

# Preterm Cognitive Function Into Adulthood

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abstract

**BACKGROUND:** Very preterm (VP; gestational age <32 weeks) and very low birth weight (VLBW; <1500 g) births are related to impaired cognitive function across the life span. It is not known how stable cognitive functions are from childhood to adulthood for VP/VLBW compared with term-born individuals and how early adult cognitive function can be predicted.

**METHODS:** The Bavarian Longitudinal Study is a prospective geographically defined cohort study that followed 260 VP/VLBW and 229 term-born individuals from birth to adulthood. Data on cognitive function were assessed with developmental and IQ tests at 5 and 20 months and at 4, 6, 8, and 26 years of age.

**RESULTS:** Across all assessments, VP/VLBW individuals had significantly lower IQ scores than term-born controls, even when individuals with severe cognitive impairment ( $n = 69$ ) were excluded. IQ scores were found to be more stable over time for VP/VLBW than term-born individuals, yet differences in stability disappeared when individuals with cognitive impairment were excluded. Adult IQ could be predicted with fair certainty ( $r > 0.50$ ) from age 20 months onward for the whole VP/VLBW sample ( $n = 260$ ) and from 6 years onward for term-born individuals ( $n = 229$ ).

**CONCLUSIONS:** VP/VLBW individuals more often suffer from cognitive problems across childhood into adulthood and these problems are relatively stable from early childhood onward. VP/VLBW children's risk for cognitive problems can be reliably diagnosed at the age of 20 months. These findings provide strong support for the timing of cognitive follow-up at age 2 years to plan special support services for children with cognitive problems.



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**WHAT'S KNOWN ON THIS SUBJECT:** Children born very preterm (VP) or with very low birth weight (VLBW) are at risk for cognitive deficits and low IQ in childhood. Recent evidence indicates that IQ discrepancies between VP/VLBW and term-born individuals are still found in adulthood.

**WHAT THIS STUDY ADDS:** Development of cognitive function is more stable for VP/VLBW than term-born individuals from infancy into adulthood and can be predicted fairly well from age 20 months onward. However, when adults with cognitive impairment are excluded, group differences in stability disappear.

Impaired cognitive function is the most common neurologic impairment in infants born very preterm (VP; gestational age [GA] <32 weeks) or with very low birth weight (VLBW; <1500 g). VP/VLBW children and adolescents have an increased prevalence of cognitive deficits<sup>1–3</sup> and recent evidence indicates that young VP/VLBW adults still have lower average IQ scores compared with those born at term.<sup>1,2,4–6</sup> It is, however, not known whether the same children who had cognitive deficits in childhood continue to have deficits in adulthood, as developmental tests in early childhood rely strongly on sensorimotor skills and may not accurately measure core cognitive ability.<sup>7</sup> Children's test scores could thus improve or deteriorate over time, because later tests may assess different aspects of cognitive function. Furthermore, early cognitive function may just set the stage for the next developmental phase rather than predicting cognitive function at later ages, whereas environmental influences, such as parenting or schooling, may lead to changes in cognitive function over time.<sup>7</sup>

VP/VLBW birth is associated with an increased risk of brain injury due to an amalgam of destructive and developmental mechanisms of the brain, including inflammation and ischemia that cause reduced white matter volume and ventricular dilation to name but a few.<sup>8–10</sup> These brain injuries can lead to altered brain development with persistent changes in intrinsic networks<sup>11,12</sup> that may limit the neural plasticity of the brain<sup>13</sup> and overall cognitive function.<sup>14</sup> Adaptation to age-appropriate challenges may be a characteristic of developmental plasticity and has, so far, rarely been studied. Yet it has been found that diagnosis of developmental disability has poor stability for VP/VLBW infants across childhood.<sup>15</sup> Finally, prospective studies of cognitive function in VP/VLBW individuals are

necessary to determine how early it is possible to predict adult cognitive function with reasonable certainty. This is important for establishing optimal timing of early follow-up and planning of supportive measures and interventions.

