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Early school-based learning difficulties in children born very preterm

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ABSTRACT

Background: Educational underachievement is a major morbidity associated with very preterm (VPT) birth. However, few studies have examined early school outcomes with most employing global, clinic based measures.
Objective: To examine the early school achievement in a cohort of children born VPT and studied to age 6 years.
Methods: A regional cohort of 102 VPT children (≤33 weeks GA) were followed prospectively alongside a comparison group of 108 full term (FT) children born during the same period (1998–2000). At 6 years corrected age, all children underwent a comprehensive neurodevelopmental evaluation that included the Woodcock-Johnson Tests of Achievement (WJ-III), teacher report and national numeracy and literacy test results. Rates of specific learning disabilities (LD) were also examined.
Results: VPT children performed less well than FT children on WJ-III subtests (*ps*<.05), national tests (*ps*<.01), and in all curricular areas rated by teachers (*ps*<.01) except expressive language. Even VPT children without severe neurodevelopmental impairment scored lower on the WJ-III math, national tests (*ps*<.05) and were 2–3 times more likely to show delays (*ps*<.02) in math (43% vs. 19%), written language (36% vs. 22%), language comprehension (26% vs. 14%), handwriting (36% vs. 17%), spelling (38% vs. 30%) and physical education (33% vs. 11%). They were also twice as likely as FT children to have math LD (47% vs. 21%).
Conclusions: By age 6, a substantial proportion of VPT children are lagging behind their FT peers across multiple curriculum areas, with difficulties being most prominent in math. Findings highlight the need for early identification and educational supports to help maximise VPT children's learning opportunities during the transition to school.

One of the major morbidities associated with preterm birth is educational underachievement. By middle childhood, children born very preterm (VPT) are 3 to 5 times more likely to show difficulties across a range of school based skills and educational domains [1–5]. In particular, findings reveal that whilst educational difficulties in mathematics and reading are relatively common [6–9], problems in language, spelling and handwriting are also evident [1,10,11]. As a consequence, it is estimated that 60–70% of VPT children will require support from special education services by middle school age [12]. Furthermore, these difficulties do not appear to be confined to children with severe neurodevelopmental problems, spanning severe cognitive delay, cerebral palsy and/or neurosensory impairments [13–16]. For example, in a prospective longitudinal study of 82 8-year old children born extremely preterm without neurosensory disorders and/or IQ>85, Bowen et al. [13] showed that preterm children performed less well on standardized measures of academic achievement and were 2 to 3 times more likely to be identified by their class teacher as achieving below grade level in reading, mathematics and spelling relative to their full term peers.

Of particular importance with respect to the longer term life course development of VPT children are recent findings suggesting that many of these educational difficulties persist and in some cases worsen over time [17–19]. Specifically, a follow up study of a British sample of VPT children to age 12 years, found no evidence of school catch up between the ages of 6 and 12 years [20]. Similar results were obtained in an Australian follow-up study to age 14 [14], while in the Netherlands, Walther et al. [21] found that the use of special education services in their cohort of VPT children increased from 19% to 28% between the ages of 9 and 14 years. Similar rates of special educational assistance were reported by Hack et al. [18] and Resnick et al. [19]. In addition, studies of educational outcome to age 25, demonstrated that compared to their full term peers, adults born VPT had lower levels of educational achievement and were less likely to be in paid work or

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work training following school leaving [17,18,22], suggesting that earlier educational underachievement may have ongoing impacts on later life course opportunities.

While these studies have been helpful in highlighting the elevated risks of educational problems associated with VPT birth, it is important to note that much of this research has been limited in a number of ways. First, to date, most studies have been based on samples of older children aged between 8 and 16 years. In contrast, few studies have investigated the extent to which educational difficulties may be evident as early as 1 year after school entry, or the likely nature of these difficulties (see studies by Resnick et al.; Vohr and Msall; Wolke and Meyer; Schneider et al. [23–26] for outcomes concerning school readiness, language development and prereading abilities shortly before school entry). Such information is important for the development of effective early identification and intervention strategies to support the learning needs of VPT children during their transition to school and in the classroom. While it has been suggested that educational or school-related difficulties may not be apparent in the first year of school [27–29], studies showing behavioral and cognitive difficulties amongst VPT children during the preschool years alongside the evidence for worsening school performance over time suggest that these children may be less able to take full advantage of early learning opportunities [4]. However, further research is clearly needed to clarify this issue.

A second limitation of existing research, and an important consideration for future studies examining the educational outcomes of children born VPT, concern the over reliance on laboratory-based measures rather than ecologically valid, curriculum and classroom-based measures. It has been argued that systematic assessment with measures relevant to the national curriculum is necessary to identify as early as possible those children who may need help to fulfill their educational potential [30]. However, with the exception of several studies that have included teacher report measures of children's school progress [14,17,31–33], most rely on standardized measures of academic achievement with little or no reference to classroom functioning or performance relative to other children on the national curriculum. Such laboratory based measures may have limited generalisability when used in cultural and educational settings different to those of the normative population, and are also typically administered during a single research assessment. Finally, and importantly, the use of normative data from standardized achievement measures can be problematic due to the Flynn effect [34,35] whereby IQ scores tend to be higher on older than on newer versions of intelligence tests [36]. This problem tends to be compounded when testing younger children [37]. As a result, a number of researchers now recommend the use of a control group rather than test norms to determine IQ cut points [4,36]. Studies of school outcomes in VPT cohorts using outdated norms may underestimate the prevalence of specific learning difficulties.

