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REGULAR ARTICLE

Reading deficits in very low birthweight children are associated with vocabulary and attention issues at the age of seven

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Keywords
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ABSTRACT

Aim: This Swedish study compared reading skills between seven-year-old children with a very low birthweight (VLBW) and controls with a normal birthweight, exploring associations between reading variables and cognition, parent-rated behaviour, perinatal factors and family factors.

Methods: We studied 51 VLBW children, with no major neurodevelopmental impairments and attending their first year at a regular school, and compared them with the 51 sex- and age-matched controls. The test battery, carried out at 7.8 ± 0.4 years of age, included reading skills, the Wechsler Intelligence Scale for Children – III and the Child Behaviour Checklist.

Results: Very low birthweight children with a mean birthweight of 1105 g (±291 g) and a gestational age of 28.8 (±2.2) weeks scored significantly lower in all reading subtests and cognition and demonstrated more behavioural problems than normal birthweight controls. We also found significant associations between poor vocabulary, combined with attention problems, and phonological awareness, rapid naming and spelling control. Perinatal factors had no association with reading function, and socio-economic factors had very few.

Conclusion: Very low birthweight children demonstrated deficits in all reading domains and had poorer cognition and more behavioural problems at the age of seven, with reading ability related to vocabulary and attention.

INTRODUCTION

Cognitive deficits, behavioural problems and learning difficulties occur more frequently among school-age children with a very low birthweight (VLBW) of <1500 g, and in particular in children with an extremely low birthweight (ELBW) of <1000 g, than children born at term (1–5). The effects of poor academic achievement in primary school persist through adolescence and into young adulthood for VLBW and ELBW infants (6,7).

Studies in several countries have demonstrated that preterm children are at risk of problems related to language and literacy development at both preschool and school (3,8–10). Most studies focusing on reading achievement have reported differences in reading skills between VLBW children and term controls, and this finding seemed to apply to most components of reading, such as word decoding, word recognition and reading comprehension (11). The reading process can be divided into two parts: word decoding and reading comprehension. Word decoding means the individual's skill to identify single words

Abbreviations

AGA, Appropriate for gestational age; BPD, Bronchopulmonary dysplasia; CBCL, Child Behaviour Checklist; CTOPP, Comprehensive Test of Phonological Processing; ELBW, Extremely low birthweight; GA, Gestational age; IVH, Intraventricular haemorrhage; PVL, Periventricular leukomalacia; RDS, Respiratory distress syndrome; ROP, Retinopathy of prematurity; SD, Standard deviation; SGA, Small for gestational age; TOWRE, Test of Word Reading Efficiency; VLBW, Very low birthweight; WISC-III, Wechsler Intelligence Scale for Children.

Key notes

- This Swedish study compared reading skills between 51 seven-year-old children with a very low birthweight (VLBW) and 51 sex- and age-matched controls with a normal birthweight.
- We found that behavioural problems, cognitive deficits and learning difficulties occurred more frequently among children with a VLBW.
- They scored worse than normal birthweight children in reading skills, and their vocabulary and attention were related to reading ability.

(orthographic decoding) and perform a phonological decoding of written language. Reading comprehension is a product of both orthographic and phonological decoding ability and of cognition and vocabulary.

However, only a few studies have examined the specific factors underlying reading disabilities in VLBW children. Although VLBW children usually demonstrate lower performance on tasks measuring various aspects of literacy skills than term controls, Samuelsson et al. (12) showed that their reading and spelling deficits were not typical of specific reading disabilities. Instead, reading deficits in VLBW children were better described as a product of developmental or behavioural delays. Wolke et al. (13) indicated that general cognitive deficits were responsible for specific language or phonetic awareness problems in ELBW children. Deficits in executive function skills, including direct goal-oriented behaviour and working memory, were reported to be associated with learning skills (5) and reading and parent-rated child behaviour in preterm born children (14,15).

A review study showed an increase in behavioural problems among low birthweight children, especially poor attention span and withdrawn behaviour (16). However, very few studies have addressed the association between reading ability and behaviour or the impact of perinatal risk factors and family factors on reading skills in VLBW schoolchildren.

Our study compares reading development among VLBW school-aged children in regionally based samples with normal birthweight controls, using identical reading tests during the early school years. It reports the results of reading ability, cognition and parent-rated behavioural problems of seven-year-old Swedish children during the second term of their first grade at a regular school. A second objective was to explore how behavioural problems, cognition, socio-economic family characteristics and perinatal risk factors related to reading abilities during the first school year.

