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Psychological development in children born with very low birth weight after severe intrauterine growth retardation: a 10-year follow-up study

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Children born small for gestational age (SGA) and children having very low birth weight, less than 1500 g, are claimed to be at risk of developmental problems, even when obvious pathology and disability are absent. In this study, sensorimotor and cognitive development of 14 medically healthy, very-low-birth-weight *and* small-for-gestational-age children were investigated. The children were born at the Karolinska Hospital between 1979 and 1981. At the time of the assessment, the children were aged 8.7–11.2 years. The assessment instruments included the Wechsler Intelligence Scale for Children, a modified version of the Bruininks–Oseretsky Test of Motor Proficiency, as well as selected subtests from the Halstead–Reitan Neuropsychological Battery and from the Southern California Tests of Sensory Integration. Information was also obtained from obstetric, neonatal and pediatric records, which included early developmental assessments. As a control group, 14 children were recruited and matched for age, sex and socio-economic background. The very-low-birth-weight–small-for-gestational-age group scored significantly lower on measures of visuospatial ability, non-verbal reasoning, strategy formation and gross-motor coordination. The group differences were largely attributable to the subnormal performance of eight of the very-low-birth-weight–small-for-gestational-age children. These children, who also tended to be born earliest (< 33 weeks), had a high incidence of behavioral and educational problems. These findings are consistent with the view that the very preterm infant develops a different neurobehavioral organization than a full-term infant. Developmental deficits may become increasingly evident in the early school years. □ *Cognitive, intrauterine growth retardation, neurobehavioral, psychological development, sensorimotor, small for gestational age, very low birth weight*

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Advances in obstetric and neonatal care have dramatically improved the survival rate of very-low-birth-weight infants (VLBW; < 1500 g). Most VLBW infants have been born very prematurely, while some have been born close to full term but have been small for gestational age (SGA). To be born with VLBW and to be born SGA are considered developmental risk factors, although reports are somewhat conflicting regarding the nature and magnitude of the risks involved (1–9). The disparity in these findings may be partially explained by variations in the definition of the clinical populations, in the inclusion or exclusion of children with known pathology, in the length of the follow-up, and in the assessment of developmental outcome. Because of this complexity, many questions regarding the risks associated with being born with VLBW and/or SGA remain unanswered.

In the present study, our objective was to investigate the long-term psychological development of children born with VLBW *and* SGA after complicated pregnancies (10). Based on the hypothesis that VLBW–SGA children may develop a different neurobehavioral organization (11), our investigation focused on cognitive and sensorimotor functioning. Previous research suggests that at-risk children should be followed into school age, when the normal variation in cognitive and sensorimotor measures is moderate and specific functions are increasingly differentiated.

Materials and methods

Former VLBW-SGA infants (n = 14)

The clinical population consisted of children that were born before 37 weeks' gestation, after severe intrauterine growth retardation (IUGR). All were SGA, with birth weights 2 SD or more below the mean weight for gestational age according to Swedish growth charts. The children were born during the period of 1979–1981 at the Karolinska Hospital. Most of the mothers had shown various complications during pregnancy. After birth, the children were transferred to the newborn intensive care unit (NICU). Infants with congenital malformations were excluded.

With the above criteria, the initial clinical population consisted of 22 infants. Five neonatal deaths (23%) reduced the population to 17. These deaths were primarily children with birth weights $\leqslant 1000$ g and/or $\leqslant 30$ weeks' gestation. Sixteen of the 17 survivors were examined by a pediatrician at the age of 3, 6, 12, and 18 months, and then at yearly intervals, until approximately five years of age.

The children had reached school age at the time of the present investigation. One record was missing and one family declined participation. Therefore, a total of 14 former VLBW–SGA infants, four boys and 10 girls, were included in the study. Their gestational age ranged from 30 to 36 weeks (median 33 weeks). The birth weights ranged from 820 to 1500 g (mean 1200 g). At the time of the psychological examination the mean age of the VLBW–SGA children was 9.7 years (range 8.7–11.2, SD 0.80 years).

