

The impact of preterm birth on mathematics achievement and schooling

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Overview

- Preterm birth: Why it matters
- Cohort studies used



- Study 1: Cognition & mathematics across the gestation spectrum
- Study 2: Preterm birth & adult wealth
- Study 3: Delayed school entry an intervention?
- Study 4: Teachers' knowledge of preterm birth
- Recommendations

Definition of preterm birth

Completed weeks of gestation																			
22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41
																	Term		
	All Preterm																		
Very Preterm							Mod	erate		Late									
Extremely																			
22 to 27 weeks Babies born extremely preterm are at high risk for intellectual impairment and physical disability later in life. Although the vast majority attend mainstream school, just over half require some degree of special educational support.				22 to Child pret for c atter emo	22 to 31 weeks Children born very preterm are at high risk for cognitive deficits and attention, behaviour and emotional problems at school age.			32 to 36 weeks Most preterm babies are born late and moderately preterm. Even these babies born a few weeks early are at slightly higher risk of developmental problems than babies born at term.				Preterm birth In the UK, around 7% of babies are born preterm each year. This means that two children in an average sized primary school class are likely to have been born preterm.							

Why preterm birth matters

Born Too Soon

The Global Action Report on Preterm Birth



Based on Millennium Development Goal regions.

Source: Blancowe et al National, regional and worldwide estimates of pretarm birth rates in the year 2010 with time trands since 1990 for selected countries: a systematic analysis and implications

Preterm birth rates are rising

All live births



Average annual percentage change for preterm birth by country, 1996–2008.* Data series begins in 2000

Zeitlin, J., Szamotulska, K., Drewniak, N., Mohangoo, A. D., Chalmers, J., Sakkeus, L., Blondel, B. (2013). Preterm birth time trends in Europe: a study of 19 countries. *BJOG*, 120(11), 1356-1365.

Adult outcomes of very preterm birth

 Cognitive problems remain and are related to widespread grey and white matter changes in the brain





Fig. 5 Correspondence between white matter changes and full-scale IQ within preterm-born adults. In the *left panel*, coronal, axial, and sagittal views illustrated significant positive correlation between fractional anisotropy (FA) and full-scale IQ independent of gestational age. *Green color* indicated the common skeleton over preterm (PT) and term groups. *Yellow color* showed affected white matter tracts with significantly reduced FA in PT group (permutation test,

P < 0.05, FWE corrected). Red illustrated related white matter tracts where decreasing FA was significantly positively correlated with decreasing full-scale IQ in preterm-born adults controlled for gestational age. MNI coordinates were provided at the *bottom*. In the *right panel* for visualization, in preterm-born adults, full-scale IQ and averaged FA of related white matter tracts were illustrated in scatter plot

Breeman, L. D., Jaekel, J., Baumann, N., Bartmann, P., & Wolke, D. (2015). Preterm Cognitive Function Into Adulthood. *Pediatrics. doi:10.1542/peds.2015-0608*

Meng, C., Bäuml, J. G., Daamen, M., Jaekel, J., Neitzel, J., Scheef, L., Wolke, D... Sorg, C. (2015). Extensive and interrelated subcortical white and gray matter alterations in preterm-born adults. *Brain Structure and Function*, 1-13. doi:10.1007/s00429-015-1032-9

From birth to adulthood - Melanie



26 weeks 30 cm 750 g









Cohort studies used

Bavarian Longitudinal Study (BLS)



- EPICure Study
- 1958 National Child Development Study (NCDS)
- 1970 British Cohort Study (BCS70)



Study 1: Cognitive ability and mathematics attainment across the full gestation spectrum

Wolke, D., Strauss, V. Y.-C., Johnson, S., Gilmore, C., Marlow, N., & Jaekel, J. (2015). Universal Gestational Age Effects on Cognitive and Basic Mathematic Processing: 2 Cohorts in 2 Countries. *The Journal of Pediatrics*, *166(6)*, *1410-1416.e1412. doi:10.1016/j.jpeds.2015.02.065*

Cognitive and mathematics problems across the full gestation spectrum

- How does the degree of prematurity relate to children's IQ, basic mathematics processing and mathematics attainment in primary school?
- Are the effects of prematurity on IQ and mathematics universal?