PATIENTS AND METHODS

VLBW children

All children with a birthweight of ≤1500 g who were born in the south-east region of Sweden from January 1998 to December 1998 were included in the study. Of the 118 VLBW infants, 94 (80%) survived the neonatal period. In Sweden, formal education begins in the autumn of the year that the child turns seven. The children were enrolled in the study during the second term of their first grade, and their parents were sent letters inviting them to participate. We excluded eight children because they lived in a geographically remote area (n = 4), they had not enrolled in school by the start of the study (n = 3), a criterion for inclusion, or their medical records had been lost (n = 1). Of the remaining 86 children, 56 (65%) agreed to participate, but five were subsequently excluded because their parents did not complete the behaviour questionnaire properly, which was one of the main instruments in the study. This meant that 51 children – 32 girls and 19 boys – participated in the study at a mean age of 7.8 ± 1 SD (±0.4 years). No significant differences were found in birthweight, gestational age, Apgar scores or severity of neonatal diagnosis between the children who were assessed and the 30 who declined to take part and the five lost to follow-up (Table 1).

Table 1 Background data for very low birthweight (VLBW) and missing VLBW children

Neonatal variables	VLBW n = 51	Missing VLBW n = 35
Birthweight, mean (SD), g	1105 (291)	1172 (278)
Birthweight, min–max, g	555–1490	410–1495
SGA (Birthweight, ≤−2 SD), n (%)	29/51 (57)	19/35 (54)
ELBW (Birthweight ≤1000 g), n (%)	16/51 (31)	8/35 (23)
Gestational age, mean (SD), weeks	28.8 (2.2)	29.6 (2.9)
Gestational age, min–max, weeks	25–34	25–35
Apgar, 5 min, mean (SD)	8.6 (1.7)	8.0 (1.7)
RDS, n (%)	23/51 (45)	14/35 (40)
Ventilator (>24 h), n (%)	18/51 (35)	15/35 (43)
BPD, n (%)	14/51 (27)	4/33 (12)
Sepsis, n (%)	14/51 (28)	5/33 (15)
IVH, n (%)	1/45 (2)	1/31 (3)
PVL, n (%)	2/44 (5)	0
Retinopathy of prematurity, n (%)	2/49 (4)	0

Perinatal data were collected, with parental approval, using medical registers. The medical history that was recorded included: parity, gestational age, birthweight, small for gestational age (SGA), ELBW, respiratory distress syndrome (RDS) and mechanical ventilation for more than 24 hours. Bronchopulmonary dysplasia (BPD) was defined based on radiographic findings and the clinical criteria of oxygen dependency at 36 weeks of gestational age (GA). Sepsis was defined as a positive blood culture in a child with clinical symptoms of infection. Severe brain damage referred to grade 3–4 intraventricular haemorrhage (IVH) or periventricular leukomalacia (PVL) as seen on ultrasound during the newborn period. Grade 2 or more retinopathy of prematurity (ROP) was noted. Table 1 provides details on this, including the missing children.

Mean birthweight in the VLBW group was 1105 g, and mean gestational age was 28.8 weeks. Three children were diagnosed with IVH (grade 3) or PVL on neonatal cranial ultrasound examinations. Grade 2 ROP was diagnosed in two children during routine eye examinations.

When they started school, two children had moderately severe cerebral palsy: one suffered from hemiplegia and another from spastic diplegia. Both children had been referred to a centre for children and youth habilitation. The children with the above diagnoses attended regular schools. Among those children who dropped out, one had severe mental retardation, three had moderately severe cerebral palsy, two had hemiplegia, and one had spastic diplegia.

Controls

A control group was selected from the Swedish Medical Birth Registry using the following criteria: normal

Table 2 Socio-economic variables for very low birthweight (VLBW) and normal birthweight (NBW) groups

Variables Continuous variables*	VLBW n = 51 Mean (SD)	NBW n = 51 Mean (SD)	p
Maternal age at child's birth (years)	29.9 (4.4)	30.9 (4.3)	ns
Formal education (years)			
Mother	12.6 (2.6)	13.6 (2.3)	0.044
Father	11.7 (2.2)	13.0 (2.4)	0.007
Categorical variables†	**n (%)**	**n (%)**	**p**
Caesarean section	39/51 (77)	4/51 (8)	<0.001
Primiparae	28/51 (55)	21/51 (41)	ns
Smoking			
Mother	16/51 (31)	6/51 (12)	0.029
Father	12/50 (24)	5/51 (10)	ns
Multilingual family	8/51 (16)	5/50 (10)	ns
Single child	11/51 (22)	12/51 (24)	ns