Controls (n = 14)

Children born at term, with birth weights appropriate for gestational age were recruited for the control group. Their mothers had voluntarily participated as controls in a pregnancy study conducted during 1979–1981 (12). Their pregnancies were therefore well-documented, and known to be uncomplicated. The control group and the VLBW–SGA group were matched for age, sex and estimated socio-economic status. At the time of the actual psychological examination the mean age of these four boys and 10 girls was 9.8 years (range 8.9–10.8, SD 0.63 years).

Procedure

The examination took place during a home visit which lasted approximately three hours. The examinations were conducted by three psychologists, which included one of the authors (ACS). The examiners worked in close collaboration to ensure equal standards in the assessment procedure.

The present height and weight of each child was recorded. The psychological assessment made use of standardized psychological tests and focused on cognitive and sensorimotor functioning. For an overall measure of intellectual ability, the Swedish version of the Wechsler Intelligence Scale for Children (WISC) was used (13). All subtests except Mazes were included. For a rough measure of motor development, with a focus on gross-motor skills, we used an adaptation of the Bruininks–Oseretsky Test of Motor Proficiency (14). We included the standardized short forms of the following subtests: bilateral coordination, strength, upper-limb coordination and fine-motor speed. Also, the complete balance subtest was included. Tactile perception was examined using the Finger Identification test, from the Southern California Tests of Sensory Integration (15). The Kinesthesia test from the same battery was used as a measure of proprioceptive functioning. As a pure measure of fine-motor speed, we included Finger Tapping, from the Halstead–Reitan Battery (16). For a measure of visuomotoric speed and cognitive flexibility, we chose the Trail Making Test, also from the Halstead–Reitan Battery.

The quantitative data were complemented by clinical observations made both during and outside the testing situation. Breaks in the testing procedure provided an opportunity to talk informally with the child and parent, and to collect information regarding school, everyday life and the earlier years.

The medical records were inspected and the following information was recorded for all children ($n = 28$): gestational age, birth weight and length, as well as Apgar scores at 1 and 5 min. The VLBW–SGA infants had all been treated in the NICU for a period ranging from 31 to 81 days. They had also been subjected to medical follow-up throughout their preschool years, including assessment of psychological development. The following information was obtained from the records of the VLBW–SGA children: weight, length and head circumference at birth, at term, at six months, one year and two years of age (corrected for prematurity). The psychological report was inspected and neonatal events were recorded (see Table 3). From the records of the mothers of the VLBW–SGA children, information on obstetric complications was obtained (summarized in Table 3). None of the control children or their mothers had suffered any complications.

Data analyses

The results from each examination were first evaluated clinically, to give a global picture of the child's sensorimotor and cognitive development, with attention paid also to emotional and social adjustment. All of the VLBW–SGA children had been assessed by a clinical child psychologist sometime between the age of 1.4 and 3.8 years. Depending on the age of the child, either Gesell's developmental scale or the Stanford–Binet scale was used. The testing had been combined with clinical observation of the child and a semi-structured interview with the mother (10). These psychological reports from preschool age were inspected closely, and summarizing statements about each child's level of development were recorded, including symptoms if present. To provide an overview of the VLBW–SGA children's development, a parallel record was made, which included the result of the recent test (8.7 to 11.2 years). The two statements for each child were then compared, to determine to what extent they were congruent.

All data from the psychological tests were analysed on a group level, comparing the performance of the VLBW–SGA group with that of the controls. Two-way ANOVAs were conducted for each test (WISC, Bruininks–Oseretsky, Finger Identification, Kinesthesia, Finger Tapping and Trail Making). Whenever the overall performance on a given test differed in a statistically significant fashion, group mean performance was evaluated for each subtest, with *t*-tests. Differences in height and weight were tested with paired *t*-tests. Multiple regression analyses were carried out to tentatively test the relative importance of birth weight and gestational age for developmental outcome.

Test results were related to the perinatal data obtained from the medical records of mother and child. Due to the heterogeneity of the clinical data and the smallness of the subgroups, this was done primarily through qualitative comparisons.