A third and related issue concerns the variability across studies in the conceptualization of educational under-achievement. In particular, while some studies use teacher reports and performance on academic achievement tests, others have used remedial support or school performance below grade level to define educational problems. Arguably, however, the assessment of rates of specific learning disabilities (LD) may provide a more valid indicator of VPT children's educational abilities and progress. A specific LD refers to a marked problem in core academic domains that is not due to below average IQ and is typically defined in one of two ways. The low achievement definition identifies a LD on the basis of a standardized academic score that falls below a certain percentile, while the IQ discrepancy definition defines LD on the basis of an academic score that falls below an achievement level predicted from the IQ score (see [6,38]). The detection of specific LD is of particular relevance to the school system, where educational problems are often interpreted as a discrepancy between ability and performance [39]. Moreover, studies using a low achievement criterion for LD suggest similar rates to those based on the use of remedial educational support [5,40].

Some of the most compelling evidence for educational underachievement amongst children born VPT comes from the few studies examining risks of specific LD. However, results to date have been mixed. For instance, a follow-up study to age 9, found that VPT children with IQ scores ≥ 85 had a higher rate of LD in math, reading, and writing at age 9 than term born children [41]. Likewise, a study of 63 non-disabled VPT children with IQ scores ≥ 80 by Litt et al. [7] showed that 34%–60% had a specific LD in either math and reading at age 11 compared to only 20% of term born children. By contrast, Saigal et al. [2] found no evidence for higher than normal rates of specific LD in 8-year-old VPT children without cognitive delay. A number of other studies also report no increased risk of either math or reading LD in preterm children (e.g., [42–44]) while a study by Johnson and Breslau [6] found specific LD on the Woodcock-Johnson Psycho-Educational Battery at age 11 years in male children only. While these mixed findings may reflect differences in methodology and sample size across studies [7], the extent and nature of specific LD experienced by VPT children need to be better understood and clarified. Also worthy of further examination is the extent to which sex differences exist in rates of specific LD. To date, a small number of studies have also found sex differences in the effect of VPT birth on learning abilities, reporting increased risks for learning difficulties in reading, math, and written language amongst non-disabled VPT boys [2,6,45].

Taken together, while studies show that VPT birth places children at elevated risk of educational underachievement by middle childhood, little is known about the kinds of early educational problems experienced by VPT children, or the extent of these problems. Even less is known about these children's classroom and curriculum based performance or the extent of specific LD shortly after the transition to school. With most research focusing on educational outcomes in older preterm children, one unanswered question is whether academic problems can be identified in VPT children in their first school year, while another is whether younger VPT children will show higher rates of specific LD than their full term peers.

Against this general background, our objective was to undertake a comprehensive examination of the early school progress of a regionally representative cohort of VPT children born between November 1998 and December 2000. A term comparison group was included to minimize the problems associated with the Flynn effect. Also of interest was the extent to which the early educational outcomes of VPT children might differ for boys and girls. The specific aims of the study were as follows:

1. To describe the educational progress of VPT and full term comparison children at corrected age 6 years. Educational achievement was assessed using a multi-method approach that included standardized tests of academic achievement, performance on national curriculum measures and independent teacher evaluations of school progress.
2. To examine the extent to which VPT children are at elevated risk of a specific LD in reading, receptive language and/or math using a low achievement criterion approach.
3. To examine possible sex differences in the effect of VPT birth on early educational progress.

1. Methods

1.1. Sample

Two groups of children were included in this study. The first group was a regional cohort of 102 VPT infants (≤ 33 weeks gestation) who were consecutively admitted to a level III neonatal intensive care unit (NICU) at Christchurch Women's Hospital (New Zealand) between November 1998 and December 2000. This neonatal service is the primary unit serving the greater Canterbury region of New Zealand. Exclusion criteria included congenital abnormalities and/or non-English speaking families. During the two-year recruitment period, 119 VPT infants met study criteria. Excluding deaths ($n=10$), 92% of all eligible infants were recruited. There were no significant ($p<.05$) differences in gestational age and birth weight between VPT infants recruited and not recruited. Since background characteristics were not available for the 8% of non-recruited VPT infants of term eligibility, we were not able to determine how representative our VPT sample was of the region from which they were recruited with regards to socio-environmental factors. At age 6 years, three families refused participation and data for one child was excluded due to blindness and another due to incompleteness. Thus 102 VPT children with a mean gestational age of 28 weeks (range: 23–33 weeks) were eligible for inclusion in the study at 6 years (97% retention rate).

The second group consisted of 108 full term comparison children with a mean gestational age of 40 weeks (range: 38–41 weeks) recruited at age 2 years. These full term children were identified from hospital birth records ($n=7{,}200$ births) by selecting a same-sex child born two births before or after the delivery of each VPT child. Exclusion criteria included congenital abnormalities, FAS, birth complications, and non-English speaking families. Of the 177 families identified, 64% (n = 113) agreed to participate. Reasons for non-participation included: untraced (47%); moved overseas (12.5%); refused (12.5%); agreed but unable to attend the clinic within the 2 week assessment window due to child illness or family circumstances (28%). No significant between-group differences were found between recruited and non-recruited full term children on measures of gestational age, birth weight, or family socioeconomic status (SES) [46]. In addition, comparison of the socioeconomic backgrounds of families in the full term group at age 2 and regional census data for the same period [47] indicate that these families were highly representative of the region from which they were recruited. At age 6 years, four families were unable to be traced and one refused participation. Thus of those originally recruited, 108 (96% retention rate) participated at age 6.

A comparison of children from families who declined to participate or were untraced at age 6 in the VPT ($n=3$) and full term ($n=5$) groups (total $n=8$) with the remainder of the sample showed no significant between group differences on measures of gestational age, SES, ethnic distribution, maternal age at birth, or maternal education.