We assessed VP/VLBW and healthy term-born comparisons from 5 months until 26 years of age and tested 3 research questions: Do VP/VLBW individuals outgrow their cognitive deficits into adulthood, indicated by mean differences in cognitive scores, compared with term-born individuals? Is cognitive function more stable and thus more early predictable from childhood to adulthood in VP/VLBW than term-born individuals? How early can we predict cognitive impairment in VP/VLBW adults?

## METHODS

### Design

The Bavarian Longitudinal Study is a prospective whole population study of VP/VLBW children born in a geographically defined area of Southern Bavaria (Germany) between January 1985 and March 1986 who required admission to 1 of 16 children's hospitals within the first 10 days after birth. Healthy term-born comparisons were recruited in obstetric units in the same catchment area during the same period.<sup>16,17</sup> The current study uses data collected at 5 and 20 months, and at 4, 6, 8, and 26 years of age. The assessments at 5 and 20 months were at corrected age for prematurity for VP/VLBW participants. Original ethical approval was obtained from the University of Munich Children's Hospital and the Landesärztekammer Bayern. Ethical approval for follow-up in adulthood was granted by the Ethical Board of the University Hospital Bonn (reference 159/09). Informed written consent was provided by parents within 48 hours of their child's birth and all participants gave fully

informed written consent for the assessments in adulthood. In case of severe impairment of the adult participant, consent was provided by an assigned guardian (usually the parents).

### Participants

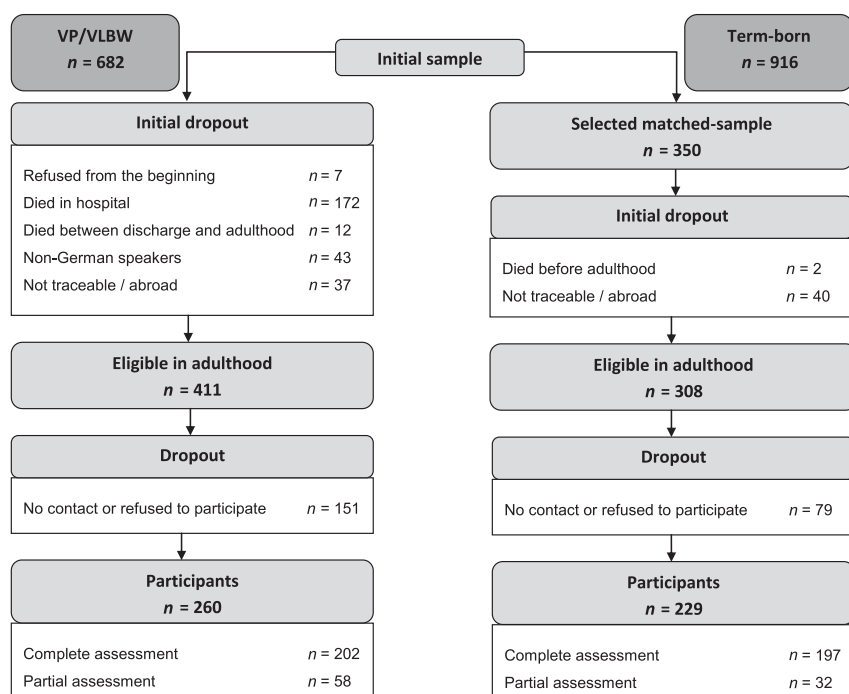
This study assessed a whole population sample of 682 VP/VLBW individuals. Of this cohort, 411 VP/VLBW were presumed alive, living in Germany, and eligible for inclusion at 26 years of age, and 260 (63.3%) participated in the current study (see flowchart in Fig 1). Of the eligible healthy term-born children (ie, born at 37–42 weeks of gestation, cared for on normal postnatal wards, and not transferred to a pediatric hospitals in the first 10 days after birth), 350 were randomly selected within 2 stratification variables (gender and family socioeconomic status [SES]) to be comparable with the VP/VLBW group. In adulthood, 308 term-born individuals were eligible for inclusion and 229 (74.4%) participated at 26 years (see Fig 1).

### Cognitive Assessments

Cognitive functioning was assessed with standardized developmental test (DQ) and intelligence tests carried out by pediatricians (infancy) or psychologists (childhood, adulthood).