Results

Our results are presented first on a group level, comparing VLBW–SGA and control group performance on all measures. A summary of the intra-individual comparisons between earlier and present psychological assessment is then given. A presentation of findings from the medical records, including observed associations between perinatal data and developmental outcome, concludes this section.

Wechsler Intelligence Scale for Children (WISC)

A two-way ANOVA, with group as the independent factor and the 11 subtests as the trial factor, was performed. The group effect was only nearly significant ($F_{1,26} = 3.45$), whereas there was a significant group-by-subtest interaction ($F_{10,260} = 3.60$, $p = < 0.01$), as seen in Fig. 1. This interaction effect could be traced to the overall lower performance of the VLBW–SGA group on the performance part of the scale, subtests 7–11 ($F_{1,26} = 8.60$, $p < 0.01$). A group-by-subtest interaction was found also within the performance scale ($F_{4,104} = 2.96$, $p < 0.05$), and the largest discrepancies in performance between the two groups were found on the block design (*t*-test, $p < 0.01$) and coding (*t*-test, $p < 0.05$) subtests. On the verbal part of the scale, subtests 1–6, the groups were essentially the same.

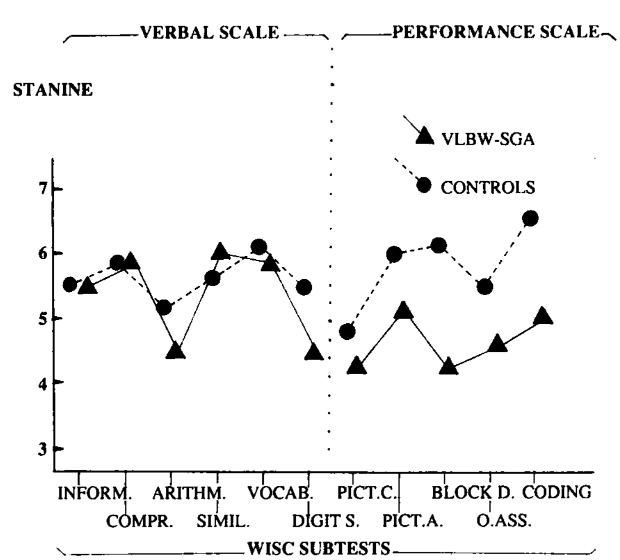

Fig. 1. Results on the Wechsler Intelligence Scale for Children (WISC). Stanine means and profiles for VLBW–SGA and control children, at 8.7–11.2 years of age. WISC subtests: information, comprehension, arithmetic, similarities, vocabulary, digit span, picture completion, picture arrangement, block design, object assembly and coding.

Table 1. Results on two sensory-motor tests, Bruininks–Oseretsky and Kinesthesia, for the VLBW–SGA group and matched controls.

	VLBW–SGA ($n = 14$) Mean ± SD	Controls ($n = 14$) Mean ± SD
Adapted version of the Bruininks–Oseretsky[a]		
Balance	24.4 ± 4.1	25.4 ± 1.6
Bilateral coordination	2.7 ± 0.6**	3.9 ± 1.0**
Strength	6.8 ± 1.5*	8.0 ± 1.6*
Upper-limb coordination	4.4 ± 0.9**	5.4 ± 0.6**
Fine-motor speed	9.9 ± 1.6	10.9 ± 1.8
Kinesthesia[b,c]		
Right upper limb	12.2 ± 3.7	10.8 ± 3.4
Left upper limb	12.7 ± 2.5*	10.1 ± 3.6*

[a] Main effect for group ($F_{1,26} = 7.14$, $p < 0.05$); [b] main effect for group ($F_{1,26} = 4.18$, $p < 0.05$); [c] score equals deviations, in mm, from perfect movement. All children ($n = 28$) were right-handed.

Statistically significant difference in group means; * $p < 0.05$; ** $p < 0.01$.

Motor proficiency

On the adapted version of the Bruininks–Oseretsky Test of Motor Proficiency, the performance of the VLBW–SGA group was inferior to that of the controls. As seen in Table 1, differences in group means were statistically significant on three of five individual subtests: bilateral coordination, strength, and upper-limb coordination.