IQ, maths processing and attainment

Same tests used in both samples

Kaufman Assessment Battery for Children (K-ABC) at approx. two years of schooling in both samples

- IQ: MPC score
- Math attainment: Arithmetic subtest score

Basic mathematics processing

Same Mathematics Estimation Test (12 items) at age 8 (BLS) and age 11 (EPICure)



Statistical analysis

- BLS: piecewise linear regressions were fitted for IQ, mathematic processing and mathematic attainment
 - Change point analyses tested the week of GA at which children's test performance differed significantly above and below
- EPICure: inserting their *observed* scores into the piecewise regressions fitted to the BLS sample
 - Prediction: the range of EPICure observed scores fell within these 50% (1 RMSE) and 75% (2 RMSEs) prediction intervals
- Analyses were controlled for family SES, child sex, and small for gestational age (SGA) birth

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ORIGINAL ARTICLES

Universal Gestational Age Effects on Cognitive and Basic Mathematic Processing: 2 Cohorts in 2 Countries

Dieter Wolke, PhD^{1,2}, Vicky Yu-Chun Strauss, PhD³, Samantha Johnson, PhD⁴, Camilla Gilmore, PhD⁵, Neil Marlow, MD, PhD⁶, and Julia Jaekel, PhD^{1,7}



Wolke D, Strauss V, Johnson S, Gilmore C, Marlow N, Jaekel J. Universal gestational age effects on cognitive and basic mathematics processing: 2 cohorts in 2 countries. *J Pediatr* 2015, 166:1410-6.

Prediction of IQ and maths development after preterm birth from BLS to EPICure: robust estimates



Wolke D, Strauss V, Johnson S, Gilmore C, Marlow N, Jaekel J. Universal gestational age effects on cognitive and basic mathematics processing: 2 cohorts in 2 countries. *J Pediatr* 2015, 166:1410-6.

Mathematics attainment is more strongly associated with schooling



Wolke D, Strauss V, Johnson S, Gilmore C, Marlow N, Jaekel J. Universal gestational age effects on cognitive and basic mathematics processing: 2 cohorts in 2 countries. *J Pediatr* 2015, 166:1410-6.

Discussion

- Prematurity has adverse effects on math attainment following birth at all gestations
 <36 weeks and on IQ and basic mathematics processing <34 weeks GA
- Universal neurodevelopmental factors explain the effect of gestation at birth on basic cognitive abilities (IQ and basic mathematics processing)
- EPICure study children had higher mathematics attainment scores than predicted by BLS data
- Mathematic attainment may be improved by schooling







Recommendation

- Follow-up assessments should include moderate and very preterm children
- Follow-up should extend into the preschool and primary school years





Study 2: Preterm birth and adult wealth

Basten, M., Jaekel, J., Johnson, S., Gilmore, C., & Wolke, D. (2015). Preterm Birth and Adult Wealth: Mathematics Skills Count. *Psychological Science. doi:10.1177/0956797615596230*

Background

- Large registry-based studies show preterm children are less likely to complete high school and go to university
- Preterm birth has been linked to lower jobrelated income, lower occupational status and decreased wealth in adulthood
- Lack of longitudinal research what are the mechanisms leading to decreased wealth in adult life?







Key questions

- What is the impact of preterm birth on wealth in adulthood?
- Do preterm children's poor reading and mathematics skills adversely affect their wealth as adults?

Methods

- Data from two national birth cohort studies:
 - NCDS 17,500 people born in 1958 (n=8573 in analyses, 66%)
 - BCS70 17,000 people born in 1970 (n=6698 in analyses, 58%)
- Both cohorts have comparable data on:
 - IQ, mathematics and reading in middle childhood (age 7-11 years)
 - Educational qualifications in young adulthood (age 33-34 years)
 - Adult wealth at 42 years of age
- Structural equation modelling used to:
 - Create latent variables for wealth, IQ, reading and mathematics
 - Create a path model to explore the mediating effects of IQ, reading and mathematics in middle childhood and educational qualifications in young adulthood

Impact of preterm birth on adult wealth



Wealth at 42 years for participants in the National Child Development Study 1958



Wealth at 42 years for participants in the British Cohort Study 1970

Pathways to lower wealth



Basten M, Jaekel J, Johnson S, Gilmore C, Wolke D. Preterm birth and adult wealth: Mathematics skills count. Psychol Sci 2015, 1-12.

