate their learning difficulties.

5. Conclusion

Children born very preterm are at risk of adverse neurocognitive and educational outcomes. Our findings have highlighted the potential unique contribution of executive function to the poorer academic achievement of children born very preterm.

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Table 1: Neonatal and demographic characteristics of the study cohort

	With complete data for analysis	Without complete data for analysis[a]

	n		n		*p*[b]
Age at test, years	76	7.21 (0.2)	49	7.20 (0.1)	0.682
Boys	76	41 (54)	53	28 (53)	0.900
Singletons	76	52 (68)	53	42 (79)	0.174
Gestational age (weeks)	76	26 (25 to 28)	53	27 (25 to 29)	0.294
Birth weight (g)	76	919 (206)	53	922 (252)	0.927
Birth weight z-score	76	0.11 (0.93)	53	-0.09 (0.93)	0.235
Birth Length z-score	71	0.04 (1.07)	49	-0.16 (1.13)	0.322
Birth Head circumference z-score	72	0.19 (1.13)	52	0.18 (0.99)	0.942
Received antenatal steroids	76	72 (95)	53	46 (87)	0.112
Clinical Risk Index for Babies-II score	74	10 (3)	53	10 (3)	0.881
5-Minute Apgar score <7	74	13 (17)	53	11 (21)	0.600
Major neonatal surgery	76	7 (9)	53	5 (9)	0.966
Length of neonatal stay (days)	76	88 (72 to 106)	53	88 (64 to 103)	0.578
Maternal ethnicity	76		53		0.235
Māori		18 (23)		14 (26)	
Pacific Island		6 (8)		10 (19)	
European		40 (53)		21 (40)	
Asian/ Other		12 (16)		8 (15)	
Socioeconomic status	75		53		0.073
Most deprived decile		13 (17)		1 (2)	
Least deprived decile		10 (13)		11 (21)	

Data are median (interquartile range), mean (standard deviation) or number (%)
[a] Reasons for incomplete data for analysis included missing academic achievement data, achievement data provided >1 year before or after the assessment, incomplete information and no follow up assessment at age 7 years
[b] Independent group t-tests or chi-square tests p values

Table 2: Performance on intelligence, executive function and teacher-rated academic achievement at 7 years and effects of sex and socioeconomic status

	Cohort	Normal value[a]	*p*	Boys	Girls	*p*	Low SES	High SES	*p*
Intelligence (WISC IV)									
FSIQ	90 (16)	100 (15)	<0.001	88 (16)	92 (15)	0.196	85 (14)	97 (15)	0.001
FSIQ <85	27 (36)	(16)	0.005	16 (39)	11 (31)	0.490	19 (49)	7 (19)	0.008
FSIQ <70	4 (5)	(2)	0.445	3 (0.1)	1 (0.03)	0.385	3 (8)	1 (3)	0.344
Executive Function- Performance based measures (Subtests of TEA-Ch)									
Sky Search- attention score	6.7 (2.9)	10 (3)	<0.001	6.4 (3.1)	7.1 (2.6)	0.320	6.9 (2.8)	6.7 (3.0)	0.824
Score!	6.7 (3.4)	10 (3)	<0.001	6.0 (2.3)	7.4 (4.1)	0.081	6.1 (3.3)	7.5 (3.4)	0.076
Creature Counting	6.4 (3.1)	10 (3)	<0.001	5.6 (2.6)	7.2 (3.5)	0.039	6.1 (3.3)	6.8 (2.9)	0.402
Sky Search Dual Task	4.9 (4.7)	10 (3)	<0.001	4.4 (5.1)	5.4 (4.3)	0.422	3.7 (3.7)	6.1 (5.4)	0.052
Sky Search- attention score <7	27 (38)	(16)	0.003	16 (42)	11 (33)	0.448	13 (36)	13 (38)	0.854
Score! <7	38 (53)	(16)	<0.001	23 (60)	15 (44)	0.164	22 (60)	15 (44)	0.196
Creature Counting <7	34 (53)	(16)	<0.001	22 (63)	12 (41)	0.087	18 (60)	15 (46)	0.248
Sky Search Dual Task <7	40 (66)	(16)	<0.001	23 (74)	17 (57)	0.150	23 (74)	17 (57)	0.150
Executive Function- Behavioural ratings									
BRIEF- Parent report GEC	54 (11)	50 (10)	0.004	55 (12)	53 (11)	0.373	57 (11)	50 (11)	0.005
BRIEF- Teacher report GEC	54 (10)	50 (10)	<0.001	55 (8)	54 (11)	0.708	57 (10)	52 (8)	0.019
Parent report GEC ≥ 60	24 (32)	(16)	0.024	14 (34)	10 (29)	0.602	16 (41)	7 (19)	0.043
Teacher report GEC ≥ 60	19 (26)	(16)	0.165	11 (28)	8 (24)	0.697	11 (30)	8 (22)	0.465
Teacher-rated Academic Achievement									
Below expected Reading	22 (29)	(22)	0.361	13 (32)	9 (26)	0.566	16 (41)	5 (14)	0.009
Below expected Writing	32 (42)	(26)	0.042	22 (54)	10 (29)	0.027	21 (54)	10 (28)	0.022
Below expected Mathematics	38 (50)	(21)	<0.001	20 (49)	18 (51)	0.080	25 (64)	12 (33)	0.008

Data are mean (standard deviation) or number (%); *p*, Independent group t-tests or chi-square tests p values; SES, Socioeconomic status;WISC IV, Wechsler Intelligence Scale for Children - Fourth Edition; FSIQ, Full Scale IQ; TEA-Ch, Test of Everyday Attention for Children; BRIEF, Behavior Rating Inventory of Executive Function; GEC, Global Executive Composite, SES, socioeconomic status. High SES is NZ Deprivation score <7.