*Independent samples *t*-test.
†Fisher's exact test.

birthweight (NBW) of ≥2500 g, same age (within ±3 days) and sex (32 girls and 19 boys) as a member of the VLBW group, absence of neonatal diagnosis in the maternity protocol and mother residing in the same district as the mother of the corresponding VLBW child. The three normal birthweight children born in succession immediately after the VLBW child were placed on a backup list so that if the first was unable to participate, the next in line could be enrolled in the study. As a result, we were able to recruit 51 control children who were happy to participate. They were tested during the second term of first grade at mean age 8.0 ± 1 SD (±0.3 years) ($p < 0.001$). Mean birthweight was 3547 g and mean gestational age 39.7 weeks. Maternal age and parity (primiparae/multiparae) at birth did not differ significantly between the VLBW and control groups (Table 2).

Sociodemographic data

Parents were asked about how many years of formal education they had, maternal smoking during pregnancy and, or, when their child started school, how many siblings the child had and any language spoken at home, other than Swedish (Table 2). Maternal smoking and maternal education were selected as independent variables in the linear regression analyses.

Parents of VLBW children had significantly less formal education than control parents. There were eight bilingual families in the VLBW group and five in the control group, and 11 VLBW children and 12 control children had no siblings. Neither of these findings were regarded as significant.

Reading tests

Reading tests were standardised for the Swedish population and had reliabilities based on English versions. Raw scores were used in the analyses. Trained examiners, blinded to the perinatal history of participants, administered the reading and cognitive tests.

Phonological awareness

Two tasks from the Comprehensive Test of Phonological Processing (CTOPP) (17) were administered to assess phonological awareness, which is understanding of sounds. In the syllable and phoneme elision task, with a test–retest reliability of 0.88, children were asked to delete syllables such as ger from tiger and phonemes such as h from hear. The next task was also from the CTOPP test battery and used a sound-matching procedure measuring the ability to recognise shared initial phonemes, such as neck and nut, and shared final phonemes, such as cap and lip. The test and retest reliability for this task has been reported to be 0.62.

Rapid automatised naming

Rapid digit naming and rapid letter naming from the CTOPP (17) were used as measures of rapid automatised naming. Six digits and letters were randomly presented in each test, and the tests included a total of 72 digits and letters. In these tests, the children were asked to name digits and letters as quickly as possible, while the numbers of seconds that elapsed were recorded.

Word decoding

The phonemic decoding efficiency subtest from the Test of Word Reading Efficiency (TOWRE) (18) was used to assess word decoding, which is the ability to translate letters to sounds and words. In this subtest, children were given 45 seconds in which to read as many nonwords as possible from the provided list. The subtest has two forms of nonwords, both of which were used to achieve a more reliable assessment. The total score was used as a measure of word decoding. Published test and retest reliability for children aged from six to nine years was 0.90.

Word recognition

A second subtest from TOWRE (18) was used to assess word recognition as a measure of orthographic decoding skill, which is the ability to recognise a word as fast as in one unit of time. In this subtest, sight word efficiency, children read a list of words as quickly as possible and are scored based on the number of correctly read words in 45 seconds. Word decoding ability was measured using two equivalent forms of the test, forms A and B. We administered both and used the total score as a measure of word recognition. Test and retest reliability was estimated at 0.97.

Reading comprehension

The Woodcock passage comprehension from the Woodcock Reading Mastery Test-Revised was used to assess reading comprehension (19). In this test, children read short passages silently and are asked to orally provide the missing word that completes the sentences. Split-half reliability for first grade has been reported to be 0.94.

Spelling
Spelling achievement was measured using the spelling subtest from the Wide Range Assessment Test-Revised (19). This test asks children to spell up to 45 words, ranging from simple words like bed to complex words such as belligerent. Testing ceases after ten consecutive errors, and scoring is simply the number of correctly spelled words. Split-half reliability has been reported to be 0.90.

Cognitive function
Two subscales from the Swedish version of the Wechsler Intelligence Scale for Children, version three (WISC-III) (20), were used, one from the performance part (block design) and one from the verbal part (vocabulary). These two subscales were chosen from a total of 12 because of their high g-factor and because they are a good reflection of general intelligence. These subscales were summarised using scale scores ranging from 0 to 69 for the block design scale and from 0 to 60 for the vocabulary scale.

