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published in
Archives of Disease in Childhood-Fetal and Neonatal Edition
2019

DOI (link to publisher)
10.1136/archdischild-2018-315028

document version
Publisher's PDF, also known as Version of record

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► Additional material is published online only. To view please visit the journal online (http://dx.doi.org/10.1136/archdischild-2018-315028).

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Received 21 February 2018
Revised 25 August 2018
Accepted 30 August 2018
Published Online First 27 September 2018

To cite: Twilhaar ES, de Kieviet JF, van Elburg RM, *et al*. *Arch Dis Child Fetal Neonatal Ed* 2019;**104**:F419–F423.

ABSTRACT

Objectives To characterise the developmental trajectories of arithmetic, reading comprehension and spelling abilities of very preterm and full-term born children during primary school.

Design A longitudinal analysis of academic performance data of very preterm and full-term born children was performed. Academic performance was assessed in grade 1–6 of primary school using a pupil monitoring system, with 11 measurements of arithmetic and spelling performance and 7 measurements of reading comprehension. Data were analysed using mixed-effects models.

Patients A Dutch cohort of 52 very preterm children born between 2001–2003 and 58 full-term controls participated.

Results No group-by-time interactions were found for any of the academic domains, indicating no differences in progress between groups. Through the course of primary school, very preterm born children scored on average 0.53 SD lower on arithmetic (95% CI −0.71 to −0.35, p<0.001), 0.31 SD on reading comprehension (95% CI −0.48 to −0.14, p<0.001) and 0.21 SD on spelling (95% CI −0.37 to −0.05, p=0.01) compared with full-term peers.

Conclusions This is the first longitudinal study to show that the academic difficulties of very preterm born children persisted during primary school. Their progression was similar to full-term born peers, suggesting intact learning abilities. This provides opportunities for interventions to improve the academic outcomes of very preterm born children.

What is already known on this topic?

- Very preterm birth is associated with academic difficulties that likely have important consequences for later life outcomes.
- Knowledge on developmental trajectories of very preterm born children is key for early identification of problems and prevention of academic failure and school drop out.

What this study adds?

- This is the first longitudinal analysis of academic performance of very preterm and full-term born children during primary school.
- Very preterm born children show difficulties in arithmetic, reading comprehension and spelling, and these persisted throughout primary school.
- Very preterm born children showed similar progression compared with full-term peers, which suggests that their learning abilities are intact.

INTRODUCTION

Very preterm (VP) birth (<32 weeks' gestation) is associated with academic difficulties.[1] These problems likely have important consequences as academic performance is substantially associated with health and life chances.[2] Close monitoring of children at risk for academic difficulties is crucial for early identification of problems and prevention of academic failure. Knowledge on developmental trajectories of VP children is key in this respect. It is currently unknown whether academic development in this population is characterised by persisting deficits, delay with catch up at later ages or deficits that become increasingly evident over time. Cross-sectional research[3] showed equal differences between VP and full-term children on complex word reading, spelling and arithmetic across grades, while differences in simple word reading disappeared from grade two onwards, suggesting catch up. A recent meta-analysis found no association between age and arithmetic, reading and spelling outcomes in preterm born children, implying stability of deficits.[1] However, when making a distinction between word decoding and reading comprehension, findings of Kovachy *et al*[4] suggest stability of deficits in word decoding but increasing differences between preterm and full-term born children in reading comprehension.

Cross-sectional studies provide valuable information about functioning at a certain point in development, but do not provide insight into developmental trajectories. Longitudinal studies have the advantage to study individual change in a certain outcome over time.[5] This provides information on the expected developmental trajectory of VP children and may indicate time points at which problems may arise or worsen. This knowledge is crucial for monitoring and support. The present study focused on arithmetic, reading comprehension and spelling performance as these are main subjects that are learnt in all schools and most often assessed in follow-up studies, facilitating comparability between studies. The current study is the first to characterise academic trajectories of VP and full-term children during primary school using a longitudinal design.