1.2. Measures

Within 2 weeks of their sixth birthday (corrected for gestational age at birth), all children attended a half day follow-up evaluation that included an assessment of general cognitive ability using the Wechsler Preschool and Primary Scales of Intelligence and an assessment of early educational achievement using the Woodcock Johnson-III Tests of Achievement. On completion of this clinic assessment, each child's classroom teacher was asked to complete a detailed questionnaire about child behavior and educational achievement at school. Finally, children's school records were obtained and health screening and national testing data recorded.[1] All procedures and measures were approved by the Canterbury Regional Ethics Committee and written informed consent was obtained from all parents/guardians. Measures included in this analysis are described below.

[1] Two children in the VPT group and one child in the full term group were not attending school at the time of the study. Of those children in the VPT group, one was attending a special school due to severe cognitive delay and the other was home schooled. The child in the full term group not attending school was also home schooled but national testing data was available for this child.

1.3. General cognitive development

A short form of the revised *Wechsler Preschool and Primary Scales of Intelligence* (WPPSI-R) [48] provided a standardized measure of general cognitive ability. This measure consisted of two verbal (Comprehension and Arithmetic) and two performance (Picture Completion and Block Design) subtests. Reliability coefficients for this short form range from 0.91–0.94 and correlations with full scale IQ range from 0.89–0.92 [49,50]. Significant cognitive delay was defined as an IQ score > 2SD (IQ score = 83) below the mean of the full term comparison group (IQ score = 107).

1.4. Clinic based measures of educational achievement

Children were administered three subtests from the Woodcock Johnson-III Tests of Achievement (WJ-III) [51]. These were selected on the basis of their developmental appropriateness and relevance to the New Zealand school curriculum, and included: Math Fluency, Understanding Directions and Passage Comprehension. The *Math Fluency* subtest is a timed test that assesses children's ability to quickly and accurately complete addition and subtraction sums on paper. The format for this test was altered slightly, following consultation with teachers and other educational specialists, after initial piloting suggested that the original items did not mirror the format used in New Zealand schools. Thus, rather than being presented vertically, the sums were presented horizontally (1 + 4 = _) in accordance with the way early calculus is typically taught in the New Zealand curriculum [52]. The *Understanding Directions* subtest assessed children's ability to comprehend and respond to sequences of complex verbal instructions. As opposed to using a tape recorder, the researcher read instructions to the child to ensure that the accent would be appropriate to the New Zealand context. Children responded by pointing to picture items in a stimulus book. Finally, the *Passage Comprehension* subtest assessed children's reading ability and comprehension. This subtest involved matching words to symbols or completing sentences with missing words. For each subtest, children who failed to complete any of the items correctly were assigned a standard score of 40, the lowest possible score. Test re-test reliabilities for the WJ-III are high (0.7–0.9) and test performance has been shown to correlate significantly with other measures of academic achievement, supporting the construct validity of these scales [53–55].

1.5. Teacher ratings of educational achievement

Approximately 12 months after school entry, class teachers were asked to rate each child's school progress in eight curricular areas including math, reading, written language, expressive language, language comprehension, handwriting, spelling and physical education. For each area, teachers were asked to indicate whether children's classroom achievement level was 1) delayed, 2) below average, 3) average, 4) above average or 5) advanced relative to their classroom peers. A total of 97 teacher questionnaires were returned for VPT children and 104 for full term children. No information was given to teachers regarding the purpose of the study or study children's birth status.

1.6. National curriculum-based measures of educational achievement

School testing data relating to each child's progress in numeracy and literacy skills was collated from school records, including their current results from the 6-year NET Observational Reading Survey and the Numeracy Project (NumPA). These measures are commonly administered as part of the New Zealand school curriculum. The NumPA is a diagnostic interview that assesses students' development of mathematical facts and strategies [56]. Teachers administer assessments on an individual basis by asking between 3 and 22 questions related to each concept. Concepts include *Operational Strategies, Forwards Number Sequence, Backwards Number Sequence, Numeral Identification, Place Value and Basic Facts*. Performance on each task is recorded as a stage score from 0 to 7, with 0 being indicative of no reliable understanding of the concept or strategies while 7 demonstrates that the student is able to use at least two different mental strategies to solve addition or subtraction problems [52]. As this is a relatively new form of assessment, data regarding reliability and validity are not yet available.

The 6-year NET [57,58] is a New Zealand and American norm-referenced assessment, which involves observing children as they carry out tasks related to reading acquisition. It is administered by the classroom teacher after 1 year of schooling. Specific subtasks include: *Understanding Print Concepts*, which assesses children's ability to engage in literacy-based behaviors such as finding the title page of the book, reading from left to right; *Reading Text*, which requires the child to read aloud as the teacher records responses and errors; *Letter Identification*, which requires children to identify letter names and produce a word that begins with the letter; *Writing vocabulary*, which requires children to write a story within a 10-minute interval; *Hearing and recording sounds in Text*, which requires children to write a sentence dictated by their teacher. Each test score is converted to a stanine score which is then compared to national test data. Reliability coefficients for the 6-year NET range from 0.62–0.97 [58].

1.7. Specific learning disabilities

Rates of low achievement LD in math, reading and language were examined using Math Fluency, Passage Comprehension and Understanding Directions subtests from the WJ-III. Consistent with a low achievement definition [6], LD in math, reading or language was defined by an achievement score one standard deviation or more below the mean of the term comparison group. The proportion of children meeting LD criteria in multiple learning domains (i.e., math, reading and language) was also determined. Because the diagnosis of a specific LD is intended to identify children with a marked problem in an academic domain that is not due to profound intellectual impairment, children with severe cognitive delay (IQ scores>2SD below the term group mean) were excluded from analysis. Thus of the 102 VPT children assessed for specific LD at age 6, 16 were excluded on this basis, leaving a total sample of 86, and of the 108 full term children assessed for specific LD, 4 were excluded, leaving a sample of 104.