Behaviour problems
The Swedish translation of the emotional/behavioural problem scale from the Child Behaviour Checklist (CBCL) was used to assess social competence and emotional and behavioural problems (21). This part of the questionnaire comprises 113 items which were answered by parents using a three-point scale: not true, somewhat or sometimes true and very true or often true. The items form eight subscales (withdrawn/depressed, somatic complaints, anxiety/depression, social problems, thought problems, attention problems, rule-breaking behaviour, aggressive behaviour), two broad band scales (externalisation and internalisation) and a total score. The raw scores were used to present the outcome of the CBCL, as recommended by Achenbach and Rescorla (21) and high scores meant more problems. A total score of 35 or more was shown to be the best predictor of psychiatric disorders in eight- to nine-year-old school children (22).

Statistical methods
The IBM Statistical Package for the Social Sciences (IBM SPSS Statistics) version 22.0 was used to register and evaluate data. Continuous variables were presented as means and ± standard deviations (SD). The characteristics of the VLBW and normal birthweight children were examined using *t*-tests for independent samples. *T*-tests for equality of means, with a 95% confidence interval for the differences between means of the groups, were used to analyse reading tests, cognition and behaviour.

Univariate variance analyses were used to analyse differences between groups to statistically control for age at examination, as confounding variable. To estimate the strength of effects, Cohen's d was calculated.

Univariate and multivariate linear regression models were performed to analyse correlations between reading variables as dependent variables and sociodemographic, perinatal and behavioural variables as predictors. The possible variables used in univariate linear regression analyses included confounders, as seen in Tables 1 and 2. Possible categorical confounders included parity (primiparae = 0, multiparae = 1), parental smoking during pregnancy and, or, at grade 1 (no smoking = 0, smoking = 1), home language other than Swedish (no = 0, yes = 1), single child, Caesarean section (no = 0, yes = 1), pre-eclampsia (no = 0, yes = 1), sex, SGA (no = 0, yes = 1), ELBW (no = 0, yes = 1) and serious neonatal diagnoses (IVH grade 3–4, PVL or ROP; no = 0, yes = 1). Among the cognitive and behavioural variables, block design, vocabulary and the CBCL subtests, including externalising, internalising and total score, were included in the univariate analyses.

Stepwise multiple linear regression analyses were performed to examine the relation between independent variables and each reading variable. Independent variables that were found to be significant in the univariate analyses were as follows: age at examination, maternal education, maternal smoking, block design, vocabulary and attention problems. p-Values below 0.05 were considered significant in all tests. R^2, the proportion of variance of the dependent variable explained by independent variables as predictors, was noted.

Ethics
All the follow-up studies, and the questionnaire study, were approved by The Regional Ethical Committee of the Faculty of Health Sciences at Linköping University (Registration number M127-05).

RESULTS
Group differences in reading outcomes, cognition and behaviour
The individuals in the VLBW group showed poorer performance in all reading tests and vocabulary than their peers in the normal birthweight control group with adjustments for age (Table 3). These differences were significant even after excluding the five VLBW children with the neonatal diagnoses IVH grade 3–4, PVL or ROP grade 2 (data not shown). The largest effect sizes were found in word recognition and reading comprehension, with a Cohen's d of −1.1 SD and −1.2 SD, respectively. The group differences and effect sizes for other reading variables were approximately −0.8 SD. In cognition, VLBW children showed poorer performance in block design and vocabulary, with effect sizes of −1.5 SD and −0.8 SD, respectively.

Very low birthweight children had significantly more parent-rated symptoms than control children on the anxiety/depression ($p < 0.05$), social problem ($p < 0.01$) and attention problem ($p < 0.05$) subscales after adjustments for age at examination (Table 3), with effect sizes of 0.3 SD, 0.6 SD and 0.5 SD, respectively. Five (9.8%) VLBW and two (4.3%) NBW children had a total score of 35 or more, but this was no significant.