METHODS

Participants

This study reports on a cohort of VP (<32 weeks' gestation) and/or very low birth weight (<1500 g) infants who were admitted to the level III neonatal intensive care unit of the Vrije Universiteit Medical Center in Amsterdam between September 2001 and July 2003. A total of 102 VP infants were enrolled in a randomised controlled trial on the effects of enteral glutamine supplementation in the first month of life.[6] The inclusion and randomisation process was described elsewhere.[7] We previously showed no differences between VP children in the glutamine-supplemented and placebo group on academic, neurocognitive, motor and behavioural functioning at 13 years.[8] After 1 year, 88 children were alive and eligible for follow-up, of whom 61 agreed to participate in the current follow-up at 13 years. Parents of six of these children gave no permission to request academic performance data from the school. Data were unavailable for another three children, resulting in a sample of 52 VP children.

Controls were classmates of VP participants or recruited from schools in the surroundings of Amsterdam, born at term (≥37 weeks' gestation), and free of developmental, behavioural or learning disorders. A total of 61 full-term controls participated. Academic performance data were available for 58 controls because parents of one child gave no permission to request data from the school and data were not available for another two children.

Academic performance

The Dutch pupil monitoring system developed by the National Institute for Educational Measurement[9] was used to assess academic performance. This system includes standardised tests[10–12] to assess arithmetic and spelling performance twice a year in grade 1–5 (halfway, end) and once in grade 6 (halfway or end), resulting in 11 measurements during primary school. Reading comprehension was assessed at the end of grade 1, twice in grade 2 (halfway, end) and once (halfway) in grade 3–6, resulting in seven measurements. The tests are based on item-response theory. Reliability coefficients for arithmetic, reading comprehension and spelling are ≥0.90, 0.83 and 0.89, respectively.[9] Test performance is reflected in standardised ability scores on a unidimensional scale. This way, a pupil's test performance at a certain time can be compared with other pupils' performance at the same time (between subjects) and with a pupil's own performance at other time points (within subjects). To facilitate interpretation, ability scores were transformed into z-scores using the sample mean and SD.

Type of education, special educational assistance and education level in secondary school were reported by parents. Special educational assistance comprised all forms of assistance regarding academic functioning within regular classes, received currently or in the past. In the Netherlands, secondary education is provided at different levels. These were clustered in four categories:[13] special or practical level, lower secondary level, higher secondary level or grade 6 of primary school.

Parental education

Parental education level was classified according to the International Standard Classification of Education 2011.[13] Because of a limited number of cases in lower categories, education level was recoded as a dichotomous variable describing whether the highest education level of either parent was equal to or higher than bachelor degree or equivalent.

Procedure

Written consent was obtained from both parents and children to request academic performance data from primary schools.

Statistical analyses

Group comparisons for demographic and perinatal characteristics were performed using independent samples t-test, χ^2 test and Fisher's exact test. The longitudinal relation between VP birth and academic performance was studied with mixed-effects models using MLwiN (V.2.22). Missing values were not imputed as mixed-effects models have been shown to adequately deal with missing data and imputation does not increase precision of estimates and may result in unstable outcomes.[14 15] To adjust for measurements being clustered within individuals, a random intercept was included in all models, allowing intercepts to vary between individuals. A group variable was included to evaluate the longitudinal relationship between VP birth and academic outcomes. A time variable was included to study academic progress over time. Using dummy variables, academic progress over time was first modelled without assuming a certain shape (ie, linear or non-linear) of the relationship to decide on the appropriate function for the continuous time variable.[5] A group-by-time interaction was included to test whether the relation between VP birth and academic performance changes over time. Inclusion of a random slope allows regression coefficients to vary between individuals. A random slope for the time variable was added to the model if inclusion resulted in better model fit, as indicated by the likelihood ratio test.[5] Interaction terms were used to test whether effects were moderated by sex and parental education level. Non-significant interaction terms were removed from the model. Instead, these variables were included as potential confounders (adjusted model). Significance level for all analyses was 0.05.

RESULTS

There were no differences between VP children in the glutamine-supplemented and placebo group on any outcome (online supplementary eTable 1). Hence, VP children were analysed as one sample. The sample of VP children participating at 13 years had a higher birth weight and lower rate of intraventricular haemorrhage grade I/II than those lost to follow-up (online supplementary eTable 2). Sample characteristics are provided in table 1.