[a] Performance on IQ and executive function was compared to normal values; Teacher-rated academic achievement was compared to the data of national samples

Table 3: Relationship between low IQ, low executive function and below-expected academic achievement

	Below-expected Reading		Below-expected Writing		Below-expected Mathematics	
	OR (95% CI)	*p*	OR (95% CI)	*p*	OR (95% CI)	*p*
Single Predictor						
Intelligence						
Low IQ	8.99 (2.77-29.25)	<0.001	12.30 (3.56-42.43)	<0.001	12.17 (3.43-43.25)	<0.001
Executive Function- Performance based measures						
Low AC (Sky Search score)	2.10 (0.68 – 6.50)	0.199	1.77 (0.61-5.15)	0.293	2.26 (0.80-6.38)	0.124
Low AC (Score!)	7.83 (1.86-32.89)	0.005	6.27 (1.93-20.39)	0.002	4.51 (1.53-13.31)	0.006
Low CF (Creature counting)	9.27 (1.04-82.79)	0.046	4.14 (1.10-15.62)	0.036	2.18 (0.72-6.61)	0.168
Low CF (Sky Search Dual Task)	1.51 (0.34-6.70)	0.589	7.07 (1.34-37.30)	0.021	5.13 (1.36-19.29)	0.016
Executive Function- Behavioural ratings						
Low EF- Parent rating	2.41 (0.81-7.18)	0.115	2.10 (0.72-6.08)	0.173	1.61 (0.56-4.61)	0.372
Low EF- Teacher rating	5.71 (1.69-19.27)	0.005	4.09 (1.23-13.65)	0.022	3.24 (1.01-10.43)	0.049
Multiple predictors						
IQ and Cognitive Flexibility (Creature Counting)						
Low IQ	4.44 (0.92–21.54)	0.064	6.64 (1.55-28.45)	0.011	7.24 (1.84-28.54)	0.005
Low CF (Creature counting)	7.45 (0.81–68.25)	0.075	3.81 (0.91-15.92)	0.067	1.80 (0.55-5.94)	0.333
IQ and Cognitive Flexibility (Sky Search Dual Task)						
Low IQ	4.97 (1.19–20.85)	0.028	10.93 (2.02-59.01)	0.005	7.37 (1.78-30.50)	0.006
Low CF (Sky Search Dual Task)	1.01 (0.20–5.00)	0.993	9.26 (1.20-71.51)	0.033	3.92 (1.00-15.45)	0.051
IQ and BRIEF- Parent rating						
Low IQ	8.88 (2.68–29.47)	<0.001	12.10 (3.47-42.17)	<0.001	12.12 (3.38-43.40)	<0.001
Low EF- Parent rating	2.33 (0.66–8.20)	0.187	2.00 (0.68-6.87)	0.273	1.53 (0.45-5.19)	0.500
IQ and BRIEF- Teacher rating						
Low IQ	7.67 (2.16–27.23)	0.002	10.11 (2.83-36.19)	<0.001	10.83 (2.92-40.26)	<0.001
Low EF- Teacher rating	5.29 (1.39–20.18)	0.015	3.39 (0.91-12.64)	0.069	2.92 (0.76-11.18)	0.118

Data are odds ratios (OR), 95% confidence intervals (CI) and p values after adjustment for sex and socioeconomic status. Low IQ (intelligence), FSIQ < 85; Low AC (attentional control) and Low CF (cognitive flexibility), scaled scores on subtests of TEA-Ch <7; Low EF (executive function), BRIEF Global Executive Composite ≥60

Data Availability Statement

Data and associated documentation are available to other users under the data sharing arrangements provided by the Maternal and Perinatal Research Hub, based at the Liggins Institute, University of Auckland (https://wiki.auckland.ac.nz/researchhub).The data dictionary and metadata will be published on the University of Auckland's data repository Figshare, which allocates a DOI and thus makes these details searchable and available indefinitely. Researchers are able to use this information and the provided contact address (researchhub@auckland.ac.nz) to request a de-identified dataset through the Data Access Committee of the Liggins Institute. Data will be shared with researchers who provide a methodologically sound proposal and have appropriate ethical approval, where necessary, to achieve the research aims in the approved proposal. Data requestors are required to sign a Data Access Agreement that includes a commitment to using the data only for the specified proposal, not to attempt to identify any individual participant, a commitment to secure storage and use of the data, and to destroy or return the data after completion of the project. The Liggins Institute reserves the right to charge a fee to cover the costs of making data available, if needed, for data requests that require additional work to prepare.