DQ at 5 and 20 months was assessed with the Griffiths Mental Development Scale (GMDS),<sup>18,19</sup> which assesses 5 dimensions of mental development: locomotor, personal-social development, hearing and speech, hand and eye coordination, and performance. A total developmental quotient across the 5 domains was computed according to German norms.<sup>18</sup> Satisfactory reliability and good construct validity of the GMDS have been demonstrated across different studies and cultures.<sup>20,21</sup>

IQ at 4 years was assessed by using the Columbia Mental Maturity Scale (CMMS), the Active Vocabulary Test



**FIGURE 1**  
Flowchart of participants through the study.

(AWST), and the Beery-Buktenica Developmental Test of Visual-Motor Integration. The CMMS assesses reasoning ability of children between age 3 and 10 years<sup>22,23</sup> by testing whether the child is able to select the 1 drawing that is out of place from a series of drawings. The reliability for the CMMS is high<sup>17</sup> and has been shown a valid assessment of nonverbal intelligence.<sup>23,24</sup> The AWST was developed for German-speaking countries and evaluated the expressive vocabulary of preschool children,<sup>25</sup> similar to the widely used and valid Peabody Picture Vocabulary Test<sup>26,27</sup> in which children are required to name the drawings depicted on item cards. The AWST has high reliability and good concurrent and prognostic validity.<sup>28</sup> The Beery-Buktenica Developmental Test of Visual-Motor Integration assesses the integration of visual and motor abilities by asking children to copy drawings of geometric forms arranged in order of increasing difficulty<sup>29</sup> and has good reliability and validity.<sup>30,31</sup> To develop 1 general

IQ score, the raw scores of all 3 measures were first standardized on a normative sample with a mean of 100 and an SD of 15 (Cronbach's  $\alpha$  for the 3 measures = 0.78) before they were averaged to 1 general IQ score at 4 years of age.

IQ at 6 and 8 years was assessed with the German version of the Kaufmann Assessment Battery for Children (K-ABC).<sup>32,33</sup> A total IQ score was calculated from the sequential (3 subtests) and simultaneous (5 subtests) processing scales. Reliability (ie, range: 0.83–0.98, split-half method) and construct validity of the K-ABC are high (eg, correlation of 0.70 with the Wechsler Intelligence Scale for Children-Revised total score).<sup>33</sup>

IQ at 26 years was assessed with a short German version of the Wechsler Adult Intelligence Scale (WAIS III).<sup>34,35</sup> The 6 subtests were vocabulary, similarities, letter-number-sequence, block design, matrix reasoning, and digit symbol coding. Cognitive functioning scores

of the subtests were converted into age-normed Full-Scale IQ scores.<sup>36</sup> The WAIS III is broadly used and a well-established measure of general cognitive abilities.<sup>35</sup>

### Assessment of Demographic Characteristics

The assessment of demographic factors is described elsewhere in detail.<sup>17</sup> In short, family SES at birth was computed as a weighted composite score of parents' education and occupation and grouped as low, middle, or high.<sup>37</sup> Severe neurologic or neurosensory disability was determined in childhood according to the following criteria: suffering from grade 3 or 4 cerebral palsy,<sup>38</sup> blindness, or deafness (not corrected or insufficiently corrected). GA (weeks); birth weight (kilograms); small for gestational age (SGA; ie, children with birth weight less than the gender-specific 10th percentile for gestational age); gender; multiple births (twins or other multiples); maternal age (years); and prepregnancy, pregnancy, birth, and neonatal complications were coded from Bavarian perinatal survey forms at birth.<sup>39</sup>

### Data Analysis

Descriptive statistics and analyses were performed in Mplus 7.3 (Muthén & Muthén, Los Angeles, CA). This program allows for the analysis of missing data by using full information maximum likelihood. All analyses were corrected for family SES, as this may affect cognitive abilities in both VP/VLBW and term-born individuals from the general population.<sup>36,40</sup> Statistical significance was set at  $P < .05$  and all tests were 2-tailed.