Discussion

- Preterm birth affects individuals into adulthood
- Developmental cascade whereby preterm children's poorer school performance leads to lower qualifications and wealth in adulthood
- Poorer primary school mathematics skills are particularly important for later wealth
- Consistent findings across cohorts suggest that the pathways leading to poor adult outcomes are time invariant, same for children born today







Recommendation

- Follow-up should be extended to the preschool and primary years
- Improving preterm children's attainment at primary school, particularly in mathematics, may enhance their outcomes across the lifespan
- Interventions at school age are needed









Study 3: Delayed school entry . . . An intervention for preterm children to improve academic attainment?

Jaekel, J., Strauss, V. Y.-C., Johnson, S., Gilmore, C., & Wolke, D. (2015). Delayed school entry and academic performance: a natural experiment. *Developmental Medicine & Child Neurology*, *57*(7), 652-659. doi:10.1111/dmcn.12713

Background

General Population:

- Summer born children are the youngest in the class and have poorer academic achievement than the oldest in the class
- Effects persist until early secondary school and have even been shown to be related to adult income
- Either school attainment scores are adjusted (weighted) according to age or children may be permitted to defer or delay school entry
- Who decides: Parents (redshirting) or teachers (deferral or delayed entry)

Background

- In most countries school entry is determined by birth date
- Preterm children are born up to 4 months before their due date
- They more often have a range of developmental problems
- Some are doubly disadvantaged: according to EDD they would start school a year later but have to enter a year earlier according to actual birth date
- Triple jeopardy: developmental risk, early admission and summer born



February March April May June July August September October



Achievement goals, gestation at birth, birth date and sex



Percentage of children (95% CI) according to gestation at birth not reaching a good overall achievement level by child age within class and for boys and girls (Foundation stage profiles rated by teachers)

Quigley, M. A., Poulsen, G., Boyle, E., Wolke, D., Field, D., Alfirevic, Z., & Kurinczuk, J. J. (2012). Early term and late preterm birth are associated with poorer school performance at age 5 years: a cohort study. *Archives of Disease in Childhood - Fetal and Neonatal Edition*, *97*, *F167-F173*.

Delayed school entry: Pros and cons

PROS

- Reduce psychological pressure and negative feedback for child
- Teachers may not be able to provide differential support to less "mature" children
- Children "mature" to be ready for school
- CONS
 - May not receive the intellectual stimulation being held back
 - This may especially be the case where families are disadvantaged
 - Costly another year of child care for parents to pay

Mixed evidence and design problems

Selection bias:

- DSE: more often behaviour problems, special needs, summer born males or socially disadvantaged
- Redshirting (parents keep child back)
- Thus DSE were not comparable to appropriate age entries (ASE)

Small samples:

statistical power issues

Natural experiment: Bavaria

- School entry age: 6 years chronological age
- 3-12 months before school entry: school entry test by community paediatrician
- Recommendation for DSE by paediatrician and agreed with school
- Parents cannot delay school entry (no redshirting)

Design

- N: 999 of BLS with full data
- 104 (DSE); 895 (ASE)
- 12 measures < 5 years (Before any DSE/ASE decision) for propensity score matching: Sex, SES, neonatal complications, Birth weight, gestation, SGA, parent-child interaction, IQ, vocabulary, language, attention span, behaviour regulation and visuomotor coordination
- 99 (DSE) matched to 895 (ASE)
- 53 (preterm DSE); 287 (preterm ASE)
- Control for confounders: Preschool rhyming and numerical tests

Outcome measures

- Teacher ratings of maths, reading and writing (average or below vs above average) and attention at end of year 1
- Standard assessment of academic achievement with standardised maths, reading and writing (Psychologists, blind to DSE status) at 8;5 years of age
- > 1 hour video-taped observation during IQ test- rating of task orientation (scale: 6 items; 9 point scales) of TRCB at 8;5 years of age



Total sample: DSE vs. ASE (vertical line: 1) shown with 95% CI (fully adjusted model)



Jaekel, J., Strauss, V. Y.-C., Johnson, S., Gilmore, C., & Wolke, D. (2015). Delayed school entry and academic performance: a natural experiment. *Developmental Medicine & Child Neurology, 57(7), 652-659. doi:10.1111/dmcn.12713*

Preterm children only: DSE vs. ASE (vertical line: 1) shown with 95% CI (fully adjusted model)