Kinesthesia

On this measure of proprioception, the VLBW–SGA children had poorer results than the controls, as seen in Table 1. This difference was stronger for the left hand.

Finger Identification

No group differences were found for this measure of tactile perception, nor were any deficits observed in individual children.

Finger Tapping

For the VLBW–SGA group, the mean number of taps per 10 s was 32.4 (SD 10.4) for the dominant hand, and 29.3 (SD 8.7) for the non-dominant hand. This did not differ significantly from the means of the control group, which were 36.4 (SD 6.4) for the dominant hand and

31.4 (SD 5.3) for the non-dominant hand. On closer inspection, it became clear that most of the VLBW–SGA children performed to the same level as the controls, while four had clearly subnormal results.

Trail Making Test

The overall results, i.e. parts A and B taken together, showed that the VLBW–SGA children were slower than the controls in completing this test (two-way ANOVA, $F_{1,26}=4.15$, $p<0.05$). However, of even greater interest was the interaction effect ($F_{1,26}=7.57$, $p<0.01$). In the cognitively less demanding part A, the mean time for completing the task was 26.1 s (SD 10.9) for the VLBW–SGA group, compared to 22.6 s (SD 9.2) for the controls (ns). However, in part B, where cognitive flexibility and speed in shifting of sets is required, the group difference was highly significant (*t*-test, $p<0.005$). The VLBW–SGA children needed, on average, 63.0 s (SD 26.7) to complete part B, while the controls finished in 43.6 s (SD 14.9).

Summary of the multiple linear regression analyses

A series of multiple linear regression analyses was carried out with birth weight and gestational age as the independent variables, and respective outcome measure as the dependent variable. All measures, where significant group effects have been reported, yielded significant multiple regression coefficients, in some cases exceeding 0.60. When one of the variables was partialled out, the relationship for the most part became non-significant. However, beta coefficients tended to be the highest for gestational age. When birth weight was partialled out, gestational age was still significantly related to outcome on the following measures: present height ($p<0.05$), upper-limb coordination ($p<0.05$), and Trail Making B ($p<0.01$).

Comparison between earlier and present psychological assessment

The psychological assessments performed during the preschool years (1.4–3.8 years, mean 2.6 years) presented a positive picture of the VLBW–SGA children's development. Of the 14 children, only one boy had been identified as having any developmental delay (in speech). Marginal delays in gross motor development had been noted in two children, but when age was corrected for prematurity, the children were within the normal limits. The remaining 11 children were reported to be at age level in the preschool assessment, in four cases even in the upper range of normal variation.

The present examinations, performed when the children were 8.7–11.2 years (mean 9.7 years), placed six children within the normal range for their age. Three of them had above average results on cognitive measures. All six children with normal results on the sensorimotor

Table 2. Comparison between the early psychological assessment (mean age 2.6 years) and the present assessment (mean age 9.7 years) of the 14 VLBW–SGA children.

	Assessment 1990		
	Below age level ($n=8$)	Borderline ($n=0$)	Normal development ($n=6$)
Early assessment			
Below age level ($n=1$)	1[a]	0	0
Borderline ($n=2$)	2[b]	0	0
Normal development ($n=11$)	5	0	6

[a] Delayed speech in early assessment; [b] Marginally delayed motor development in early assessment.

and cognitive tests also showed satisfactory emotional, social and educational development. As many as eight children showed less than optimal development, with cognitive and sensorimotor test results that fell below the normal range on at least two major measures. Consistently, they had subnormal results on the gross-motor measure (Bruininks–Oseretsky), non-verbal reasoning (WISC Performance), and cognitive flexibility (Trail Making, part B). Indeed, the lower performance of the VLBW–SGA group on these measures was largely attributable to the subnormal performance of these eight children. Three had been identified in their school setting as motorically delayed, and had received special physical education to stimulate motor and educational development. Five were reported to be 'very shy', to the point where it presented some problem in relating to people outside the family, e.g. at school. Thus, the preschool and present assessments are at considerable variance with one another, as is summarized in Table 2, and the present assessment presents a less positive developmental outcome.

