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

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Objective To determine whether general cognitive ability, basic mathematic processing, and mathematic attainment are universally affected by gestation at birth, as well as whether mathematic attainment is more strongly associated with cohort-specific factors such as schooling than basic cognitive and mathematical abilities.

Study design The Bavarian Longitudinal Study (BLS, 1289 children, 27-41 weeks gestational age [GA]) was used to estimate effects of GA on IQ, basic mathematic processing, and mathematic attainment. These estimations were used to predict IQ, mathematic processing, and mathematic attainment in the EPICure Study (171 children <26 weeks GA).

Results For children born <34 weeks GA, each lower week decreased IQ and mathematic attainment scores by 2.34 (95% CI: −2.99, −1.70) and 2.76 (95% CI: −3.40, −2.11) points, respectively. There were no differences among children born 34-41 weeks GA. Similarly, for children born <36 weeks GA, mathematic processing scores decreased by 1.77 (95% CI: −2.20, −1.34) points with each lower GA week. The prediction function generated using BLS data accurately predicted the effect of GA on IQ and mathematic processing among EPICure children. However, these children had better attainment than predicted by BLS.

Conclusions Prematurity has adverse effects on basic mathematic processing following birth at all gestations <36 weeks and on IQ and mathematic attainment <34 weeks GA. The ability to predict IQ and mathematic processing scores from one cohort to another among children cared for in different eras and countries suggests that universal neurodevelopmental factors may explain the effects of gestation at birth. In contrast, mathematic attainment may be improved by schooling. *(J Pediatr 2015;166:1410-6)*.

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Around 15 million babies worldwide (~10% of all births) are born preterm (<37 weeks gestational age [GA]) each year. Changes in reproduction patterns and improved neonatal medicine have led to increased numbers of moderately (32-33 weeks GA) and late preterm (34-36 weeks GA) births and increased survival rates of those born very preterm (<32 weeks GA). Despite improved neonatal care, prematurity remains the leading cause of infant mortality and long-term morbidity today,[1] and the high prevalence of cognitive problems (>20%) in preterm populations has not changed over the last 2 decades.[2]

Studies suggest that delivery at any gestation other than full-term may confer an insult to brain development[3] rendering survivors at risk for adverse cognitive and educational outcomes, particularly in mathematics.[4-6] It remains controversial whether the dose response effect of GA on early mathematical abilities is linear[6] or curvilinear.[7] Emerging evidence from different cohorts demonstrate a significant impact of GA at birth on basic cognitive abilities (eg, IQ, mathematic processing)[8,9] and mathematic attainment,[4,6,10] but there is uncertainty about its specific nature and magnitude. The relationship of GA with cognitive and educational outcomes may be affected by differences in neonatal care across cohorts or eras of care, particularly across the 1980s and 1990s, with increased survival following advances in surfactant treatment, ventilation techniques, or nutrition.[1,2,11,12] Furthermore, cognitive abilities and attainment may be affected by socioeconomic status (SES) and early education.[13,14]

BLS	Bavarian Longitudinal Study
EP	Extremely preterm
GA	Gestational age
K-ABC	Kaufman-Assessment Battery for Children
MPC	Mental processing composite
RMSE	Root mean square error
SES	Socioeconomic status
SGA	Small for GA
UK	United Kingdom

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We investigated the association of GA with cognitive ability (IQ), basic mathematic processing, and mathematic attainment assessed during second grade of elementary school (8 years of age) in the Bavarian Longitudinal Study (BLS) cohort born 1985/1986 in the South of Germany at 27-41 weeks GA. We then used the regression functions identified in the BLS sample to predict IQ, basic mathematic processing, and mathematic attainment assessed at second grade in the United Kingdom (UK) (6 years) and 11 years of age using the same tests in the EPICure national cohort of extremely preterm (EP) children born in 1995 in the whole of the UK and Ireland at 23-25 weeks GA.

We, first, hypothesized that the effects of GA on IQ and basic mathematic processing[8,15] are universal; that is, similar deficits would be found across cohorts assessed in different countries and during different eras of neonatal care.[2] Second, we hypothesized that mathematic attainment[9,16] may be susceptible to country specific schooling and that outcomes may, thus, differ between cohorts; that is, prediction from one cohort to another may be less accurate compared with predictions of basic cognitive abilities.