Jaekel, J., Strauss, V. Y.-C., Johnson, S., Gilmore, C., & Wolke, D. (2015). Delayed school entry and academic performance: a natural experiment. *Developmental Medicine & Child Neurology, 57(7), 652-659. doi:10.1111/dmcn.12713*

Conclusions

- Delayed school entry has no advantage on teacher ratings (same school experience but older)
- Delayed school entry has clear disadvantage to performance at the same age (less school experience)
- Findings are similar for all and preterm children only but for attention (worse at age-based assessment)

Interpretation

- Inadequacy of the model of "maturation" of school skills for preterm children
- (a) Basic abilities (IQ, Attention) are more stable over time from preschool age in preterm children – do not outgrow or "mature" out of them
- (b) Preterm children are more sensitive or vulnerable to poor parenting (teaching?) than term children

Recommendations

- Current best evidence does not support the case for delayed school entry of preterm children
- ASE school entry may be facilitated by increased special support in school
- The current mixed evidence supports the need for a RCT for preterm children only

DELAYED SCHOOL ENTRY MAY NOT AFFECT YEAR 1 TEACHER RATINGS BUT DOES AFFECT TEST SCORES AT 8 YEARS







Study 4: Teachers' knowledge and information needs regarding preterm birth

Johnson, S., Gilmore, C., Gallimore, I., Jaekel, J., & Wolke, D. (2015). The long-term consequences of preterm birth: what do teachers know? *Developmental Medicine & Child Neurology*, *57(6)*, *571-577. doi:10.1111/dmcn.12683*

Background

- Growing number of preterm children
- Almost all teachers will be responsible for supporting children born preterm
- Teachers' knowledge and preparation about health conditions is crucial for appropriate educational management
- Teachers lack training and knowledge about effect of health conditions on children's adaptation at school

2 children in an average UK primary school class are born preterm



Key questions

- What do teachers and educational psychologists know about the developmental and educational outcomes of children born preterm?
- What are their information needs related to the educational management of preterm children?

Methods & respondents

- Electronic survey of teaching staff in all schools in England
 - Email to the head teacher to cascade to all staff
 - Study posters sent to all schools in 4 local counties
 - Promoted via social media
 - Respondents: 585 teaching staff with complete data (93% teachers; 82% in mainstream schools; 21% had SEN role)
- Electronic survey of educational psychologists in the UK
 - Email sent to all members of the Association for Educational Psychologists (AEP)
 - Promoted via social media
 - Respondents: 212 educational psychologists with complete data (91% with complete data)

The survey

Demographic questions

Preterm Birth Knowledge Scale (PB-KS); 33 statements, e.g.

- Of all the subjects studied at school, very preterm children are likely to have the greatest difficulties in mathematics
- Almost all children born very preterm who attend mainstream school will have a statement of SEN
- Children born very preterm are likely to be inattentive and withdrawn
- Total PB-KS score (range 0-33)
- 7 items to assess opinions about educational management, training and information needs, e.g.
 - I feel adequately equipped to support the learning and development of children born very preterm
 - I have received sufficient training in this area

Johnson S, Gilmore C, Gallimore I, Jaekel J, Wolke D. The long term consequences of preterm birth: what do teachers know? *Dev Med Child Neurol* 2015, 57:571-577.

Results: Specific areas of knowledge



Figure 1: Proportion of correct responses on individual Preterm Birth-Knowledge Scale (PB-KS) items for teaching staff and educational psychologists. The y axis details the PB-KS statement number and a summary descriptor of the statement content. The full statement for each item is shown in Appendix S1 (supporting information available online). SEN, special educational needs.

Results: Opinions and training



Johnson S, Gilmore C, Gallimore I, Jaekel J, Wolke D. The long term consequences of preterm birth: what do teachers know? *Dev Med Child Neurol* 2015, 57:571-577.

Discussion

- Teachers and educational psychologists recognise the role they have to play in supporting preterm children, but lack knowledge and formal training
- Why is this so important?
 - Current follow-up arrangements
 - Complex learning difficulties
 - Preterm phenotype means problems may be missed
- Information about preterm children's outcomes and strategies to support their learning are needed



Recommendation

- Training teachers about the long term consequences of preterm birth is needed to enable them to understand the special constellation of problems faced by children born preterm
- New teaching approaches need to be developed to deal with the special educational and social needs of preterm children in the classroom

Summary of Recommendations

- Follow-up assessments into the late preschool and primary school years
- Interventions around school entry
- Delayed school entry not recommended RCT needed
- Training teachers about preterm birth
- New teaching approaches

Questions?