Table 3 Mean (SD) and mean difference (95% CI) between very low birthweight (VLBW) and normal birthweight (NBW) children with respect to reading variables, WISC (block design and vocabulary) and child behaviour checklist (CBCL) variables. Differences are nonadjusted and adjusted for age at examination

Variables	VLBW n = 51 Mean (SD)	NBW n = 51 Mean (SD)	Difference between VLBW and NBW children (nonadjusted) Mean difference and (95% CI)	*t*-test p Value	Difference between VLBW and NBW children adjusted for age at examination Mean difference and (95% CI)	*t*-test p Value	Effect size Cohen's d
Reading variables	n = 51	n = 51					
Phonological awareness							
Elision	9.8 (6.8)	15.0 (4.9)	−5.2 (−7.6, −2.9)	<0.001	−5.7 (−8.2, −3.2)	<0.001	−0.9
Sound matching	16.0 (4.7)	19.0 (2.1)	−3.0 (−4.5, −1.6)	<0.001	−3.2 (−4.8, −1.7)	<0.001	−0.8
Rapid automatised naming							
Digits	62.9 (21.8)	47.5 (9.8)	15.4 (8.8, 22.1)	<0.001	17.0 (10.0, 24.1)	<0.001	0.9
Letters	80.2 (47.5)	52.3 (16.4)	27.9 (14.0, 41.0)	<0.001	30.3 (15.4, 45.2)	<0.001	0.8
Word decoding	24.1 (19.6)	38.7 (17.5)	−14.6 (−21.9, −7.3)	<0.001	−13.8 (−21.7, −6.0)	0.001	−0.8
Word recognition	33.1 (21.1)	59.5 (25.1)	−26.4 (−35.4, −17.3)	<0.001	−26.6 (−36.3, −16.8)	<0.001	−1.1
Reading comprehension	12.1 (8.3)	21.3 (6.4)	−9.2 (−12.1, −6.2)	<0.001	−9.4 (−12.5, −6.3)	<0.001	−1.2
Spelling	13.1 (7.8)	18.8 (5.8)	−5.7 (−8.4, −3.0)	<0.001	−6.5 (−9.4, −3.6)	<0.001	−0.8
WISC-III	n = 50	n = 51					
Block design	17.6 (10.6)	33.4 (10.2)	−15.8 (−20.1, −11.9)	<0.001	−14.7 (−19.1, −10.4)	<0.001	−1.5
Vocabulary	16.1 (4.0)	19.3 (3.9)	−3.2 (−4.8, −1.7)	<0.001	−2.6 (−4.3, −1.0)	0.002	−0.8
CBCL	n = 48	n = 50					
Withdrawn/depressed	0.9 (1.2)	1.1 (1.2)	−0.2 (−0.6, 0.4)	0.567	−0.2 (−0.7, 0.3)	0.440	–
Somatic complaints	1.4 (2.1)	1.1 (1.6)	0.3 (−0.4, 1.2)	0.365	0.6 (−0.2, 1.3)	0.159	–
Anxiety/depression	2.2 (2.2)	1.6 (1.5)	0.6 (0.1, 1.7)	0.020	1.0 (0.1, 1.8)	0.022	0.3
Social problems	2.3 (2.4)	1.0 (1.6)	1.3 (0.5, 2.1)	0.002	1.2 (0.4, 2.1)	0.006	0.6
Thought problems	1.2 (1.8)	1.3 (1.5)	−0.1 (−0.8, 0.6)	0.740	0.1 (−0.6, 0.8)	0.730	–
Attention problems	3.0 (3.5)	1.5 (1.8)	1.5 (0.3, 2.6)	0.013	1.8 (0.6, 3.0)	0.004	0.5
Rule-breaking behaviour	0.8 (1.5)	1.1 (1.6)	−0.3 (−0.9, 0.4)	0.393	−0.3 (−1.0, 0.4)	0.377	–
Aggressive behaviour	3.9 (3.8)	3.8 (3.4)	0.1 (−1.4, 1.5)	0.920	0.2 (−1.4, 1.7)	0.187	–
Other symptoms	2.7 (2.5)	1.9 (2.2)	0.8 (−0.2, 1.7)	0.125	0.7 (−0.3, 1.7)	0.182	–
Internalising	4.5 (4.1)	3.4 (2.8)	1.1 (−0.3, 2.5)	0.128	1.3 (−0.2, 2.8)	0.089	–
Externalising	4.7 (5.0)	4.9 (4.7)	−0.2 (−2.1, 1.7)	0.844	−0.1 (−2.2, 2.0)	0.915	–
Total score	18.3 (15.2)	14.0 (11.6)	4.3 (−1.1, 9.7)	0.119	5.0 (−0.7, 10.8)	0.087	–

–, means Cohen's d < 0.3.

