 ORIGINAL ARTICLES

Preterm Birth and Dyscalculia

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Objective To evaluate whether the risk for dyscalculia in preterm children increases the lower the gestational age (GA) and whether small-for-gestational age birth is associated with dyscalculia.

Study design A total of 922 children ranging from 23 to 41 weeks' GA were studied as part of a prospective geographically defined longitudinal investigation of neonatal at-risk children in South Germany. At 8 years of age, children's cognitive and mathematic abilities were measured with the *Kaufman Assessment Battery for Children* and with a standardized mathematics test. Dyscalculia diagnoses were evaluated with discrepancy-based residuals of a linear regression predicting children's math scores by IQ and with fixed cut-off scores. We investigated each GA group's ORs for general cognitive impairment, general mathematic impairment, and dyscalculia by using binary logistic regressions.

Results The risk for general cognitive and mathematic impairment increased with lower GA. In contrast, preterm children were not at increased risk of dyscalculia after statistically adjusting for child sex, family socioeconomic status, and small-for-gestational age birth.

Conclusion The risk of general cognitive and mathematic impairments increases with lower GA but preterm children are not at increased risk of dyscalculia. *(J Pediatr 2014;164:1327-32)*.

Poor mathematical skills impede lifelong achievements such as academic and occupational attainment as well as social functioning.[1,2] Mathematic impairments are common in very preterm children[3,4] and account for a substantial number of learning disabilities in this population.[5-7] Some authors have suggested that very preterm children's mathematic deficits are specific and not explained by global cognitive function.[8-11] However, it is not known whether these specific mathematic impairments that are independent of general cognitive deficits are related to prematurity across the whole spectrum of gestational age (GA). Dose-response effects of GA on early mathematic performance and special educational needs have been reported,[12,13] but in these studies authors did not control for general cognitive abilities. Furthermore, only very preterm children may be at significantly increased risk of scoring below −1 SD in mathematic tests.[14] In addition, effects of a small-for-gestational age (SGA) birth on mathematic deficits remain unclear: SGA birth is a result of fetal growth retardation, which is a major contributing factor to preterm birth.[15] Children with SGA tend to have general cognitive problems[16,17]; however, recent reviews on mathematic problems in preterm children have neglected possible effects of SGA birth.[6]

To understand the nature of specific mathematic impairments across the total spectrum of GA, general cognitive, general mathematic, and dyscalculia need to be concurrently investigated while taking possible confounders into account. Children are diagnosed with dyscalculia when there is a clear discrepancy between their mathematic achievement scores and expected performance based on IQ and age.[18] However, preterm children often have lower than normal IQ scores[19,20]; thus, fixed definitions of dyscalculia (ie, math test scores ≤10th percentile, IQ scores >15th percentile[21,22]) may miss many children who have low IQ and a very deficient performance in math (**Figure 1**). We propose to use residuals of a regression analysis predicting math by general IQ to obtain specific math scores that are independent of IQ.[23] In this study, we will compare application of the 2 diagnostic alternatives (fixed cut-off scores vs discrepancy-based residual scores) in children born across the whole GA spectrum.

First, we hypothesized that the risk for general cognitive and mathematic impairments increases with lower GA. Second, we tested whether the risk for dyscalculia similarly increases with lower GA after statistically adjusting for child sex, family socioeconomic status (SES), and SGA birth.

Methods

Data were collected as part of the prospective Bavarian Longitudinal Study.[20,24] Participating parents were approached within 48 hours of the infant's hospital admission and were included in the study with written consent. At 8 years of

GA	Gestational age
K-ABC	*Kaufman Assessment Battery for Children*
SGA	Small-for-gestational age
MPC	Mental processing component
SES	Socioeconomic status

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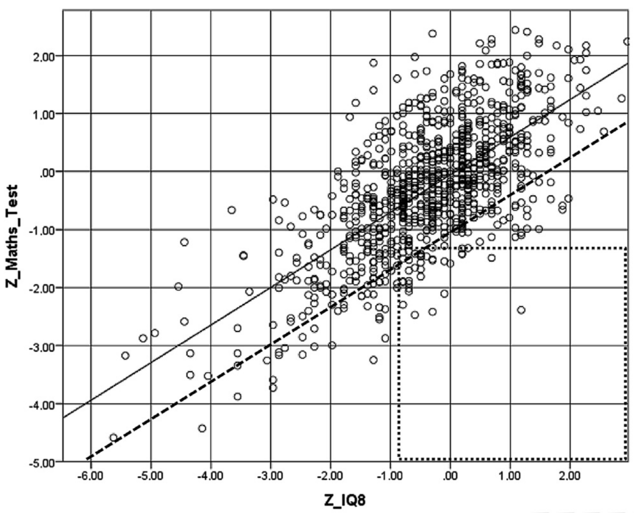