Differences between VP/VLBW and term-born individuals in mean IQ scores were assessed with analyses of covariance, and effect sizes are reported as Cohen's  $d$  of the adjusted estimated means (ie, 0.20 small, 0.50 medium, and 0.80 large effects).<sup>41</sup> Stability of continuous IQ scores was

assessed with Pearson correlations. To compare VP/VLBW and term-born comparisons, correlations were converted to Fisher *z*-scores with 95% confidence intervals. Effect sizes for the difference in magnitude between population correlations were calculated and interpreted according to Cohen's guidelines as small (0.10), medium (0.30), and large effects (0.50). To assess how early one can reliably predict cognitive function in adulthood, correlations between childhood and adulthood IQ measures were examined and deemed clinically meaningful if correlations (*r*) were at least 0.50 (ie, a large correlation and explained variance [*r*<sup>2</sup>] of 25% in adulthood IQ). Analyses were repeated excluding individuals with severe cognitive impairment in adulthood (ie, -2 SD of term-born adults' mean IQ). For those individuals with missing IQ scores at 26 years (15.5%), their latest available childhood IQ score with its associated < -2 SD cutoff criterion was used as a proxy for grouping these individuals.<sup>36</sup> Finally, to estimate how early cognitive impairment can be predicted in

VP/VLBW adults, point biserial correlations of developing a cognitive impairment in adulthood were calculated for each childhood IQ score, by using only participants with complete data available.

## RESULTS

### Sample Characteristics and Dropout

Compared with term-born individuals, VP/VLBW individuals were by definition born at earlier gestational age and weighed less. In addition, VP/VLBW individuals were more often SGA, more often multiple births, and more complications were recorded for mother and child before pregnancy, during pregnancy, during birth, and the neonatal period. VP/VLBW adults more often had been born to socioeconomically disadvantaged families than their term-born counterparts. The VP/VLBW and term-born individuals did not differ in terms of gender and maternal age (Table 1).

The VP/VLBW adult participants did not differ from VP/VLBW dropouts (*n* = 151) in terms of GA, birth weight, SGA, gender, multiple births, and complications before pregnancy, during birth, and the neonatal period.

However, VP/VLBW dropouts had younger mothers, were more often socially disadvantaged, and their mothers had more complications during pregnancy. The participating term-born individuals did not differ from term-born dropouts (*n* = 79) in terms of GA, birth weight, SGA, gender, multiple births, and mothers' complications before pregnancy, during birth, and the neonatal period. However, the term-born dropouts had younger mothers, their mothers had more complications during pregnancy, and they were more often socially disadvantaged.

### Stability of Cognitive Functioning Into Adulthood

Raw means and 95% confidence intervals of IQ scores over time are presented in Table 2. Across all time points, VP/VLBW individuals had lower IQ scores than term-born individuals. With the exception of the Griffiths assessment at 5 months, all corresponding ESs regarding corrected group differences in mean IQ scores were large.

Correlations between IQ scores in childhood and adulthood are shown in Fig 2 and exact estimates and test

**TABLE 1** Demographics of Participating and Dropout VP/VLBW and Term-Born Individuals

	Participants					Dropouts					
	VP/VLBW <i>n</i> = 260		Term-Born, <i>n</i> = 229		<i>P</i> <sup>a</sup>	VP/VLBW, <i>n</i> = 151		<i>P</i> <sup>b</sup>	Term-Born, <i>n</i> = 79		<i>P</i> <sup>c</sup>
	<i>M</i> / %	95% CI	<i>M</i> / %	95% CI		<i>M</i> / %	95% CI		<i>M</i> / %	95% CI	
GA, wk, mean	30.6	30.3–30.9	39.7	39.5–39.8	<.001	30.4	30.0–30.8	.50	39.6	39.4–39.9	.91
Birth weight, kg, mean	1.32	1.29–1.36	3.36	3.31–3.42	<.001	1.27	1.22–1.31	.06	3.44	3.34–3.54	.19
SGA, %	41.5	35.5–47.5	10.0	6.2–13.9	<.001	45.0	37.1–53.0	.49	10.1	3.5–16.8	.98
Females, %	46.9	40.9–53.0	53.3	46.8–59.7	.16	51.0	43.0–59.0	.43	40.5	29.7–51.3	.05
Maternal age, y, mean	28.9	28.3–29.4	29.1	28.5–29.7	.61	27.8	26.9–28.7	.05	27.5	26.3–28.7	.02
Multiple births, %	26.5	21.2–31.9	3.1	0.8–5.3	<.001	22.5	15.9–29.2	.37	6.3	1.0–11.7	.21
Complications, mean											
Pregpregnancy	1.38	1.28–1.48	1.14	1.03–1.24	.001	1.27	1.13–1.40	.18	1.05	0.88–1.22	.40
Pregnancy	2.26	2.12–2.41	0.72	0.61–0.83	<.001	2.61	2.41–2.81	.006	1.06	0.84–1.29	.007
Birth	4.65	4.48–4.82	2.11	1.92–2.31	<.001	4.45	4.22–4.67	.16	2.16	1.82–2.51	.80
Neonatal	9.30	8.97–9.62	0.38	0.30–0.47	<.001	9.53	9.09–9.96	.43	0.39	0.25–0.54	.93
SES, %											
High	20.5	15.6–25.4	33.6	27.5–39.7	.001	18.5	12.3–24.7	.64	19.0	10.3–27.6	.02
Middle	47.1	41.0–53.2	42.8	36.4–49.2	.34	33.8	26.2–41.3	.009	30.4	20.2–40.5	.05
Low	32.4	26.7–38.1	23.6	18.1–29.1	.03	47.7	39.7–55.6	.002	50.6	39.6–61.7	<.001

