Pattern of Learning Disabilities in Children With Extremely Low Birth Weight and Broadly Average Intelligence

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Objectives: To examine the prevalence and pattern of specific areas of learning disability (LD) in neurologically normal children with extremely low birth weight (ELBW) (≤800 g) who have broadly average intelligence compared with full-term children with normal birth weight of comparable sociodemographic background, and to explore concurrent cognitive correlates of the specific LDs.

Design: Longitudinal follow-up; geographically defined region.

Setting: Regional follow-up program.


Participants: One hundred fourteen (87%) of 131 children with ELBW born between 1982 and 1987 were seen at ages 8 to 9 years. Of the 114 children, 74, who were neurologically normal, with a Verbal or Performance IQ greater than or equal to 85, formed the study group. A group of 30 full-term children with normal birth weight and similar sociodemographic status comprised a comparison group. The children were predominantly white and middle class.

Results: Significantly more children with ELBW (65%) met criteria for LD in 1 or more areas compared with 13% of the comparison children. In the ELBW group, the most frequently affected area was written output, then arithmetic, then reading. Visuospatial and visual-motor abilities in combination with verbal functioning primarily explained performance in arithmetic and reading among children with ELBW, unlike the control children, whose scores were associated only with verbal functioning.

Conclusions: Complex LDs in multiple academic domains are common sequelae among broadly middle class, predominantly white, neurologically normal children with ELBW compared with control peers. The developmental etiology of LDs in children with ELBW and control peers differs.

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Most children born with extremely low birth weight (ELBW) demonstrate IQ scores within broadly normal limits.1,2 Despite seemingly adequate cognition, these children frequently experience difficulties in academic achievement, attention, and fine motor functioning.3 School difficulties appear to be the main sequelae in children with ELBW.4,5,6 School-aged children with ELBW, when compared with their peers with normal birth weight, have significantly higher rates of educational assistance, grade failure, and placement in special classes.7,8,9 and score significantly lower on standardized tests of mathematics, reading, and spelling,8,9,10,11 with arithmetic standing out as a common problem area. Even neurologically intact children with ELBW who have average intelligence demonstrate poorer academic achievement than their full-term peers with normal birth weight.10,11

Risk for learning disabilities (LDs) increases as birth weight decreases. In one of the few studies that has included significant numbers of ELBW survivors at the threshold of viability, children whose birth weights were less than 750 g performed more poorly on measures of mathematics, reading, and spelling than both full-term children and children with low birth weights in a heavier range (751-1499 g).12,13 In general, among survivors of ELBW, developmental risks appear to increase with decreasing gestational age and birth weight.
PATIENTS AND METHODS

POPULATION

ELBW Cohort

Between January 1982 and December 1987, 298 infants with birth weight less than or equal to 800 g were admitted to the neonatal intensive care unit at the Children and Woman's Health Centre of British Columbia (Vancouver), which was, at that time, the only tertiary neonatal intensive care unit in the province. Of the 131 children who survived to school age, 114 (87%) were seen at age 9 years. Children with major neurosensory impairments (bilateral blindness, defined as visual acuity worse than 20/200 in the better eye with optimal refractive correction; hearing loss uncorrectable by amplification; nonambulatory cerebral palsy; and/or IQ ≤ 69) (n = 18) were excluded. An additional 39 children were excluded due to ambulatory cerebral palsy and/or Verbal IQ (VIQ) and Performance IQ (PIQ) scores of 70 to 84. The study target group, therefore, was composed of 74 neurologically normal children (30 boys, 44 girls) with VIQ or PIQ scores greater than or equal to 85.

Full-Term Controls With Normal Birth Weight

For the comparison group, 40 children born at full term between 1983 and 1984 were recruited at age 3 years through community centers and health clinics in districts with similar SES distributions to our overall ELBW population. The comparison children were followed up prospectively, with 37 (93%) of 40 seen at school age. At the time the comparison children were recruited, SES was comparable in the 2 groups. However, at age 9 years, there were differences, with overall maternal education higher in the comparison group. Therefore, for this study, 30 of the comparison children (15 boys, 15 girls), whose maternal educational level most closely matched that of the study group, were selected for the control group. This selection was carried out blind to all other variables. Perinatal and demographic characteristics for both groups are presented in Table 1. The groups did not differ significantly in maternal education or ethnicity.