Small for gestational age children did not differ significantly in outcome variables from appropriate for gestational age (AGA) children within the VLBW group.

Associations with reading tests

There were no significant associations between neonatal variables, sex, multilingual family or being a single child as predictors and reading variables in univariate analyses in the VLBW group (data not shown).

Table 4 demonstrates the relationship between reading variables, cognitive and behavioural variables and parental factors using partial correlation analysis controlling for age at examination and sex. Vocabulary showed significant correlations with reading variables in both groups. Anxiety/depression, social and attention problems in CBCL were significantly correlated with both phonological and orthographic decoding skills and rapid naming in the VLBW group. There were no significant correlations between high total score (≥35) and the reading variables (data not shown). Parental education was significantly correlated with phonological and orthographic decoding in both groups. Maternal smoking was negatively correlated with the outcome in phonological awareness, reading comprehension and spelling in the VLBW group.

Multiple regression analyses were carried out to examine the relations between independent variables and each reading variable as dependent. The results for the VLBW group controlling for block design are shown in Table 5. Poor results in the vocabulary scale and more attention problems explained poor results in most reading variables. Young age at examination, maternal smoking and impairment of vocabulary were associated with poor results in phonological awareness and reading comprehension. In the control group, the same analyses showed associations between vocabulary as one of the predictors and most reading variables (data not shown).

DISCUSSION

The focus of this study was to compare various aspects of reading ability and behaviour and their relationships in VLBW and normal birthweight control children. The

Table 4 Partial correlation coefficients between reading test variables, WISC-III (block design and vocabulary), child behaviour checklist (CBCL) subscales (anxiety/depression, social problems and attention problems), parental education and maternal smoking for very low birthweight (VLBW) and control children (NBW) controlling for age at examination and sex

Variables	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Reading variables															
Phonological awareness															
1. Elision															
2. Sound matching	**0.66* (0.47**)**														
Rapid automatised naming															
3. Digits	**−0.54*** (−0.26)	**−0.54*** (−0.17)													
4. Letters	**−0.45** (−0.51**)**	**−0.67* (−0.37***)**	**0.83* (0.47**)**												
5. Word decoding	**0.58* (0.48**)**	**0.61*** (0.28)	**−0.69*** (−0.13)	**−0.59* (−0.50*)**											
6. Word recognition	**0.59* (0.55*)**	**0.61*** (0.28)	**−0.74*** (−0.26)	**−0.65* (−0.57*)**	**0.95* (0.84*)**										
7. Reading comprehension	**0.69* (0.64*)**	**0.69* (0.51*)**	**−0.62*** (−0.25)	**−0.57* (−0.62*)**	**0.76* (0.72*)**	**0.84* (0.73*)**									
8. Spelling	**0.70* (0.60*)**	**0.77* (0.41**)**	**−0.60*** (−0.11)	**−0.52* (−0.44**)**	**0.63* (0.69*)**	**0.72* (0.75*)**	**0.74* (0.78*)**								
WISC-III															
9. Block design	0.21 (0.27)	**0.40**** (0.05)	−0.11 (0.15)	−0.15 (0.02)	0.24 (0.24)	0.26 (0.32)	**0.36**** (0.23)	**0.32*** (0.34***)**							
10. Vocabulary	**0.41** (0.37**)**	**0.40** (0.34***)**	−0.24 (−0.27)	−0.27 **(−0.36***)**	0.27 (0.24)	0.24 **(0.32***)**	**0.43** (0.50*)**	**0.37*** (0.44**)**	0.21 (0.25)						
CBCL															
11. Anxiety/ depression	−0.01 (0.09)	−0.02 (0.10)	**0.31***** (−0.11**)**	0.16 (−0.18)	**−0.34***** (0.12)	**−0.38**** (0.04)	−0.17 (0.19)	−0.11 (0.11)	−0.04 (−0.15)	0.02 (0.12)					
12. Social problems	−0.18 (0.16)	−0.29 (−0.21)	**0.58* (−0.29***)**	**0.52*** (−0.14)	**−0.40**** (−0.03)	**−0.39**** (0.08)	−0.23 (0.22)	**−0.31***** (0.07)	−0.24 (0.17)	0.04 (0.19)	**0.50* (0.53*)**				
13. Attention problems	**−0.33***** (0.17)	−0.25 (0.14)	**0.51*** (−0.27)	**0.49**** (−0.09)	**−0.42**** (0.02)	**−0.36***** (0.03)	−0.20 (0.02)	−0.28 (0.08)	−0.07 (0.05)	0.08 (0.06)	**0.36*** (0.32***)**	**0.71* (0.56*)**			
Social factors															
14. Maternal education	0.27 (0.12)	**0.33***** (0.14)	−0.25 **(−0.35***)**	−0.22 (−0.28)	**0.40**** (0.08)	0.26 (0.24)	0.24 (0.28)	0.24 (0.17)	0.28 **(0.30***)**	**0.39 (0.38**)**	−0.10 (0.04)	−0.13 **(0.30***)**	−0.20		
15. Paternal education	0.18 (0.17)	0.12 (0.20)	−0.26 (−0.21)	−0.14 **(−0.31***)**	**0.33*** (0.37**)**	**0.33*** (0.39**)**	0.25 **(0.44**)**	0.21 (0.27)	**0.43**** (0.27)	0.12 **(0.41**)**	−0.22 (0.03)	−0.22 (0.05)	−0.12 (−0.06)	**0.40** (0.57*)**	
16. Maternal smoking	**−0.34***** (0.08)	−0.18 (0.03)	0.25 (−0.10)	0.07 (−0.09)	−0.12 (−0.07)	−0.17 (−0.07)	**−0.36***** (−0.12)	**−0.30***** (−0.02)	−0.28 (0.16)	−0.13 (−0.18)	−0.09 (0.26)	0.15 (0.08)	0.09 **(0.32***)**	−0.04 (−0.13)	−0.17 **(−0.36***)**