CI, 95% confidence interval.

<sup>a</sup> Compares VP/VLBW and term-born individuals.

<sup>b</sup> Compares participating and dropout VP/VLBW individuals.

<sup>c</sup> Compares participating and dropout term-born individuals.

**TABLE 2** Raw Means With Their 95% CI and Tests of Group Differences in Mean IQ Scores

	VP/VLBW Whole Sample, <i>n</i> = 260			Term-Born Whole Sample, <i>n</i> = 229			ES <sup>a</sup>	VP/VLBW With Impairment, <i>n</i> = 69			VP/VLBW Without Impairment, <i>n</i> = 191			ES <sup>b</sup>	ES <sup>c</sup>
	<i>n</i>	Mean	95% CI	<i>n</i>	Mean	95% CI		<i>n</i>	Mean	95% CI	<i>n</i>	Mean	95% CI		
DQ 5 mo	248	96.3	93.7–98.8	229	107.1	105.7–108.5	0.59	62	78.9	73.9–84.0	186	102.0	99.6–104.5	1.07	0.35
DQ 20 mo	244	93.7	91.4–96.0	229	106.9	106.0–107.7	0.86	59	73.6	67.5–79.7	185	100.1	98.7–101.5	1.45	0.81
IQ 4 y	230	87.2	84.8–89.6	228	101.8	100.5–103.2	0.85	53	66.0	61.4–70.7	177	93.5	91.6–95.5	1.39	0.68
IQ 6 y	218	87.2	85.1–89.3	229	102.0	100.5–103.4	0.92	52	68.4	64.2–72.6	166	93.1	91.4–94.8	1.52	0.81
IQ 8 y	233	90.3	88.2–92.5	227	102.0	100.7–103.3	0.76	55	69.1	64.6–73.6	178	96.9	95.4–98.4	1.60	0.56
IQ 26 y	216	86.2	83.6–88.9	197	102.6	100.9–104.4	0.77	58	59.4	55.9–62.9	158	96.1	94.4–97.8	1.79	0.55

Tests and ESs are corrected for socioeconomic status; all tests are significant with  $P < .001$ . CI, 95% confidence interval; ES, effect size.

<sup>a</sup> Comparison between whole VP/VLBW and term-born sample.

<sup>b</sup> Comparison between VP/VLBW individuals with and without cognitive impairment.

<sup>c</sup> Comparison between VP/VLBW and term-born individuals without cognitive impairment.

results are shown in Table 3. Correlations were higher for VP/VLBW than term-born individuals across all time points with corresponding large ESs. Stability for different subdomains of intelligence can be found in the online Supplemental Information 1. Cognitive function could be reliably estimated ( $r \geq 0.50$ ) in adulthood from age 6 years in term-born children and from age 20 months in VP/VLBW children.