Measures of postnatal growth

The postnatal growth of the VLBW–SGA group was satisfactory. There was a complete and ubiquitous catch-up in head circumference, beginning between birth and full term. A slight drop in relative body length and weight was seen at full term. However, by age two years the VLBW–SGA group was approximately only 1 SD below normal height and weight. The variance was considerable, however, and a strong growth catch-up during the first two years of life appeared to be associated with better long-term development, as is illustrated in Fig. 2. At the time of the present study, the VLBW–SGA children were still about 1 SD below normal height and weight, and they were significantly shorter and lighter than the control group (paired *t*-test, $p<0.005$).

Obstetric and neonatal complications

By definition, pregnancies resulting in severe intrauter-

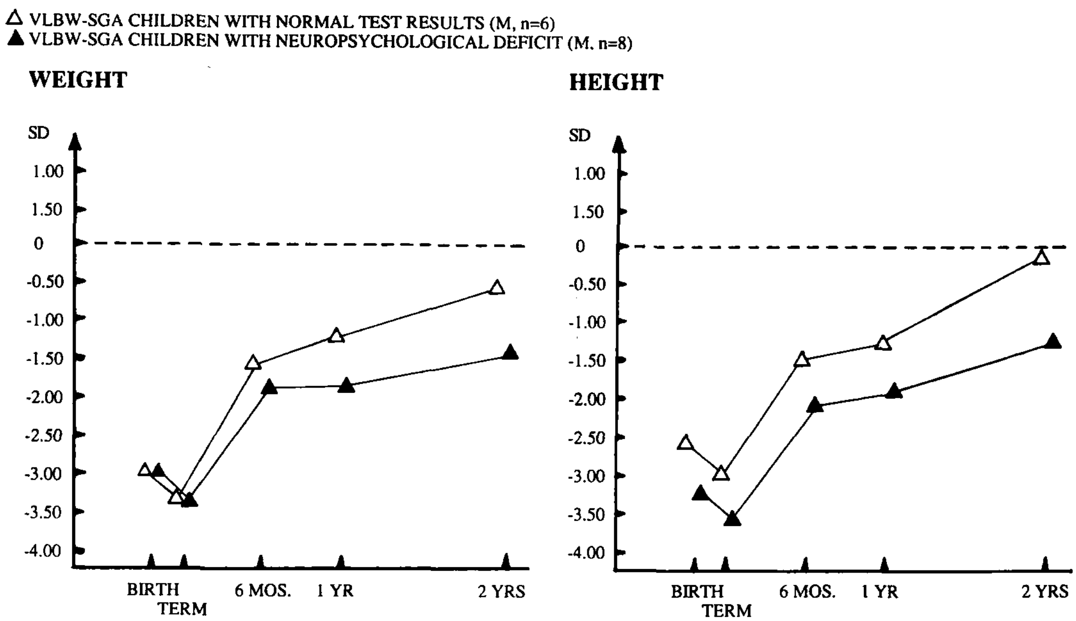

Fig. 2. Postnatal growth of the 14 VLBW-SGA children (four boys and 10 girls). Mean weight and height from birth until 2 years corrected age, expressed in SD below expected values according to Swedish growth charts.

ine growth retardation are complicated. However, there was a relatively low frequency of complications after birth; three children had no complications, and only two had as many as three risk events recorded. Perinatal complications are summarized in Table 3.

Perinatal complications and developmental outcome

No perinatal complication, obstetric or neonatal, could be singularly linked to developmental outcome. Having a high number of complications appeared to place the child at risk, however. The six children born earliest were found among the eight children who displayed some degree of neuropsychological deficit. One child with neuropsychological deficit was born during the 36th week, but had the largest number of obstetric and neonatal complications.

Table 3. Perinatal complications for VBLW-SGA children with and without (w/o) neuropsychological deficit.