ASSESSMENT PROCEDURES

The study was approved by the clinical research ethics board of the University of British Columbia (Vancouver). Informed parental consent was obtained at the time of recruitment to the Neonatal Follow-up Programme at the Children's and Women's Health Centre of British Columbia (Vancouver). Standardized psychoeducational assessment of cognition, academic achievement, memory, and visual-motor integration was carried out in the Neonatal Follow-up Programme. The assessment battery included the Wechsler Intelligence Scale for Children, the Gray Oral Reading Test–Revised (GORT-R), the Reading (Word Recognition), Spelling, and Arithmetic subtests that comprise the Wide Range Achievement Test–Revised (WRAT-R), the Spontaneous Writing subtest from the Test of Written Language-2 (TOWL-2), the Developmental Test of Visual-Motor Integration, and memory subtests from the Stanford-Binet Intelligence Scale, Fourth Edition. Test protocols were scored using the age calculated from date of birth with no adjustment for prematurity.

Learning disabilities were identified using a low-achievement criterion. Complex functional academic outcome was of interest. Performance on paragraph reading and comprehension (GORT-R) was, therefore, used to assess LD in reading, and complex written output of story writing (TOWL-R) was used to assess LD in written output. The criterion for LD was a standard score of more than 1 SD below the mean of 100 (ie, <85) on each domain. For children with normal intelligence, an achievement score less than 85 indicates that the child is not meeting expected age-appropriate standards for that academic subject. This cutoff is at the 16th percentile, which is consistent with previous research in LD subtyping.

Subtypes of LD were examined, following the criteria of Rourke and Strang for examining discrepancies among VIQ, PIQ, and fundamental academic tasks of the WRAT-R. The prevalence of NLD and VI were examined using discrepancy criteria following the methodology of Harnadek and Rourke. Children without a VIQ-PIQ discrepancy but low scores in Reading, Spelling, and Arithmetic subscales were designated as having low achievement. In addition, children with discrepancies between either VIQ or PIQ and scores on the WRAT-R Reading (Word Recognition) and Arithmetic subscales were examined and referred to as “other LD.” Children who had low scores only on the WRAT-R Spelling subscale were not considered to have an LD no matter how their Spelling subscale scores were relative to other domains.

DATA ANALYSIS

The Fisher exact test was used to compare the incidence and pattern of LD between the ELBW and control groups. One-way multivariate analysis of variance followed by t tests was carried out on the set of cognitive and achievement test scores to compare the performance of the 2 groups. Stepwise regression analysis was used to examine the relationships between academic achievement and cognitive, visual-motor, and memory abilities, separately for each group. Stepwise regression analysis was carried out on each academic domain (reading, arithmetic, and written output) separately, with the following independent variables: VIQ, PIQ, the Developmental Test of Visual-Motor Integration, and the short-term visual memory (Bead Memory) and short-term auditory memory (Memory for Sentences) subtests from the Stanford-Binet Intelligence Scale for Children.
normal birth weight and of comparable sociodemographic background. A standardized test battery was used in both groups to assess the occurrence of reading, arithmetic, and written output LDs. We hypothesized that the ELBW group would show higher rates and different patterns of LDs in reading, arithmetic, and written output, as well as more multiple LDs than the comparison group. It was also expected that the ELBW and control groups would show different relationships between each type of LD and cognitive, memory, and visual-motor abilities.

The specific aims of the study were to compare (1) the prevalence of LD in reading, arithmetic, and written output, (2) the relationships between academic achievement and cognitive, memory, and visual-motor abilities, and (3) the rates of nonverbal LD (NLD) and verbal impairment (VI) subtypes between children with ELBW and their socially comparable peers.

Children in the ELBW group scored significantly lower than the comparison group on all measures (Table 2).