### Severe Cognitive Impairment

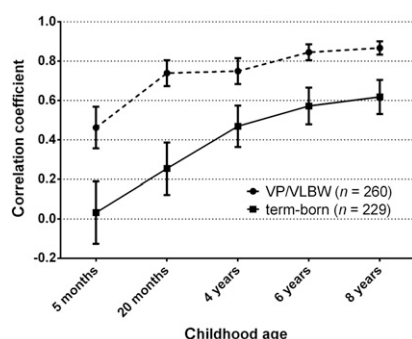
More than a quarter of VP/VLBW ( $n = 69$ , 26.5%) and 3.9% ( $n = 9$ ) of term-born adults were diagnosed with severe cognitive impairment, based on mean and variance of term-born adult IQ scores. The right side of Table 2 shows the raw mean IQ

scores of VP/VLBW individuals with and without severe cognitive impairment. Once individuals with cognitive impairment were excluded, VP/VLBW individuals' mean IQ scores remained significantly lower than term-born individuals' mean IQ scores across all time points, yet ESs decreased to a medium to large range. Correlations between IQ scores in childhood and adulthood of VP/VLBW individuals with and without cognitive impairment and test results comparing VP/VLBW and term-born individuals without impairment are shown in Table 4. When individuals with impairment were excluded, differences between VP/VLBW and term-born individuals in stability of IQ scores disappeared. Finally, for VP/VLBW individuals, point biserial correlations between childhood IQ scores and having a cognitive impairment in adulthood were all in the medium to large range (5 months:  $r = -0.48$ ; 20 months:  $r = -0.64$ ; 4 years:  $r = -0.63$ ; 6 years:  $r = -0.67$ ; 8 years:  $r = -0.71$ ). In the online Supplemental Information 2, we also report on the performance of different subtests in discriminating adults who do and do not develop cognitive impairment. When VP/VLBW individuals were divided into those with and without severe cognitive impairment, those with cognitive impairment showed the highest stability in IQ scores (Fig 3). Of those 69 VP/VLBW adults with cognitive impairment, 53.6% ( $n = 37$ )

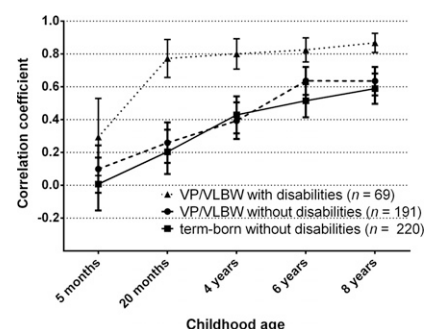
also had a diagnosis of a neurologic or neurosensory impairment in childhood, yet additional analyses showed that this impairment by itself could not account for differences in IQ stability.

### DISCUSSION

VP/VLBW individuals had significantly lower IQ scores than term-born individuals across all time points into adulthood. Approximately 1 in 4 VP/VLBW adults had a severe cognitive impairment and mean differences between VP/VLBW and term-born individuals in IQ scores were partly explained by those with cognitive impairment. IQ scores were consistently found to be more stable from childhood to adulthood in VP/VLBW than term-born individuals, yet this difference in stability



**FIGURE 2** Stability of IQ scores. Correlations between IQ scores in childhood and IQ score as measured in adulthood (26 years of age) with 95% confidence intervals. Differences are all significant ( $P < .001$ ).



**FIGURE 3** Stability of IQ scores for individuals with and without cognitive impairment. Correlations between IQ scores in childhood and IQ score as measured in adulthood (26 years of age) with 95% confidence intervals.

**TABLE 3** Correlations Between IQ Measures at the Different Time Points for VP/VLBW Individuals and Term-Born Comparisons and Test of Group Differences in IQ Stability From Childhood to Adulthood