Table 1
Characteristics of the sample

Measure	Full term (n=108)	Very preterm (n=102)	p
Clinical characteristics			
Mean (SD) gestation	39.5 (1.2)	27.9 (2.3)	<.0001
Mean (SD) birth weight	3575 (410)	1071 (315)	<.0001
% Male	54.6	52	.70
% Singleton birth	96.3	66.7	<.0001
% Small (<2SD) for gestational age	0.9	10.8	<.002
% Oxygen at 36 weeks	–	33.3	
% Intraventricular haemorrhage grade III/IV and/or periventricular leukamalacia	–	10.8	
% Postnatal corticosteroid exposure (dexamethasone only)	–	5.9	
Family social background characteristics			
Mean (SD) maternal age (birth)	31.1 (4.4)	30.8 (5.1)	.66
% European ethnicity (birth)	98.1	89.2	<.02
% Un/semi-skilled family socio-economic status (2 years)[a]	11.1	34.3	<.01
Neurodevelopmental impairment			
% Moderate–severe cerebral palsy (4 years)	0	7.8	<.001
% Severe (>2SD) cognitive delay (6 years)	3.7	15.7	<.001
Early childhood education and school characteristics			
Mean (SD) age started preschool (months)	23.5 (12.3)	25.1 (10.9)	.33
Mean (SD) total months at preschool (at 4 years)	24.6 (14.1)	24.5 (12.6)	.94
Mean (SD) primary school decile rating[b]	6.6 (2.6)	6.9 (2.3)	.29
% school days attended in Year 1	93.7	93.9	.80

[a] Socioeconomic status defined according to Elley and Irving (2003).
[b] The decile ranking of New Zealand schools (from 1–10) is used as an indictor of SES, with high-decile schools constituting the highest 30% in SES, medium decile schools the middle 40%, and low decile schools the lowest.

2. Results

2.1. Clinical, social background and educational experiences of very preterm and full term children

Table 1 describes the clinical, social background and school experiences of the two study groups. Results revealed clear differences between the groups on measures of gestational age (p<0.001), birth weight (p<0.001), multiple births (p<0.001) and small for gestational age (birth weight >2SDs below that expected for gestational age p<0.01) [59,60]. No differences in gender composition were found between the groups. Use of postnatal corticosteroids in the VPT cohort was low (n=6). With regard to social background factors, children in the VPT group tended to come from families of lower SES (p<0.01). No between group differences were found for maternal age. At follow-up, VPT children had higher rates of severe cognitive delay (15.7% vs. 3.7%) and were more likely to have a diagnosis of moderate to severe cerebral palsy (CP; 7.8%/n=8 vs. 0%). In terms of educational characteristics, both groups had similar preschool experiences and were attending schools with comparable socioeconomic decile ratings.[2] No between group differences were found in terms of the age children started preschool, the total months spent at preschool or in the number of school days attended in Year 1 (ps>.05).

2.2. Early educational outcomes of children born very preterm

2.2.1. Performance on clinic based tests

Table 2 shows the mean standard scores and standard deviations for the VPT and full term groups on each of the three WJ-III subtests. The table also indicates the significance of group differences and their practical importance (effect size) using Cohen's d. This analysis was undertaken in three steps. First, mean scores for each subtest are reported for all children in the VPT and full term groups. Second, to assess the extent to which between group differences persisted after taking into account severe neurodevelopmental impairment, the above analysis was replicated excluding those children with severe cognitive delay and/or moderate to severe CP. Third, given the over-representation of lower socioeconomic status families in the VPT group, results are reported before and after SES was entered as a covariate.

As shown in Table 2, VPT children obtained lower scores than full term children on the Understanding Directions (p<.01) and Math Fluency subtests (p<.001). No group differences were found with mean Passage Comprehension scores. Examination of the extent to which group differences in academic achievement scores remained after the exclusion of children with severe impairments showed that educational delays were not confined to children with severe impairments. As shown in Table 2, although there was some attenuation in between group differences following the exclusion of these children, VPT children without neurodevelopmental impairment still performed significantly less well than full term children on

[2] The decile ranking of New Zealand schools (from 1–10) is used as an indictor of SES, with high-decile schools constituting the highest 30% in SES, medium decile schools the middle 40%, and low decile schools the lowest.

Table 2
Performance on Woodcock Johnson Tests of Achievement (WJ-III)

Measure	Full term ($n = 108$)	All VPT children ($n = 102$)	Very preterm (VPT)						
			p	Effect size	Adjusted for SES p	VPT without NDI ($n = 83$)	p^a	Effect size	Adjusted for SES p
WJ-III Math Fluency									
Mean (SD) standard score	101.20 (12.99)	86.18 (24.30)	<.001	.77	<.001	92.11 (19.31)	<.001	.62	<.001
WJ-III Understanding Directions									
Mean (SD) standard score	113.48 (7.91)	109.15 (11.45)	<.002	.44.	.02	111.74 (7.26)	<.03	.45	.14
WJ-III Passage Comprehension									
Mean (SD) standard score	113.00 (15.50)	108.88 (15.60)	<.04	.26	.22	111.11 (15.78)	.25	.17	.67

NDI = children with severe neurodevelopmental impairments.
For the Math Fluency subtest, 20 VPT children and 5 full term children were assigned a standard score of 40, the lowest possible score. All children were able to complete one or more items in the Passage Comprehension subtest correctly, while only one child in the VPT group was assigned a standard score of 40 on the Understanding Directions subtest.
[a] Contrasts made with children born full term without NDI.

the Math Fluency and Understanding Directions subtests ($p<.05$ and $p<.001$, respectively). These differences also persisted after adjusting for SES.