### PREVALENCE OF LD

Forty-eight children in the ELBW group (65%) met criteria for LD in 1 or more areas compared with 4 in the control group (13%) (odds ratio [OR], 12.0; 95% confidence interval [CI], 0.4-38.1; *P* < .001). Rates of LD in written output, arithmetic, and reading differed significantly between the ELBW and control groups. In written output, 40 children with ELBW (54%) compared with 2 controls (7%) (OR, 16.5; 95% CI, 3.7-74.3; *P* < .001) were identified as having an LD; in arithmetic, 22 of the children with ELBW (30%) compared with 2 controls (7%) (OR, 5.9; 95% CI, 1.3-27.1; *P* = .01) had an LD; and in reading, 17 of the children with ELBW (23%) compared with 2 controls (7%) (OR, 4.2; 95% CI, 0.9-19.4; *P* = .06) were identified as having an LD. Of the 48 children with ELBW and LD in 1 or more areas, written output was the single most frequently affected domain, affecting 40 (83%) of 48, followed by arithmetic in 22 (46%) of 48, and reading in 17 (35%) of 48. Prevalence rates of problems in each academic area are shown in Figure 1.

There were striking differences between the ELBW and control groups in the prevalence of complex LDs affecting multiple domains (Figure 2). Learning disabilities affecting more than 1 domain occurred in 22 (30%) of 74 children with ELBW compared with 1 of 30 controls (OR, 12.3; 95% CI, 1.6-95.8; *P* < .003). Of the 48 children with ELBW and LD, 22 (46%) had an LD in more than 1 area as opposed to only 1 from the control group. In the ELBW group, 9 (19%) had an LD in all 3 domains (written output, arithmetic, and reading), 5 (10%) in reading and written output, 7 (15%) in arithmetic and written output, and 1 (2%) in reading and arithmetic. The one control child with an LD in more than 1 area had low scores in arithmetic and written output. Reading as the sole area of LD was equally prevalent in both groups (3%). Among the 74 children with ELBW, 14 (19%) had either a VIQ or PIQ score less than 85. Therefore, overall low achievement in these cases might be expected. To ad-

### Table 1. Demographic and Perinatal Characteristics of ELBW and Control Groups

<table>
<thead>
<tr>
<th>Variable</th>
<th>ELBW (n = 74)</th>
<th>Control (n = 30)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Birth weight, g</td>
<td>718.8 (480-800)</td>
<td>3540 (2948-4706)</td>
</tr>
<tr>
<td>Gestational age, wk</td>
<td>26.0 (23-33)</td>
<td>40.0 (38-40)</td>
</tr>
<tr>
<td>Ventilation, d</td>
<td>52.7 (0-137)</td>
<td>0</td>
</tr>
<tr>
<td>Level III NICU, d</td>
<td>108.8 (24-411)</td>
<td>0</td>
</tr>
<tr>
<td>Maternal education, y</td>
<td>12.1 (6-19)</td>
<td>12.6 (7-16)</td>
</tr>
<tr>
<td>White race, %</td>
<td>87</td>
<td>83</td>
</tr>
<tr>
<td>Age at assessment, y</td>
<td>9.0 (8.4-12.5)</td>
<td>9.3 (8.96-10.0)</td>
</tr>
</tbody>
</table>

*Data are given as mean (range). ELBW indicates extremely low birth weight; NICU, neonatal intensive care unit.

### Table 2. Psychometric Test Scores of ELBW and Control Groups

<table>
<thead>
<tr>
<th>Test</th>
<th>ELBW (n = 74)</th>
<th>Control (n = 30)</th>
<th>P Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Full-Scale IQ</td>
<td>99.3 (10.9)</td>
<td>117.3 (13.0)</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>Verbal IQ</td>
<td>101.2 (10.3)</td>
<td>116.8 (9.9)</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>Performance IQ</td>
<td>98.0 (12.9)</td>
<td>115.0 (15.8)</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>Paragraph Reading (GORT-R)</td>
<td>93.1 (14.1)</td>
<td>106.9 (15.2)</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>Word Reading (WRAT-R)</td>
<td>94.5 (16.5)</td>
<td>107.0 (14.1)</td>
<td>.001</td>
</tr>
<tr>
<td>Arithmetic (WRAT-R)</td>
<td>90.3 (11.0)</td>
<td>99.9 (10.5)</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>Written Story (TOWL-2)</td>
<td>87.0 (17.9)</td>
<td>105.5 (17.1)</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>Number of words in story (TOWL-2)</td>
<td>73.7 (50.7)</td>
<td>120.4 (53.6)</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>Beery Developmental Test of VMI</td>
<td>94.0 (10.8)</td>
<td>106.3 (8.0)</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>Visual Memory</td>
<td>45.1 (7.0)</td>
<td>51.2 (7.3)</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>Memory for Sentences (TOWL-2)</td>
<td>51.7 (8.4)</td>
<td>55.9 (5.2)</td>
<td>.02</td>
</tr>
</tbody>
</table>