	All VLBW-SGA children ($n=14$)	Children with neuropsych. deficit ($n=8$)	Children w/o neuropsych. deficit ($n=6$)
Neonatal record			
Apgar score ⩽7 at 1 min	2	1	1
Apgar score ⩽7 at 5 min	1	0	1
Hyaline membrane disease	1	1	0
Intraventricular hemorrhage	1?	0	1?
Assisted ventilation	2	1	1
Oxygen support	4	3	1
Hypoglycemia (< 1.5 mmol)	6	3	3
Polycythemia (venous hematocrit > 65%)	3	1	2
Hyperbilirubinemia (> 250 mmol)	2	2	0
Septicemia	4	3	1
Obstetric record			
Preeclampsia	10	6	4
Preeclampisa with underlying renal dysfunction	3	2	1
Smoking	2	1	1
Caesarean section	13	7	6
Fetal distress	4	2	2
Multiple birth	1	1	0
Placental hypoxia	3	3	0
Placental infarctions	8	3	5
Subnormal placental weight	11	7	4

Discussion

The results show that being born VLBW–SGA poses a developmental risk, even in the absence of pathology in the neonatal period and during the first years of life. However, as many as six of the 14 VLBW–SGA children were functioning at, or in some instances even above, age level. Eight children displayed developmental deficits, although mostly of a mild degree not equated with pathology or obvious abnormality. A typical parental comment would be that their VLBW–SGA child was less robust and capable than his siblings.

These eight children had some deficit in the gross-motor area, most typically in coordination and proprioceptive tasks, as well as in the cognitive domain. Cognitively, they lacked in strategy formation, spatial ability and non-verbal problem-solving, as indicated by Trail Making B and the WISC Performance scale. This pattern of cognitive and motoric deficits resembles what Mykleburst (17) called non-verbal learning disability, which has been cited as a behavioral correlate of CNS white-matter dysfunction (18). The apparent association between motor and cognitive development is of theoretical, as well as clinical interest. Contemporary research in motor development emphasizes action, which implies planning and cognitive skills (19–25).

Greater sensitivity, reactivity and lower threshold to disorganization observed in preterm infants born before 33 weeks' gestation have been linked to differences in brain activity in the right hemisphere and frontal lobes (26, 27). In our study, eight VLBW–SGA children displayed deficits that are critically related to these very areas in the CNS. Five children were presently reported to be "very shy". Might this be later, behavioral manifestations of the immature infant's increased sensitivity to stimulation, and ensuing threat of overstimulation and disorganization?

However, we would caution against a simple causal interpretation. A child develops in continuous, dynamic and reciprocal interaction with his or her environment (29). The premature infant is less skilled than a full-term baby in signalling his needs and initiating social interaction (30), and is also more easily overstimulated (31). During the neonatal period, the medical condition of the immature infant may put some real constraints on the interaction between mother and child. Obviously, these factors set a less than optimal stage for mother and child to develop a sound primary relationship, which in turn may negatively affect the child's sensorimotor and cognitive development (32).

The discrepancy between the present findings and the preschool assessments may seem puzzling. However, the normal variation in development during the first years of life is quite sizable, which calls for a sound conservatism when discussing the prognosis of an individual child. Furthermore, as the child matures specific functions become increasingly differentiated, making certain deficits more discernible when the child is 6 years and beyond (18, 33). According to a growing body of evidence, including the present study, the notions of "neuromaturational delay" and a general "catch-up" in preschool children are indeed questionable. Instead, we may think of more or less unique neurobehavioral reorganizations (11, 19). This does not exclude prognostic optimism, which is often a clinically sound attitude.

In our view, the present findings have the following clinical implications. Being born VLBW–SGA poses a developmental risk. Children born SGA before 33 weeks' gestation may be more vulnerable. The number of obstetric and neonatal complications is another warning sign. Worries and concerns that parents express regarding their VLBW–SGA child's development during its toddler and preschool years should not be dismissed. Some children with a VLBW–SGA background will need and benefit from special educational and therapeutic intervention. These concerns notwithstanding, there is reason to be optimistic regarding the development of VLBW–SGA children, and not to conceive of them in pathological terms.

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