Table 2 presents type and level of education at 13 years, grade repetition and educational assistance for VP and full-term children. VP children attending regular education received more educational assistance (RR=3.40, 95% CI 2.47 to 4.33) and repeated grades more frequently (RR=2.14, 95% CI 1.32 to 2.96) than controls.

A non-monotone pattern of missing data was observed with higher proportions of missing values for the first measurements (first grade, mid-second grade) than subsequent measurements (20%–24% vs 11%–12%, p=<0.001–0.002). This is due to the fact that not all schools started monitoring academic performance from the first grade. Importantly, for all academic domains proportions of missing values were not different between groups (p=0.25–0.59). The longitudinal relation between VP birth and academic outcomes was not moderated by sex and parental education level, but these variables were considered as potential confounders. There were no differences between crude analyses and analyses adjusted for sex and parental education. Hence, only adjusted results are reported. Based on the observed relationship between time and academic performance (see figure 1), time was modelled by a linear function.

No group-by-time interaction was found for arithmetic (β=0.01, 95% CI −0.008 to 0.03, p=0.23), reading comprehension (β=0.01, 95% CI −0.03 to 0.06, p=0.60) and spelling (β=−0.01, 95% CI −0.03 to 0.02, p=0.58). Over the course of primary school, VP children scored on average 0.53 SD lower on arithmetic (95% CI −0.71 to −0.35, p<0.001), 0.31 SD lower

Table 1 Demographic details of the very preterm and full-term sample and perinatal characteristics of the very preterm sample

	Very preterm (n=52)	Full-term (n=58)	P values
Sex, n (%) boys	26 (50)	24 (41)	0.37
Parental education, n (%) ≥bachelor degree or equivalent	31 (60)	35 (60)	0.94
GA, weeks, M (SD)	29.36 (1.47)		
BW, g, M (SD)	1278.60 (354.67)		
SGA*, n (%)	12 (23)		
Caesarean section, n (%)	29 (56)		
BPD†, n (%)	13 (25)		
IVH grade I/II, n (%)	7 (14)		
IVH grade III/IV, n (%)	1 (2)		
PVL, n (%)	2 (4)		
PDA, n (%)	7 (14)		
ROP, n (%)	4 (8)		
NEC, n (%)	0 (0)		
≥1 serious neonatal infection‡, n (%)	31 (60)		
Glutamine supplementation, n (%)	25 (49)		

*BW <10th percentile.
†Oxygen requirement at 36 weeks postmenstrual age.
‡Sepsis, pneumonia, meningitis, pyelonephritis or arthritis diagnosed based on a combination of clinical signs and positive culture.
BW, birth weight; BPD, bronchopulmonary dysplasia; GA, gestational age; IVH, intraventricular haemorrhage; NEC, necrotising enterocolitis; PVL, periventricular leukomalacia; PDA, patent ductus arteriosus; ROP, retinopathy of prematurity; SGA, small for gestational age.

on reading comprehension (95% CI −0.48 to −0.14, p<0.001) and 0.21 SD lower on spelling (95% CI −0.37 to −0.05, p=0.01) than controls. Arithmetic, reading comprehension and spelling scores increased with respectively 0.27, 0.41 and 0.27 SD over time (p<0.001). For all academic domains, inclusion of a random slope for time (ie, allowing regression coefficients to vary among individuals) resulted in a significantly better model fit (p<0.001). Figure 1 shows the longitudinal development of academic skills for VP and full-term children.

DISCUSSION

VP birth was associated with impaired arithmetic, reading comprehension and spelling performance. This relationship was stable over time, implying that deficits apparent in the first grades of primary school did not improve or worsen with progression through later grades. Academic difficulties of VP children were indicated by increased educational assistance and grade repetition, and lower secondary education levels.

Table 2 Type and level of education, grade repetition and educational assistance in very preterm and full-term born children

	Very preterm (n=61)	Full-term (n=61)	P values
Special education	8 (13)	0 (0)	0.006*
Regular education	53 (87)	61 (100)	
Grade repetition	18 (30)	8 (13)	0.02
Educational assistance	17 (28)	5 (8)	0.001
Education level at age 13 years			
Grade 6 primary school	9 (15)	3 (5)	0.07
Special secondary school	4 (7)	0 (0)	0.12*
Lower secondary education	18 (30)	9 (15)	0.05
Upper secondary education	30 (50)	49 (80)	<0.001

All data are presented as n (%) and were analysed using χ^2 test unless otherwise specified.
*Fisher's exact test.