*Data are given as mean (SD) unless otherwise indicated. ELBW indicates extremely low birth weight; GORT-R, Gray Oral Reading Test–Revised; WRAT-R, Wide Range Achievement Test–Revised; TOWL-2, Test of Written Language-2; and VMI, Visual-Motor Integration.
dress this issue, WRAT-R Reading and WRAT-R Arithmetic scores were examined. Among the 14 children, 6 scored higher than 85 in both WRAT-R Reading and WRAT-R Arithmetic, 5 scored lower than 85 in one of the tests, and 3 scored lower than 85 in both tests. Only 1 control child had either a VIQ or PIQ score lower than 85; both WRAT-R Reading and WRAT-R Arithmetic scores for this child were higher than 85.

**RELATIONSHIPS BETWEEN ACADEMIC ACHIEVEMENT AND COGNITIVE, VISUAL-MOTOR, AND MEMORY ABILITIES**

Reading achievement was significantly associated with VIQ and short-term visual memory for the children with ELBW ($F_{2,71} = 17.65; P = .001$), with a multiple correlation of $R = 0.58$. Verbal IQ accounted for 28% of the variance and visual memory explained a further 5%. In the control group, VIQ was the only significant factor associated with reading ($F_{1,28} = 14.61; P = .001$), with a multiple correlation of $R = 0.59$ accounting for 34% of the variance. Arithmetic achievement was significantly associated with Visual-Motor Integration and VIQ for the children with ELBW ($F_{2,71} = 13.43; P = .001$), with a multiple correlation of $R = 0.52$. Visual-Motor Integration accounted for 19% of the variance and VIQ explained a further 8%. In the control group, VIQ was the only significant factor associated with arithmetic ($F_{1,28} = 12.76; P = .001$), with a correlation of 0.56 accounting for 31% of the variance. Written output was significantly associated only with PIQ for both groups: ELBW ($F_{1,72} = 10.27; P = .002$), with a correlation of 0.35, accounting for 13% of the variance; and control ($F_{1,28} = 6.30; P = .02$), with a correlation of 0.43, accounting for 18% of the variance.

**LD SUBTYPES**

The prevalence of NLD and VI subtypes following the model of Harnadek and Rourke, and other LD based on VIQ, PIQ, and academic discrepancies, are presented in Table 3. Criteria for NLD were met by 10 children with ELBW (13%) vs 0 controls; 5 children with ELBW (7%) and 1 control (3%) were classified as verbally impaired. An additional 19 children with ELBW (26%) compared with 2 control children (7%) were classified as other LD (Rourke’s subtype 2) because they displayed significantly lower Reading and/or Arithmetic subscale scores compared with their VIQ or PIQ scores (but did not show a significant discrepancy between VIQ and PIQ). A total of 41 children in the ELBW group (55%) compared with 3 in the control group (10%) met the criterion for either NLD, VI, or other LD. An additional 7 children with ELBW and 0 controls had low achievement scores (standard score on the WRAT-R <85 in Word Recognition or Arithmetic), without a discrepancy with IQ.

To the best of our knowledge, this is the first study to examine the prevalence of domains of LD and the specific patterns of LD in children with ELBW. In this study, only children with broadly normal intelligence and no sensory or motor impairment were included. Thus, this study examined academic outcomes of the most intact of the preterm survivors of neonatal intensive care. Yet, despite broadly normal intellectual functioning, the children with ELBW in this study were at significant risk for LDs in written output, arithmetic, and reading, in that order. They were also much more likely than full-term children to display LDs in multiple academic domains. To have an LD in reading and not in other areas is rare among children with ELBW. All but 2 of the ELBW group who displayed LD in reading had coexisting LD in arithmetic or written output unlike their full-term peers with normal birth weight. Thus, the complexity of LDs in children with ELBW has probably been underestimated in the past. Our study demonstrates the co-occurrence of LDs in multiple domains and provides initial evidence that LD is more complex in ELBW samples compared with children born at full term. The academic difficulties of the children with ELBW in our study reflected multiple weaknesses in visuospatial, visual-motor, and verbal abilities. Moreover, different psychological factors were related to each LD domain, and these factors differed between the ELBW and control groups.