	Correlations						Group Differences <sup>a</sup>	
	5 mo	20 mo	4 y	6 y	8 y	26 y	zScore	ES
DQ 5 mo	1	0.62 <sup>b</sup>	0.50 <sup>b</sup>	0.43 <sup>b</sup>	0.46 <sup>b</sup>	0.46 <sup>b</sup>	5.13*	0.47
DQ 20 mo	0.17 <sup>c</sup>	1	0.78 <sup>b</sup>	0.73 <sup>b</sup>	0.77 <sup>b</sup>	0.74 <sup>b</sup>	7.54*	0.69
IQ 4 y	0.09 <sup>c</sup>	0.32 <sup>c</sup>	1	0.80 <sup>b</sup>	0.79 <sup>b</sup>	0.75 <sup>b</sup>	5.06*	0.46
IQ 6 y	0.03 <sup>c</sup>	0.29 <sup>c</sup>	0.51 <sup>c</sup>	1	0.91 <sup>b</sup>	0.85 <sup>b</sup>	6.44*	0.59
IQ 8 y	-0.02 <sup>c</sup>	0.31 <sup>c</sup>	0.47 <sup>c</sup>	0.68 <sup>c</sup>	1	0.87 <sup>b</sup>	6.56*	0.60
IQ 26 y	0.03 <sup>c</sup>	0.25 <sup>c</sup>	0.47 <sup>c</sup>	0.57 <sup>c</sup>	0.62 <sup>c</sup>	1	—	—

Correlations and tests are corrected for socioeconomic status. \*  $P < .001$ .

<sup>a</sup> Tests of group differences in correlations between the specific childhood IQ score and adulthood IQ (26 y).

<sup>b</sup> VP/VLBW individuals.

<sup>c</sup> Term-born comparisons.

disappeared when individuals with severe cognitive impairment in adulthood were excluded. Cognitive function in adulthood could be fairly well estimated from age 6 years in term-born children and already from age 20 months in VP/VLBW children. IQ scores were highly stable in VP/VLBW individuals who had cognitive impairment in adulthood.

VP/VLBW children are known to be at risk for neurodevelopmental problems, including cognitive impairment and higher risk of lower educational qualifications in young adulthood compared with term-born children.<sup>1-4,6,42</sup> In the general population, low childhood IQ has been found to predict low adult SES,<sup>43,44</sup> as well as reduced survival and health into old age.<sup>45,46</sup> IQ is thus

an important marker of brain health.<sup>47</sup> Yet, as far as we are aware, this is the first prospective study report on the change and stability of cognitive function into adulthood (26 years of age) on a whole population sample of VP/VLBW individuals. Compared with term-born individuals, VP/VLBW individuals had lower IQ scores, not only as previously found in childhood, but also in adulthood at the age of 26 years consistent with other recent studies.<sup>6</sup> As a consequence, lower cognitive function may contribute to more problems in academic achievement of VP/VLBW individuals and thus ultimately in earning a lower salary and less wealth in adulthood.<sup>48</sup> Consistent with results from previous longitudinal studies,<sup>49,50</sup> cognitive

function was relatively stable from middle childhood onward in term-born children. Specifically, adulthood cognitive function could be fairly well predicted from age 6 years onward, a result comparable to age 7 to 11 onward, as reported previously.<sup>45,49</sup> Yet, as expected, IQ scores were significantly and consistently more stable from childhood to adulthood in VP/VLBW than term-born individuals, even when results were adjusted for family SES.

We found that IQ scores were most stable for VP/VLBW individuals who had severe cognitive impairment in adulthood. Thus, those who turned out to be cognitively impaired in adulthood most often already had a cognitive impairment in early and middle childhood or had lower scores on IQ tests. Furthermore, 53.6% of the VP/VLBW adults with severe cognitive impairment also had severe neurologic or neurosensory impairment diagnosed in childhood. The high stability of cognitive function into adulthood for VP/VLBW individuals with severe cognitive impairment suggests that alterations in brain development associated with being born preterm place limits on neurodevelopmental plasticity, especially in individuals with relatively high levels of initial brain trauma. Thus, next to visual dishabituation tests,<sup>51</sup> developmental tests, such as the GMDS, are well suited to detect preterm children who, toward the end of the second year of life, have enduring cognitive impairment. The GMDS did not reliably predict cognitive development at 5 months. This is likely due to faster state fluctuation of cognitive function in younger compared with older infants. That cognitive development can be predicted from age 2 years is important information for health practitioners and validates existing efforts to monitor these children around this time to plan and provide appropriate support.<sup>52</sup> Yet, it is important to realize that these