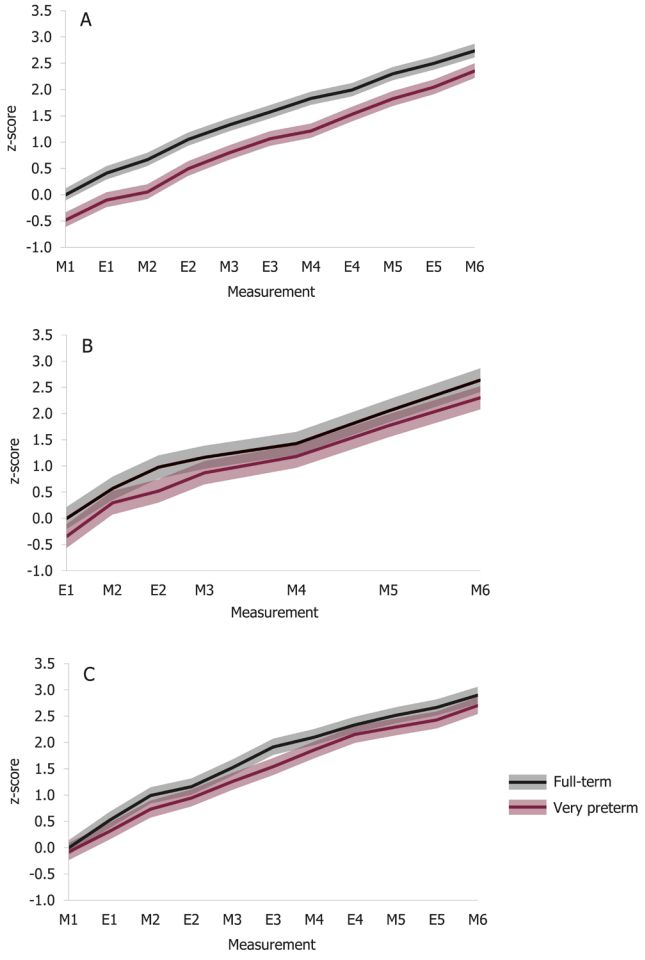

Figure 1 Longitudinal development of arithmetic (A), reading comprehension (B) and spelling abilities (C) of very preterm born children and full-term controls during primary school. The plots show the predicted values at each measurement for both groups with a 80% prediction interval. M1, mid-first grade; E1, end first grade; M2, mid-second grade, etc. The z-score for the control group at the first measurement was set to zero.

The persisting academic deficits in VP children during primary school are in line with the stable differences in intelligence between VP and full-term children reported from comparable longitudinal analyses.[16–18] Furthermore, the findings are in agreement with a recent meta-regression analysis that showed no association between age and arithmetic, reading and spelling performance,[1] but are inconsistent with an earlier meta-regression that suggested increasing reading comprehension deficits with increasing age.[4] This meta-regression included only five studies, implicating cautious interpretation of these results. Moreover, the different types of analysis may explain the inconsistency in findings between studies. Using meta-regression analysis, the association between studies' effect sizes and the samples' average age was assessed. In contrast, longitudinal studies allow to assess change in academic performance within subjects over time and examine whether this change differs between groups. This information is necessary to draw conclusions about academic trajectories of VP born children compared

with full-term peers. However, replication of our findings in other samples is warranted.

The present findings indicate that VP children show academic growth to the same extent as full-term children, suggesting intact learning abilities. This may have important implications for the potential of interventions. However, our study also showed that given the present education, including special educational assistance and grade repetition, VP children in general were not able to reach similar performance levels as full-term children. Brain abnormalities associated with VP birth and subsequently lower intelligence, attention problems and executive function deficits have previously been linked to poor academic outcomes.[19–21] This suggests that these children may simply lack capacities to perform at similar levels as their full-term counterparts. Nevertheless, interventions may help children reaching their full potential. Research focus has mostly been on early intervention and effects on academic or cognitive performance were limited to infancy and toddlerhood.[22] Furthermore, a significant part of the VP children with low achievement scores do not appear to receive any early support.[23 24] Understanding the nature and origin of academic difficulties in VP children is a first prerequisite for successful prevention and intervention. Subsequently, randomised controlled trials are necessary to clarify which skills and neurocognitive functions can be trained in what way, at which time in development, and in which children.