Why preterm birth matters

Figure 2: Global burden of preterm birth in 2010



The boundaries and names shown and the designations used on this map do not imply the expression of any opinion whatsoever on the part of the World Health Organization concerning the legal status of any country, territory, city or area or of its authorities, or concerning the delimitation of its frontiers or boundaries. Dotted lines on maps represent approximate border lines for which there may not yet be full agreement. Data Source: World Health Organization Map Production: Public Health Information and Geographic Information Systems (GIS) World Health Organization



Cost of preterm birth



Mangham LJ, Petrou S, Doyle LW, Draper ES, Marlow N. The cost of preterm birth throughout childhood in England and Wales. Pediatrics. 2009; **123**(2): e312-27.

Bavarian Longitudinal Study

- Prospective longitudinal study of neonatal at-risk children
- Children born in South Bavaria (02/1985 -03/1986) and admitted to a hospital within 10 days of birth; controls were recruited from the same hospitals.



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Assessments





EPICure Study



- National Study of children born <26 weeks gestation in 1995
- 98% of neonatal units in UK and Ireland participated (276 nurseries; 171 neonatal units)

4004 deliveries reported (20-25 weeks) 1289 live births 314 discharged 308 alive at 2 ½ years of age: 283 (92%) 308 alive at 6 years of age: 241 (78%) 307 alive at 11 years of age: 219 (71%)



National Child Development Study (NCDS)

- Also known as the 1958 Birth Cohort Study
- National study following the lives of 17,500 babies born in England, Scotland and Wales in a single week of 1958
- Data collected on health, physical and educational development, economic circumstances, employment, family life, health behaviour, wellbeing and social participation
- Data collected at birth and assessment waves at age 7, 11, 16, 23, 33, 42, 46, 50 & 55 years



1970 British Cohort Study (BCS 70)

- National study following the lives of 17,200 babies born in England, Scotland and Wales in a single week of April 1970
- Data are collected on health, physical, educational and social development, employment and economic circumstances, family life and social participation
- Data collected at birth and assessment waves at age 5, 10, 16, 26, 30, 34, 38 and 42 years



IQ and mathematics attainment: K-ABC

- Same tests used in both samples
 - Kaufman Assessment Battery for Children (K-ABC) at approx. two years of schooling in both samples
 - IQ: MPC score
 - Math attainment: Arithmetic subtest score
- Tests were standardized according to full term control children in each sample (standardized control mean 100; SD 15)

Basic mathematics processing

- Same Mathematics Estimation Test (12 items) at age 8 (BLS) and age 11 (EPICure)
- Item responses were scored for accuracy and summarized into a total score
- Test scores were standardized based on full term controls in each study separately (standardized control mean 100; SD 15)



Methods

Wealth	Intelli	gence	Rea	ding	Mathematics			
NCDS & BCS70	NCDS	BCS70	NCDS	BCS70	NCDS	BCS70		
Family income	Non-verbal	British Ability	Southgate Group	Edinburgh Reading	Arithmetic test	Friendly Maths		
	and verbal	Scales 4	Reading Test (7)	Test (10)	(7)	Test (10)		
	general ability	subtests (10)						
	test (11)							
Family social class	-	-	Teacher rating of	Teacher report of	Teacher rating	Teacher report		
(occupation)			reading ability (7)	extra help with	of number skills	of extra help		
				reading (10)	(7)	with maths (10)		
Housing tenure	-	-	Teacher report of reading level (7)	Maternal rating of child's difficulty with reading (10)	Arithmetic test (11)	Maternal rating of child's difficulty with maths (10)		
Employment status	-	-	Reading	-	Teacher rating	-		
			Comprehension		of number skills			
			Test (11)		(11)			
Self-perceived	-	-	Teacher rating of	-	-	-		
financial situation			reading ability (11)					

Results: Information needs



Johnson S, Gilmore C, Gallimore I, Jaekel J, Wolke D. The long term consequences of preterm birth: what do teachers know? *Dev Med Child Neurol* 2015, 57:571-577.