Correlations in parenthesis are NBW children.

Correlations in bold are significant. *p < 0.001, **p < 0.01 and ***p < 0.05.

Table 5 Regression coefficients (B, 95% CI) in stepwise multiple regression analyses of covariates (vocabulary, attention problems, maternal education, maternal smoking and age at examination) predicting the reading variables; phonological awareness (two tests), rapid automatised naming (two tests), word decoding, word recognition, reading comprehension and spelling in very low birthweight (VLBW) children controlling for block design

Variables	WISC–III: vocabulary	CBCL: attention problems	Maternal education	Maternal smoking	Age at examination	Adjusted R^2
Phonological awareness: Ellision	0.62 (0.24, 1.00)**	−0.62 (−1.08, −0.16)**	ns	−3.37 (−6.59, −0.15)*	−0.48 (−0.89, −0.07)*	0.404
Phonological awareness: Sound matching	0.46 (0.15, 0.76)**	−0.55 (−0.90, −0.20)**	ns	ns	ns	0.245
Rapid automatised naming: digits	ns	3.06 (1.67, 4.46)***	ns	ns	ns	0.287
Rapid automatised naming: letters	−2.74 (−5.02, −0.46)*	6.23 (3.64, 8.83)***	ns	ns	ns	0.349
Word decoding	ns	−1.62 (−2.66, −0.58)**	1.94 (0.47, 3.41)*	ns	ns	0.281
Word recognition	ns	−2.51 (−4.01, −1.00)**	ns	ns	ns	0.182
Reading comprehension	0.77 (0.24, 1.30)**	ns	ns	−5.16 (−9.56, −0.76)*	−0.65 (−1.19, −0.12)*	0.278
Spelling	0.68 (0.23, 1.12)**	−0.66 (−1.19, −0.12)*	ns	ns	−0.74 (−1.22, −0.25)**	0.356

ns = Nonsignificant coefficient.
*p < 0.05, **p < 0.01, ***p < 0.001.

reason for waiting until the second term of first grade to test VLBW children was to ensure that all children had been taught reading skills for almost one year. Our results confirm that low birthweight children were at a disadvantage when they started school with regard to reading and cognitive measures. The differences in reading variables between the groups were significant, when the confounders of age at examination and sex were controlled for. The largest differences between the VLBW and control children were found in word recognition, a measure of orthographic decoding, and reading comprehension, supporting our earlier findings that reading deficits in VLBW children were not those typically resulting from developmental phonological dyslexia (12). The results were supported by a Dutch report of a population of VLBW children with dyslexia (23). The prevalence of preterm born children in their study was not higher than in a general population.

High scores on the vocabulary test were essential for good performance in reading comprehension among both VLBW and control children. The largest difference between the groups was seen in block design, although vocabulary was the main factor for good reading comprehension in the regression analyses. However, the regression analyses must be interpreted with some caution, as vocabulary is known to have a reciprocal relation with reading ability.