Methods

Two prospective geographically defined birth cohorts were included, the BLS and the EPICure study. Descriptive characteristics of the BLS and EPICure study participants are in Table I.

BLS Cohort

The enrollment procedures have been described in detail elsewhere.[17-19] A total of 7505 infants (10.6% of all live births) who were born between January 1985 and March 1986 in Southern Bavaria, Germany, and required admission to a children's hospital within the first 10 days of life were invited to participate in this study (index children). In addition, 916 term-born infants who received normal postnatal care were identified in the same hospitals. Ethical approval was obtained from the Ethics Committee of the University of Munich Children's Hospital and the Bavarian Health Council (Landesärztekammer). Analyses for this study use follow-up data at 8 years. At this age, we assessed 336 very preterm survivors and a sample of 1169 children born >31 weeks GA stratified by child sex, family SES, and degree of neonatal risk. Of these, 156 children could not complete the full battery of tests and were excluded. Data from 20 EP children (<27 weeks GA) were excluded as the number was too small to allow for appropriate statistical estimates. Finally, 40 children born post-term (>41 weeks GA) were excluded given the established association with adverse developmental outcomes.[20] The final BLS sample for this study thus comprised 1289 children born between 27 and 41 weeks GA. All tests were standardized according to 584 children born full term (39-41 weeks) within the sample (298 receiving normal postnatal care and 286 index full-term children) who were followed to 8 years.

Table I. Descriptive characteristics of BLS and EPICure children included in analyses

	BLS children (N = 1289)	EPICure children (N = 171)
IQ	96.97 (16.70)	78.63 (16.62)
Basic mathematic processing	97.63 (15.58)	83.99 (16.12)
Mathematic attainment	96.87 (16.82)	81.84 (19.84)
GA	36.52 (3.94)	24.53 (0.66)
Sex (boys)	655 (50.81%)	74 (43.27%)
Age	8.34 (0.23)	6.28 (0.46)
SES		
High	386 (29.95%)	67 (45.58%)
Medium	485 (37.63%)	34 (23.13%)
Low	418 (32.43%)	46 (31.29%)
SGA	325 (25.21%)	14 (8.19%)

Data are presented as mean (SD) for numerical variables or numbers (percentages [%]) for categorical variables. Please note that EPICure children's basic mathematic processing abilities (Mathematics Estimation Test) were assessed at 11 years of age (mean = 10.91 [SD = 0.37]).

EPICure

The EPICure study included EP infants who were born before 26+0 weeks GA in the UK and Ireland from March through December 1995. The sampling of the study population has been described previously.[10,21] Ethics approval was granted by the Trent Multicenter Research Ethics Committee. In total, 241 and 219 survivors were followed to age 6 and 11 years, respectively. Children with severe physical disability who could not complete the tests were excluded (n = 48), leaving 171 EP children. Cognitive abilities and mathematics attainment were assessed at 6 years and mathematic processing at 11 years. All tests were standardized according to full-term control children (37-41 weeks gestation) from the same classes in mainstream schools at 6 (n = 160) and 11 years of age (n = 153).[22,23]

Measures

In both studies, GA (completed weeks) was calculated from maternal reports of the last menstrual period and serial ultrasounds during pregnancy.[23,24] In both studies, psychologists assessed cognitive abilities using the Kaufman-Assessment Battery for Children (K-ABC).[25,26] This yielded a mental processing composite (MPC) score indicating general cognitive ability (IQ).

Children in both studies were administered a Mathematics Estimation Test[9,27] at age 8 (BLS) and 11 (EPICure) years, respectively. Tasks were presented to children in book form with 12 items assessing the estimation of dot array and number line magnitude, as well as judgments of approximate length and distance (Figure 1; available at www.jpeds.com). Item responses were scored for accuracy and summarized into a total score. Test scores were standardized based on term controls in each study separately (standardized control mean 100; SD 15).

In both studies, the age-appropriate K-ABC arithmetic subtest (separate from the MPC) assessed children's attainment in mathematics.[25,26] At the time of the K-ABC assessment, children in both cohorts had received, on average,