Authorship Statement

Darren Dai: Conceptualization, Methodology, Data analysis, Writing - original draft preparation. **Trecia Wouldes:** Conceptualization, Methodology, Writing- reviewing and editing. **Gavin Brown:** Data analysis, Writing- reviewing and editing. **Anna Tottman:** Project design, Funding acquisition, Investigation, Writing- reviewing and editing. **Jane Alsweiler:** Project design, Funding acquisition, Investigation, Writing- reviewing and editing. **Greg Gamble:** Data analysis. **Jane Harding:** Project design and supervision, Conceptualization, Methodology, Funding acquisition, Writing- reviewing and editing.

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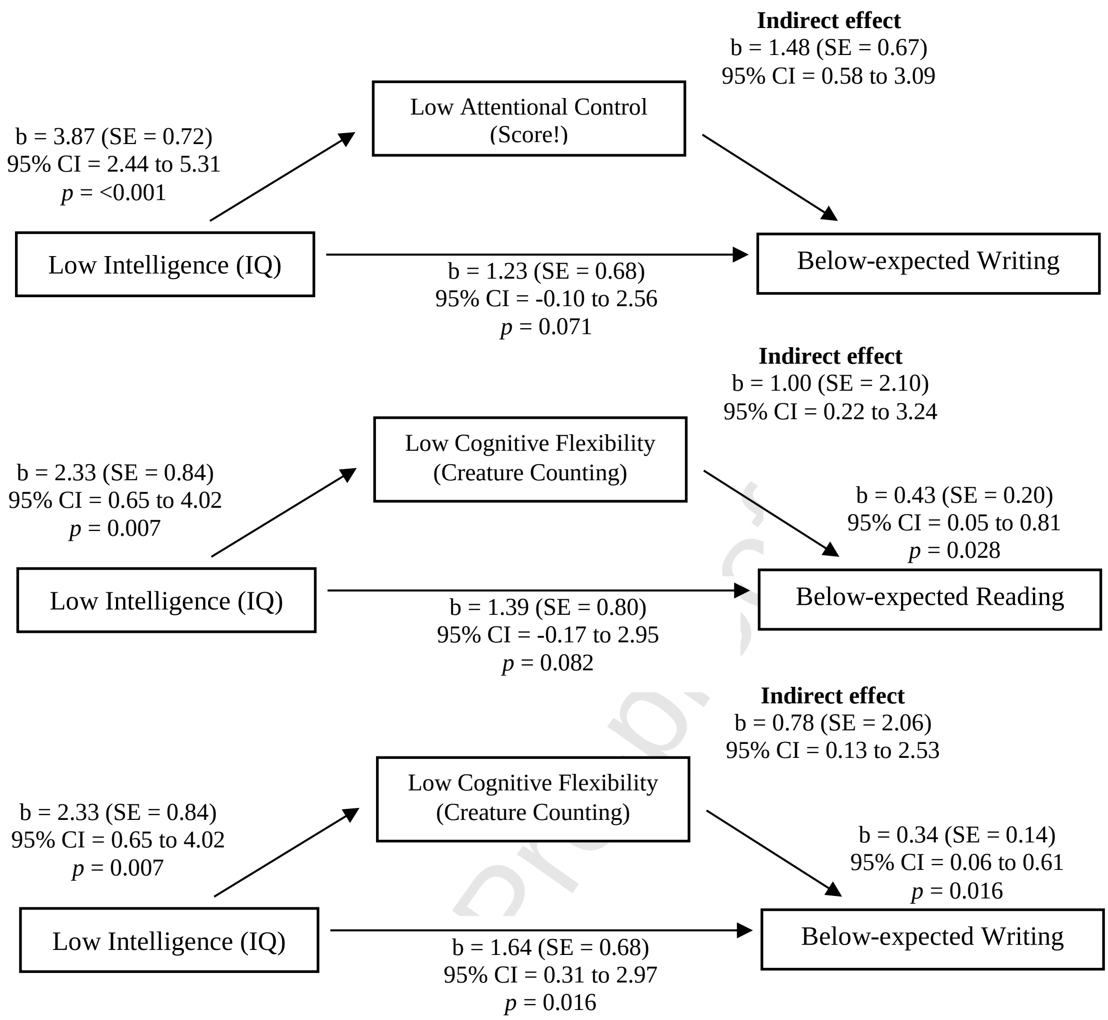

Fig. 1. Mediation models of the indirect effect of IQ on academic achievements through executive function. Measures of the indirect effects include the bootstrapped 95% confidence intervals

Highlights

- Children born very preterm are at high risk of low IQ, low executive function and below-expected academic achievement at 7 years of age.
- Performance measures of low cognitive flexibility, and teacher, but not parent, ratings of executive function were associated with below-expected academic achievement, after adjustment for IQ, sex and socioeconomic status.
- IQ may influence academic outcomes in part through executive function.