2.2.2. Performance on curriculum based tests

Similar analyses were conducted for the NumPA and the 6-year NET tests of numeracy and literacy skills, with results presented in Table 3a. Where percentages are reported, logistic regression analysis was used to assess the extent to which the reported group differences persist after statistical adjustment for SES. Results for the NumPA test of early numeracy skills showed that VPT children performed less well than full term children in all domains assessed and were significantly more likely to score below the national norms in Forwards and Backwards Number Sequences ($p<.001$) and Numeral Identification ($p<.001$). Furthermore, as seen in Table 3a, with the exception of Basic Facts and Operational Strategies, group differences remained significant when the analysis was restricted to the subsample of children without severe impairments and after adjustments were made for SES. Table 3b provides a summary of the performance of VPT children on the N.Z. NumPA Framework relative to end of Year 1 curriculum expectations and national norms, revealing that larger numbers of VPT children are falling within an "at risk" category. Compared to 32.8% of full term children, 51.8% of VPT children were working below the expected level for Year 1 and were classified as a student at risk or of concern, ($p<.05$).

Although fewer group differences were seen for the total VPT and full term sample on the 6-Year NET test of literacy skills, VPT children performed significantly less well than full term children on 3 out of the 5 indictors of early literary skills (i.e., Concepts about Print ($p<.003$), Reading Text ($p<.01$), and Writing Vocabulary ($p<.02$) and

Table 3a
Performance on curriculum-based tests

Measures	Full term ($n = 108$)	All VPT children ($n = 102$)	Very preterm						
			p	Effect size	p Adjusted for SES	VPT without NDI ($n = 83$)	p^a	Effect size	p Adjusted for SES
N.Z. early numeracy project [b]									
Operational strategies	2.17 (.98)	1.81 (1.11)	.04	.35	.04	1.93 (1.10)	.20	.23	.19
% Below national norm	16.0	25.8	.10	.24	.10	23.0	.29	.16	.34
Forwards number sequences	2.76 (.95)	2.11 (1.11)	<.001	.63	<.001	2.17 (1.09)	<.001	.58	<.001
% Below national norm	26.6	51.1	<.001	.50	.001	49.3	<.001	.52	<.001
Backward number sequences	2.44 (1.28)	1.67 (1.20)	<.001	.62	<.001	1.78 (1.22)	<.003	.53	<.002
% Below national norm	16.0	32.6	<.003	.44	<.002	31.5	<.01	.38	<.01
Numeral identification	2.39 (1.13)	1.62 (1.14)	<.001	.68	<.001	1.71 (1.14)	<.001	.60	<.001
% Below national norm	18.1	37.5	<.003	.43	<.002	34.2	<.014	.39	<.01
Place value	2.15 (1.09)	1.63 (1.15)	<.01	.47	<.004	1.78 (1.12)	<.04	.34	<.02
% Below national norm	20.2	26.4	.32	.15	.20	22.2	.58	.09	.34
Basic facts	1.52 (1.12)	1.02 (1.12)	<.01	.45	<.01	1.15 (1.15)	.09	.33	.10
% Below national norm [c]	0	0	–		–	0	–	–	–
Mean stage on numeracy framework	2.29 (.89)	1.70 (.97)	<.001	.61	<.001	1.80 (0.97)	<.01	.51	<.004
N.Z. 6 year NET reading project									
Concepts about print	5.62 (2.12)	4.56 (2.10)	<.003	.50	<.01	4.69 (2.10)	<.01	.44	<.02
% Below national mean	13.8	29.9	<.01	.39	<.01	27.4	<.04	.33	.06
Reading text	5.33 (1.83)	4.86 (2.34)	.28	.23	.40	5.10 (2.37)	.52	.11	.82
% Below national mean	15.3	31.0	<.02	.37	<.02	28.2	<.04	.33	<.05
Letter identification	6.63 (2.17)	5.79 (2.36)	<.03	.37	<.05	6.06 (2.30)	.11	.26	.19
% Below national mean	9.7	17.2	.14	.22	.20	15.1	.22	.19	.37
Writing vocabulary	5.19 (1.96)	4.32 (2.26)	<.02	.42	<.05	4.60 (2.24)	.11	.28	.25
% Below national mean	28.0	47.1	<.01	.40	<.04	42.5	.07	.28	.21
Hearing and recording sounds in words	5.62 (1.90)	5.03 (2.21)	.10	.29	.24	5.31 (2.22)	.37	.15	.71
% Below national mean	19.6	31.4	.07	.27	.17	26.0	.29	.16	.53
Mean 6-year NET Stanine Score	5.75 (1.70)	4.92 (1.88)	<.01	.47	<.02	5.16 (1.90)	<.05	.33	.15

[a] Contrasts made with Full Term without NDI.
[b] Numeracy Framework: Stage 0 indicates that a child is unable to count up to 10 objects or recognize numerals to 10. Stage 1 indicates that the child is able to count using concrete objects. Stage 2 indicates the child is able to identify numerals above10 and use more advanced arithmetic strategies, such as the min strategy [99] where relationships are recognized between numbers (e.g. 9 comes before 10, 7 comes after 6). At stage 2, the child may also demonstrate an emergent understanding of more advanced conceptual principles, including the base-10 number system (i.e., in the Place value subtest) and the recall of a number of basic addition answers by rote (i.e., in the Basic facts subtest). As can be seen in Table 3b below, children typically perform at Stage 2 level in Year 1.
[c] No stage expectancy for Basic facts indicator in Year 1.