The VLBW children showed more parent-rated behavioural problems than the control children regarding anxiety/depression, social and attention problems. Similar results for attention problems were found in the meta-analysis by Aarnoudse-Moens et al. (2). Attention difficulties that had an impact on academic achievement were detected in children born very preterm, even in the absence of a diagnosis and without signs of hyperactivity/impulsivity (24), indicating a core deficit in attention in children born preterm (25). Attention problems without hyperactivity have often been undetected by teachers (26), resulting in a high risk of poor school performance in the future.

The three CBCL subscales that differed between the groups were correlated and we chose attention problems as a behavioural predictor in the regression analyses. Few attention problems were related to satisfying performance in all reading domains in VLBW children. Vocabulary was significantly associated with phonological awareness, reading comprehension and spelling in both groups. Among VLBW children, the critical factors associated with difficulties in these reading domains were double deficits, low results on vocabulary and attention problems. In the control children, vocabulary was the only predictor that was associated with reading subtests.

The social and environmental predictors that we selected were the number of years of formal school education that the parents had received, the language spoken in the home and being an only child. However, the effect of the level of parental education was small in both groups. Socio-economic differences between families in Sweden might be compensated for by a general preschool curriculum being included in the communal day care system.

Parental smoking, both during pregnancy and after birth, was selected as another social marker. Our results demonstrated that reading comprehension was dependent on maternal smoking together with vocabulary and attention problems in VLBW children. The association is interesting but doubtful, due to the relatively small number of cases. One recent study, however, suggested that prenatal use of nicotine was an important causal risk factor for attention deficit hyperactivity disorder (27).

More than 50% of the VLBW children in our study were SGA at birth, in addition to being premature. Morsing et al. (28) described a relationship between intrauterine growth restriction due to absent or reversed end-diastolic blood

flow in the umbilical artery and poor cognitive function among boys of school age. The incidence of intrauterine growth retardation was not known in this study, as we lacked data on intrauterine ultrasound examinations of blood flow. However, we found no association between SGA and the reading variables in this cohort of children, who were also born preterm. We were unable to identify any other neonatal predictors, including ELBW or neonatal complication such as PBD, IVH, PVL or ROP that significantly correlated with reading variables. Most infants in the VLBW group had ultrasound examinations of the brain during the newborn period, but magnetic resonance imaging examinations of the brain were not carried out, which is why we were unable to exclude children with diffuse noncystic lesions. White matter abnormality at term-equivalent age in very preterm VLBW children was an important predictor of poor language development including phonological awareness assessed at the age of seven in very preterm VLBW children (29). Studies of white matter in adolescents born preterm with normal clinical and postnatal neuroimaging have shown associations between disturbances in the structure of white matter tracts and inattention and poor lexical decoding ability (30).

Some strengths of the study should be mentioned. Firstly, the regional VLBW cohort was representative of Sweden as a whole and came from a mixture of rural and urban areas. Secondly, the control group was matched for gender, age and maternal home district. Data from children who withdrew from the study did not differ significantly from those examined in the VLBW group. The test battery was comprehensive and standardised with acceptable test and retest reliability, and with possibilities to discriminate between different types of reading disabilities. Neonatal care has changed since our birth cohort was born, but the care for VLBW infants at that time was normally intensive care, including surfactant and high frequency ventilation, if needed. Parental caregiving during the neonatal stay has probably changed, which might be advantageous to the child's neurodevelopment.

The findings of poor reading functions in VLBW children when they start school, demonstrate that, as well as impairments in general cognitive abilities, considerable behavioural abnormalities may exist that affect reading attainment. To prevent reading difficulties, it should be essential to provide early information to parents of children at risk. In addition, nursery school teachers meeting children born preterm with behavioural deviations should be aware of the importance of introducing language and literacy acquisition in daily play situations.

CONCLUSIONS

Swedish VLBW children aged seven to eight years of age showed poorer performance with respect to reading skills than normal birthweight children in the second term of first grade. Vocabulary and poor attention proved to be rather strong predictors of phonological performance, rapid naming functioning, reading comprehension and spelling in VLBW children. Reading tests had little association with parental education and perinatal factors in VLBW children. This study may have direct clinical implications for the information that parents and schools need on how to support VLBW children during the first school year. In order to provide an efficient proactive approach, one option could be a screening programme, involving preschool teachers and parents, to identify and support children with behavioural problems.

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CONFLICT OF INTEREST

The authors have no conflict of interests to disclose.

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