In a thoughtful editorial, McCormick pointed out that in studies of long-term follow-up, outcome is often confounded by race and poverty. Further, the variation in social status may be too limited in samples of chil-
Children of low SES to allow the effect of the postdischarge environment to be assessed. Saigal and colleagues followed up a regional cohort of infants with birth weight less than or equal to 1000 g (born between 1977 and 1981) and reported a significant disadvantage in intellectual status and academic achievement in these children compared with controls at age 8 years and during adolescence. The sample was also Canadian, predominantly white, English-speaking, and had access to universal health care, comparable to our sample (but included children with birth weight up to 1000 g). Saigal et al found that 58% of teenagers with low birth weight had either repeated a grade or were receiving special educational assistance compared with 13% of controls. This is comparable to our control group, of which 10% displayed an LD despite their relatively high IQs. In an ELBW cohort whose functional outcome was described in an earlier study of children born between 1974 and mid 1985, 60% of the children showed either borderline intelligence or an LD. The children in our study were born more recently, between 1982 and 1987; however, the high rate of LDs was still evident. Thus, children with ELBW from predominantly middle-class, relatively advantaged environments display an excess of developmental and/or academic problems. A major difference in children with ELBW from disadvantaged backgrounds is the high rate of global intellectual impairment. This outcome is far less evident in children with ELBW from more socially advantaged circumstances, who typically have lower IQs than their peers, increased prevalence of IQ in the borderline range (70-84), or have normal IQs but with LDs.

In another study, Klebanov et al found that after controlling for SES and family variables, children with birth weight less than or equal to 1000 g still had poorer scores on measures of language and attention. There is ample evidence that very low SES compounds the risk of preterm birth or other adverse biological beginnings. Low SES appears, however, to influence intelligence and language development most directly whereas there appears to be a biologically based vulnerability to complex visual processing skills. The interactive developmental determinants of risk, resilience, and protective factors are currently of considerable interest since understanding these dynamics will lead to opportunities for environmental intervention.

Examination of LD subtypes suggests that twice as many children with ELBW have an NLD compared with a VI, confirming the findings of ourselves and others of the relative vulnerability of visuospatial, visual-motor, and nonverbal reasoning domains in this population rather than specific verbal difficulties. The results of our study suggest that this subtyping approach significantly underestimates NLD in children with ELBW and that it is essential to evaluate complex written output in this population, which is not routinely done in clinical follow-up and rarely reported in follow-up studies. Moreover, the relative strength in verbal functioning does not imply that language functioning is spared. Differences in language development are apparent at age 3 years and at early school age. Furthermore, the main academic tasks used to assess LD in this study (paragraph reading and comprehension, story writing, and arithmetic calculation) involve complex skills, including planning, sequencing, inhibition, and executive functions. These are higher-order skills known to be compromised in children with low birth weights. Executive function is critical to attention, memory, and learning.

Our findings are consistent with previous reports of greater relative deficits in visuospatial processing, visual-motor integration, and achievement in mathematics relative to other abilities. Our results are compatible with previous findings that both spatial and sequential functioning contribute to ability to carry out arithmetic calculation in a study using task-related electroencephalograph measures. Furthermore, Saigal and colleagues have found that arithmetic performance deteriorated over time.

Due to recent medical advances, increasing numbers of newborns with ELBW are surviving, and relatively few of these children will have severe sensory or motor impairments as sequelae. Indeed, most survivors of birth weight less than or equal to 1000 g who are not socially deprived have intelligence within the broadly defined average range in middle childhood. Yet, although the mean IQ for children with low birth weight is often reported to be within the average range, rates of below-average IQ are significantly greater among ELBW compared with comparison groups of children with normal birth weight. Currently, the concerns related to academic achievement have become more salient as the growing number of survivors of ELBW begin to attend school. While major functional impairments are most likely to be noticed relatively early in life, more subtle learning difficulties may not be detected until school entry or until academic demands increase as the child progresses through school grades. Performance in school is an important indicator of how children with ELBW will ultimately fare in the world. Visuospatial and visual-motor functioning are particularly vulnerable areas in children with ELBW and interact with verbal abilities to affect all aspects of the school curriculum.

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