Table 3b
National and VPT numeracy results compared to 2006 New Zealand curriculum expectations for Year 1

End of Year 1 curriculum expectations	5%	11%	39%	22%	21%	2%	0%	0%	0%
National norms	2.2%	10.9%	44.2%	24.2%	16.4%	2%	0%	0%	0%
Total VPT sample[a]	25%	26.8%	39.3%	8.9%	0%	0%	0%	0%	0%
VPT without NDI	23.4%	23.4%	42.6%	10.6%	0%	0%	0%	0%	0%
Numeracy stage	Stage 0 Emergent	Stage 1 One-to-one counting	Stage 2 Count from one on materials	Stage 3 Count from one on materials	Stage 4 Advanced counting by imaging	Stage 5 Early additive part–whole	Stage 6 Advanced additive part–whole	Stage 7 Advanced multiplicative part–whole	Stage 8 Advanced proportional part–whole
Achievement level	⟷ Students at risk in numeracy	⟷ Students who may cause concern	⟷ Students achieving at or above expectations			⟷ Students with high abilities in numeracy			

Reference: Appendices A–K: Patterns of Performance and Progress on the Numeracy Development Project: Looking Back from 2005. In *Findings from the New Zealand Numeracy Development Project 2005* (pp. 5–20 and pp. 115–127). Wellington: Ministry of Education.
[a] Contrasts were significant with full term children ($p<.05$), of whom 67.2% were achieving in the ranges of at or above end of Year 1 curriculum expectations.

were also more likely to score below national norms on these indicators ($ps<.02$). When children with severe impairments were excluded from the analysis, only group differences in the Concepts about Print indicator remained significant. However, VPT children without severe impairments were still more likely to score below national norms on Concepts about Print and Reading Text ($ps<.04$) and obtain a lower overall score on the 6-Year NET. After adjustments for SES, only group differences for Concepts about Print remained significant.

2.2.3. Teacher ratings

As shown in Table 4, examination of teacher rating of school achievement showed that irrespective of neurodevelopmental status, VPT children were 2 to 3 times more likely to be rated by their Year 1 teacher as performing at below average or delayed levels in math ($p<.001$), reading ($p<.001$), written language, language comprehension ($p<.01$), spelling ($p<.001$) and physical education ($p<.001$). Of the total VPT sample, 75% ($n=70$) were rated as below average or delayed in one or more academic skill areas and 56.4% ($n=53$) were below average or delayed in three or more areas. No significant between group differences were found in expressive language. Most marked amongst children born VPT was poor performance in math, with 44% ($n=41$) of VPT children rated as below average or delayed compared to only 14% ($n=14$) of full term children. The next most common areas of concern were physical education (39% vs. 10.5%), writing (45% vs. 17%), written language (48% vs. 22%), spelling (49% vs. 20%) and reading (50% vs. 25%). Moreover, between group differences in rates of delay were not accounted for by higher rates of severe neurodevelopmental impairments in the VPT group. As shown in Table 4, group comparisons excluding VPT and full term children with impairment yielded a highly similar pattern of results. However, when logistic regression analysis was used, group differences in reading appeared to be largely accounted for by family SES.

2.3. Learning disability

Fig. 1 shows the percentage of children in each group meeting criteria for a specific LD in math, reading or language comprehension according to the low achievement definition. Also shown are the number of children who had combined LD (i.e., concurrent math, reading and language LD) and one or more specific LD. Results revealed that VPT children had a significantly higher rate of any LD ($p<.01$). Specifically, of the 86 VPT children without severe cognitive delay, 54.7% ($n=47$) met criteria for a specific LD in reading, language or math relative to 36% ($n=37$) of the full term children with IQ scores ≥ 83. With regards to rates of LD in each academic domain, VPT children had relative risks of math impairment that were twice that of full term children (46.5% vs. 22.1%, $p<.0001$). No significant between group differences were found for rates of reading or language LD. However, a larger proportion of VPT children than full term children had combined LD (20% vs. 10%, $p<.05$). This pattern of results was largely unchanged by the inclusion of SES as a covariate in the analysis.

2.4. Sex differences

To examine the extent to which between group differences in educational achievement amongst the children without neurodevelopmental impairments might vary between boys and girls, the sample was stratified by sex, and tests of sex (male vs. female) by group (VPT vs. full term) interactions were conducted for the WJ-III subtests, NumPA and 6-year NET measures. To assess the extent to which between group differences in LD might also vary according to

Table 4
Performance on teacher rating scales

Class teacher ratings	Full term ($n=108$)	All VPT children ($n=102$)	Very preterm						
			p	Effect size	p Adjusted for SES	VPT without NDI ($n=83$)	P^a	Effect size	p Adjusted for SES
% Below average/delayed math	13.5%	43.6%	<.001	.67	<.001	37%	<.001	.62	<.001
% Below average/delayed reading	24.8%	48.9%	<.001	.50	<.01	39.5%	<.02	.36	0.07
% Below average/delayed written language	21.9%	47.9%	<.001	.58	<.001	35.5%	<.02	.34	<.02
% Below average/delayed expressive language	19.0%	29.8%	0.07	.25	0.14	23.7%	0.19	.20	0.22
% Below average/delayed language comprehension	14.3%	31.9%	<.01	.43	<.02	26.3%	<.02	.36	<.04
% Below average/delayed handwriting	17.1%	44.7%	<.001	.61	<.001	35.5%	<.001	.52	<.01
% Below average/delayed spelling	20.0%	48.9%	<.001	.62	<.001	38.2%	<.01	.45	<.01
% Below average/delayed physical education	10.5%	39.4%	<.001	.67	<.001	32.9%	<.001	.64	<.001
Grade point average (SD) for teacher ratings (i.e., total number of curricular domains for which below average/delayed performance was evident).	1.41 (2.12)	3.35 (3.00)	<.0001	.75	<.001	2.68 (2.82)	<.0001	.51	<.001

Note: teacher ratings on a scale in which 1 = delayed, 2 = below average, 3 = average, 4 = above average, 5 = advanced.
[a] Contrasts made with Full term without NDI.