Figure 1. Comparison of dyscalculia diagnosis criteria applied to preterm children: the box framed by the *dotted line* in the right bottom corner indicates all children who would be diagnosed with dyscalculia according to a fixed definition (math test scores <10th percentile, IQ scores >15th percentile), whereas the *dashed diagonal line* indicates all children who would be diagnosed with dyscalculia according to the residuals of a regression analysis predicting math scores by K-ABC MPC scores (residual score below −1 SD of the sample mean residual score).

age, children were assessed by an interdisciplinary study team, including neurologic (done by pediatricians) and cognitive assessments (done by psychological assistants). All assessors were blind to group membership. Ethical permission for the study was granted by the Ethics Committee of the University of Munich Children's Hospital and the Bavarian Health Council (Landesärztekammer).

The Bavarian Longitudinal Study is a whole-population sample of children born between January 1985 and March 1986 within a geographically defined area of Southern Bavaria (Germany) who required admission to a children's hospital within the first 10 days of life (N = 7505; 10.6% of all live births). In addition, 916 healthy control infants (normal postnatal care) were identified at birth from the same hospitals in Bavaria during the same period.

Of the initial sample 206 survivors born <32 weeks of GA (n = 26 children diagnosed with severe neurologic impairment were excluded as they could not participate in the tests), 248 healthy full-term control infants, and a subsample of 468 children born between 32 and 38 weeks of gestation (randomly drawn within the stratification factors sex, SES, and degree of neonatal risk) were assessed at 8 years of age. Full details of the sampling criteria and dropout rates are provided elsewhere.[16,20] The **Table** shows the characteristics of the final sample of 922 children according to GA groups.

GA was determined from maternal reports of the last menstrual period and serial ultrasounds during pregnancy. When the estimates of these 2 differed by more than 2 weeks, postnatal Dubowitz scores were used.[25] Birth weight was documented in the birth records. Infants were classified as SGA if they weighed less than the sex-specific 10th percentile for their respective GA according to the national standard weight charts (1985-1986).[26]

Information was collected through structured parental interviews within 10 days of child birth. Family SES was computed as a weighted composite score derived from the occupation of the self-identified head of each family together with the highest educational qualification held by either parent and entered into 6 categories (1 = very low, 6 = very high).[27]

Assessment at 8 Years of Age

Cognitive assessments and tests were performed by trained assistant psychologists who were blind to children's background characteristics. Target testing age was 8 years and the children were between 7 years, 11 months and 9 years, 6 months old ($M = 8.34$; 95% CI 8.33-8.35). All test scores were z-standardized according to the scores of the 248 healthy, full-term control children.

General Cognitive Impairment

Children's cognitive abilities were assessed with the German version of the *Kaufman Assessment Battery for Children* (K-ABC).[28,29] In the K-ABC, IQ is measured as a composite score (mental processing component [MPC]) based on 8 subtests tapping general cognitive functioning. Children were diagnosed with general cognitive impairment if their K-ABC MPC score was below −1 SD.

General Mathematic Impairment

To assess numerical representations and reasoning, children were administered a comprehensive mathematic test.[10,24,30,31] Test tasks were presented to children in book form with 79 items assessing numerical estimations, calculation, reasoning, and mental rotation abilities: 12 estimation tasks measured children's accuracy in estimating numbers and comparing distances between numbers. Retrieval of arithmetic facts and procedural competence were measured with 50 calculation tasks (simple addition), whereas application of these 2 ability dimensions on real-world problems was assessed with 6 reasoning tasks. Finally, children's visual-spatial problem solving was tested with 11 mental rotation tasks. Item responses were scored for accuracy and subscale scores were then summed into a comprehensive total score. Children were diagnosed with general mathematic impairment if their total score was below −1 SD.

Dyscalculia

Children are diagnosed with dyscalculia when there is a clear discrepancy between their mathematic test scores and expected performance based on general intelligence.[18] Preterm children often have lower than normal IQ scores[19,20]; thus, commonly used fixed definitions of dyscalculia may miss children who nevertheless have very poor math performance. **Figure 1** shows a comparison of 2 different dyscalculia