**TABLE 4** Correlations Between IQ Measures at the Different Time Points for VP/VLBW Individuals Without Cognitive Impairment and VP/VLBW Individuals With Cognitive Impairment and Test of Group Differences in IQ Stability From Childhood to Adulthood Between VP/VLBW and Term-Born Individuals With Cognitive Impairment Excluded

	Correlations						Group Differences <sup>a</sup>	
	5 mo	20 mo	4 y	6 y	8 y	26 y	zScore	ES
DQ 5 mo	1	0.47 <sup>b</sup>	0.23 <sup>b</sup>	0.12 <sup>b</sup>	0.14 <sup>b</sup>	0.10 <sup>b</sup>	0.93	0.09
DQ 20 mo	0.53 <sup>c</sup>	1	0.46 <sup>b</sup>	0.32 <sup>b</sup>	0.34 <sup>b</sup>	0.26 <sup>b</sup>	0.58	0.06
IQ 4 y	0.39 <sup>c</sup>	0.83 <sup>c</sup>	1	0.54 <sup>b</sup>	0.50 <sup>b</sup>	0.39 <sup>b</sup>	0.43	0.04
IQ 6 y	0.29 <sup>c</sup>	0.75 <sup>c</sup>	0.83 <sup>c</sup>	1	0.77 <sup>b</sup>	0.64 <sup>b</sup>	1.82	0.18
IQ 8 y	0.30 <sup>c</sup>	0.77 <sup>c</sup>	0.83 <sup>c</sup>	0.92 <sup>c</sup>	1	0.64 <sup>b</sup>	0.74	0.07
IQ 26 y	0.29 <sup>c</sup>	0.77 <sup>c</sup>	0.80 <sup>c</sup>	0.83 <sup>c</sup>	0.87 <sup>c</sup>	1	—	—

All correlations and tests are corrected for socioeconomic status.

<sup>a</sup> Tests of group differences, term-born (values in Table 3) versus VP/VLBW with impairment excluded, in correlations between the specific childhood IQ score and adulthood IQ.

<sup>b</sup> VP/VLBW individuals without cognitive impairment.

<sup>c</sup> VP/VLBW individuals with cognitive impairment.

stability values based on the whole VP/VLBW group may not be as predictive of cognitive development of a single individual.

This study has a range of strengths, the most important being the long-term follow-up of a large whole population sample of VP/VLBW and term-born individuals recruited in the same obstetric hospitals and the use of reliable and valid tests to assess IQ. There are also limitations. First, although 68% of the eligible VP/VLBW and term-born individuals assessed in childhood could be reached at 26 years, the dropout was not random. VP/VLBW and term-born individuals at social disadvantage were less likely to continue participation, as reported in many longitudinal studies.<sup>53</sup> Additional analyses showed that VP/VLBW and term-born individuals with lower cognitive abilities were also less likely to continue participation. However, simulations have shown that even when dropout is selective or correlated with the outcome of interest, predictions only marginally change.<sup>54</sup> In addition, to control for possible bias, we adjusted IQ scores for family socioeconomic status at birth in all analyses.

## CONCLUSIONS

Although some VP/VLBW children scoring low on cognitive tests beat the odds and improve into adulthood, many with persistent problems can be detected in the second year of life. Standardized developmental tests are suited for screening VP/VLBW children for enduring cognitive impairment. Where not all VP/VLBW children can be followed up, parent reports may be a valid alternative as first-stage screening.<sup>55,56</sup> Cognitive problems in early childhood are associated with increased vulnerability for learning problems and academic achievement with long-lasting consequences into adulthood.<sup>1–4,6</sup> Early identification of cognitive problems in VP/VLBW

children may help to plan specialized therapeutic and educational interventions for these children and their families.<sup>52,57</sup>

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## ABBREVIATIONS

AUC: area under the curve  
 AWST: Active Vocabulary Test  
 CMMS: Columbia Mental Maturity Scale  
 DQ: developmental quotient  
 GA: gestational age  
 GMDS: Griffiths Mental Development Scale  
 K-ABC: Kaufmann Assessment Battery for Children  
 SES: socioeconomic status  
 SGA: small for gestational age  
 VLBW: very low birth weight  
 VP: very premature  
 WAIS III: Wechsler Adult Intelligence Scale  
 ZPF: Fisher *r*-to-*Z* transformed *rs*

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