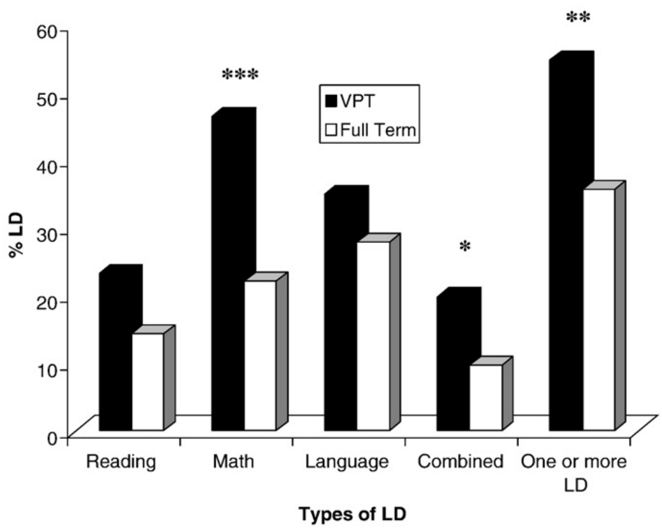

Fig. 1. Rates of learning disabilities (LD) in reading, math, language, and combined reading/math/language in full term and VPT children without severe cognitive delay, as defined by low achievement scores (>1SD below mean of full term group) on respective WJ-III subtests. *$p<.05$, **$p<.01$, ***$p<.001$.

child sex, similar analyses were also performed for the reported rates of LD. Overall, results of these analyses suggested that, in general, there were no significant interactions between sex and preterm status on later educational outcome at age 6. The only exception was a small interaction effect for the WJ-III Understanding Directions subtest ($p=0.04$), indicating a tendency for VPT boys to obtain lower scores on this test than VPT girls, but that boys and girls showed comparable performance in the full term group. In terms of specific LD, no significant sex by group interactions were observed.

3. Discussion

To date, research concerned with the educational progress of children born VPT has been largely restricted to performance in the middle-school years, with most studies relying heavily on standardized laboratory-based measures of academic achievement. In this study we examined the relationship between VPT birth and educational progress at corrected age 6 years using a range of measures spanning standardized measures, teacher report and school administered curriculum-based tests. Two issues of further interest were whether VPT children were at elevated risk of early LD and the extent to which male children born VPT might fare less well than their female peers. Strengths of the present study included the use of a demographically representative full term comparison group, high sample recruitment, and a comprehensive multi-method assessment approach. The major findings and implications of the study are reviewed below.

Across multiple measures and independent report sources, this study identified pervasive educational delays amongst VPT children by age 6 years. Compared to full term children, VPT children were at increased risk of performing less well on the math, reading and language subtests of the WJ-III Tests of Achievement and on curriculum-based school measures of numeracy and literacy skills. In addition, VPT children were 2 to 3 times more likely to be identified by their teachers as performing at below average or delayed levels across seven different curricular areas, spanning math, reading, spelling, language and writing skills. Moreover, with the exception of performance on the WJ-III reading and language subtests and teacher-based reading assessment, educational delays were not confined to the VPT children with severe neurodevelopmental impairments (i.e., moderate to severe CP and IQ≥83). Even VPT children free from moderate to severe CP and with at least low average IQ demonstrated lower scores on the WJ-III Math Fluency subtest compared to their full term peers. They were also identified as showing difficulties in 4 out of 6 curriculum-based measures of math proficiency (NZ NumPA) and achieving below national normative levels on a number of specific numeracy skills, including ability in backward and forward number sequencing and numerical identification. In addition, VPT children without neurodevelopmental impairment were rated by their teachers as being 2 to 3 times more likely to be achieving at below average or delayed levels relative to their classmates across six different curricular areas.

These results at 1 year post school entry are generally consistent with those found for older VPT children. For example, with respect to performance on academic achievement tests, lower scores on reading and math measures from the Woodcock-Johnson Psycho-Educational Battery have also been documented for VPT children at age 9 [40,61]. Unlike Hack et al. [40] however, we failed to find group differences in WJ reading at age 6 after the exclusion of children with neurodevelopmental impairments. In terms of teacher-report, VPT children had rates of reported difficulties that were identical to those found by Bowen et al. [13] in a study of extremely preterm children (GA<28 weeks) at age 8. In addition, teacher reported difficulties for our VPT sample were evident across a wide range of curricular areas, revealing a breadth of deficits in educational progress that has previously only been reported for extremely low birth weight VPT children in the middle school years [1,32]. O'Callaghan et al. [1] for instance, found that at age 9, children born extremely low birth weight were rated by their teachers as experiencing marked difficulties in math and several different aspects of reading, spelling and writing skills relative to their full-term classmates.

Also consistent with the broader preterm literature, the area of academic achievement in which the poorest performance was observed was math [7]. Specifically, VPT children showed clear and consistent difficulties in math across both laboratory and curriculum-based measures, as well as teacher report. By contrast, differences between VPT and full-term children on measures of reading that included the WJ-III Passage Comprehension subtest, the NZ 6-year NET and teacher report were largely explained by group differences in neurodevelopmental impairment and SES. Group differences in language were also less apparent, with group differences on the WJ-III Understanding Directions subtest reduced to non-significance after severe neurodevelopmental impairment and SES were taken into account.

Several previous studies have also demonstrated a greater impact of VPT birth on math than on reading that is independent of neurosensory and global intellectual impairments [7,45]. For example, studies of VPT children aged between 8 and 14 years excluding children with IQ≤80, have found VPT birth to be linked with impaired performance on academic achievement tests of math, but not reading [3,45,61–63]. Thus, there is some suggestion that math may be a particular area of educational vulnerability for children born VPT [14,45]. The breadth of math difficulties revealed in our VPT sample implies that a number of different aspects of math cognition such as calculation, number sequencing and the accurate visual identification of numerals were problematic. These findings are of some concern given that ability in math at school entry is a strong predictor of later educational success, and has been shown to be more predictive of later outcomes than early reading ability [64].