Taking inter-individual variability into account significantly improved the fit of our model. This suggests there may be subgroups of children with varying academic trajectories. Several medical and environmental factors may influence academic trajectories after VP birth. Parental education level is generally known to be directly related to children's academic outcomes, and indirectly, through parenting and home environment.[25] Children with biological or behavioural vulnerabilities may be disproportionally affected by adverse environmental influences, as stated by the diathesis-stress model,[26] or, according to the differential susceptibility theory, may be more susceptible for both adverse and beneficial environmental influences.[27] Although parental education level did not affect the relation between VP birth and academic outcomes in the current study, possibly due to the high parental education level in our sample, parental education may serve as an extra risk or protective factor affecting outcomes after VP birth. Jaekel *et al*[28] tested the differential susceptibility hypothesis in (very) low birth weight children by studying effects of maternal sensitivity on academic performance. Compared with normal birth weight peers, (very) low birth weight children were disproportionally susceptible to insensitive parenting, in line with the diathesis-stress model, but did not *disproportionately* benefit from highly sensitive parenting, contradicting the differential susceptibility theory. More research is needed to identify risk factors, both medical and environmental, that may be target of preventive strategies for poor academic outcomes and to identify protective factors that may be stimulated through intervention.

A clear strength of this study is its longitudinal design, which allowed to study individual development of academic performance over a significant time period. Moreover, the large number of measurements provided a precise evaluation of academic development and all measurements were taken using the same, well-validated tests. A limitation of this study is the relatively small sample, recruited from a single-centre neonatal intensive care unit. VP children that participated in the current study did not differ from those who were lost to follow-up on the majority of perinatal and demographic characteristics, although birth weight was higher and the incidence of mild intraventricular haemorrhage was lower among participants. This suggests that attrition was to some extent selective. Moreover, the level of parental education in our sample was higher than one would expect in the VP population. These are common issues in long-term follow-up studies that also limited the current study. Consequently, the present findings may underestimate the academic difficulties in the population and generalizability of results to other samples may be affected. Indeed, effect sizes in this study were smaller compared with recent meta-analytic results.[1] The large number of measurements per individual, together with the fact that effects that would have reached the significance threshold are very small, indicates that the study was sufficiently powered. However, the relatively small sample size limited possibilities to explore VP subgroups with varying developmental trajectories based on medical or environmental characteristics.

CONCLUSION

To our knowledge, this study is the first to examine academic performance of VP children in a longitudinal design. VP children showed difficulties in arithmetic, reading and spelling that persisted throughout primary school. However, they showed similar progression as full-term children. This suggests intact learning abilities, providing opportunities for intervention. Increased understanding of neurocognitive mechanisms underpinning these academic difficulties is necessary to help these children reaching their full potential. Conversely, brain abnormalities and neurocognitive impairment may limit VP children's abilities to reach similar performance levels as their full-term peers. Identification of perinatal risk factors that are associated with poor academic outcomes in VP-born children and the subsequent development of preventive strategies targeting these risk factors is crucial to minimise this gap.

Acknowledgements The authors acknowledge and thank professor Jos Twisk for his advice regarding the longitudinal data analysis.

Contributors All authors contributed to the study concept and design. EST, JFdK, RMvE and JO were involved in the acquisition, analysis and interpretation of the data. EST and JFdK drafted the manuscript and all authors contributed to the critical revision of the manuscript. EST and JO were responsible for the statistical analyses. Funding was obtained by RMvE and JO, who also supervised the study.

Funding This study was funded by Danone Nutricia Research, Utrecht, The Netherlands.

Competing interests RMvE is employed at Danone Nutricia Research, Utrecht, The Netherlands.

Patient consent Not required.

Ethics approval This study was conducted according to the Declaration of Helsinki (2013) and approved by the Scientific and Ethical Review Board of the Faculty of Behavioural and Movement Sciences, Vrije Universiteit Amsterdam.

Provenance and peer review Not commissioned; externally peer reviewed.

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