In addition, among children with IQ>83 we found higher rates of specific LD in math amongst the VPT group, with VPT children being more than twice as likely as full term children to have math LD (47% vs. 21%). Without exception, the few studies that have examined VPT birth in relation to specific LD in children with at least low average IQ (≥80) have focused on VPT children aged between 7 and 11 years. Furthermore, results have been mixed. While several of these studies have failed to show a higher prevalence of LD amongst VPT children compared to full-term children [3,42–44], others have reported higher rates of math and reading LD [7,41], as well as combined reading/math or other LD [38,65]. More often than not, however, risks of LD in cohorts of VPT children have typically been considered only amongst children born extremely low birth weight (<750 g), rather than for all children born VPT [7,38].

Examination of other types of specific LD in our study also revealed higher rates of combined math/reading/language LD in the VPT group. Specifically, the rate of combined LD in the VPT group was twice that of the term born group (20% vs. 10%). In addition, VPT children were also more likely to be subject to one or more LDs (55% vs. 37%). These differences remained significant even after controlling for SES. No group differences in rates of LD were found for reading or language. Thus, our findings tend to confirm previous evidence for higher rates of LD amongst VPT children [7,38,41] whilst expanding this to include younger VPT children. In addition, our findings of higher rates of LD in math for the VPT group also lend further support for the link between math disabilities and VPT birth.

The final key finding was that virtually no sex differences in the early educational outcomes of VPT children were evident by age 6. Unlike prior evidence to suggest that male children born VPT may be at increased risks of learning problems and specific or combined LD [2,6,45], we found no evidence to suggest that VPT birth was associated with higher rates of educational risk or specific or combined LD in boys only. Rather, findings showed that the risk of later educational difficulties were similar for boys and girls born VPT. These findings converge with a growing number of more recent studies that have also failed to find sex specific effects in learning abilities [7,8,32,66].

More generally, this study clearly demonstrates that pervasive educational delays are common and detectable in VPT children at early school age and in particular within 1 year of starting school. They also highlight the importance of early identification and intervention to minimize the impacts of these early learning challenges on educational attainment and learning motivation. Matthew effects in education [67,68], whereby initially modular learning deficits often broaden into a generalised intellectual difficulty are well recognized. This is particularly true for reading and math [67,69,70] with initial difficulties in these areas often becoming compounded by the negative motivational consequences of failure. Thus, there is a need for teachers to be well informed about the potential difficulties facing some VPT children as they make the transition to school and to ensure that they are provided with the necessary resources to support the learning requirements of these children in their classrooms. Knowledge of the neurocognitive deficits that often characterise preterm children may also be invaluable for educational professionals and teaching assistants. For example, multivariate assessments of executive skills or ability in the execution and regulation of purposeful goal-directed behaviors in VPT children within the context of average IQ scores have been helpful in identifying distinct cognitive weaknesses associated with VPT birth [71,72].

Impaired working memory, for instance, is a robust finding amongst VPT samples [71,73–76]. Reduced inhibitory control is also common, with VPT children often showing a more impulsive response style than full term children [77–79]. In addition, several studies now report that such deficits are evident in VPT children before school entry. For example, Edgin et al. [80] found VPT children showed deficits on measures of behavioral inhibition and mental flexibility that persisted between the ages of 2 and 4 years, while Vicari et al. [75] found VPT children demonstrated impaired selective attention at age 2. Importantly, differences between full term and VPT children in executive function have been found to account for variance in classroom performance. For example, in a U.K. study of 180 extremely preterm children and 160 full term children attending mainstream school at age 6, Marlow et al. [81] found that poor ability in visuospatial function, planning, and inhibition contributed independently to teacher rated school failure. Outside of the preterm literature, a study by Assel et al. [82] found that individual differences in executive processes moderated later educational outcomes, particularly in math, while a number of other studies suggest that working memory and inhibitory control independently predict math competence in preschoolers and are important for reading acquisition (see [83], for a review).

Other developmental and neuropsychological challenges that are relatively common to children born VPT include mild forms of motor impairment or developmental coordination disorder [84], visual–motor difficulties [85] and processing speed difficulties [86]. In addition, in terms of externalizing behavioral problems, inattention is the most commonly reported problem experienced by VPT children [72,87–89], with a number of other studies also reporting increased rates of hyperactivity [16,90,91]. These subtle, but clinically significant, impairments are likely to have ongoing consequences for academic achievement.

Alerting educational professionals to the difficulties that often face the preterm survivor is a critical first step in helping classroom teachers to address these challenges. Potential support strategies include the provision of skill scaffolding and the teaching of metacognitive aids. For example, given that working memory deficits and inattention are common problems in VPT children, providing guidelines for minimizing working memory overload and managing off-task or inattentive behavior will be particularly important. For instance, children's memory for tasks is often improved through frequent repetition of instructions [92] and breaking instructions down into smaller units. The learning progress of children with poor working memory skills may also be improved by reducing working memory demands in the classroom. Providing children with self help strategies such as a memory checklist or other such memory aids may help reduce processing demands while increasing children's self awareness of working memory demands might help to reduce frustration [93,94]. With regards to managing inattentive behavior, group alerting cues and class participation have been found to improve attention [95,96]. Other studies of proactive classroom management show that the provision of 'attention breaks' after the completion of focused activities and training students to transition quickly between activities makes for more effective use of the student's level of attention [97,98].

3.1. Summary

In summary, the key findings of this study were as follows: 1) clear educational delays were evident in VPT children at age 6 across multiple measures of math, reading and language in both laboratory and school-based settings; 2) poor school function was not restricted to VPT children with neurodevelopmental impairments; 3) VPT birth is associated with higher rates of LD in math at age 6; and 4) with the exception of WJ-III scores for language, few sex differences were evident amongst children born VPT. Early identification and raising awareness amongst educators and schools ought to be a priority, alongside developing a better understanding of the risk and protective factors influencing VPT children's educational achievement.

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