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Neurological, psychological and articulatory impairment in five-year-old children with a birthweight of 2000 g or less

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Abstract. The study comprised 324 children with a birthweight ≦2000 g born in 1971-1974 at the Institute of Midwifery, Helsinki. The low birthweight (LBW) infants totalled 1.46% of the live-born during that time. At the age of 5 years 197 children were investigated; 15 had severe handicaps while 182 were without any immediate noticeable defects. The rest were not investigated for the following reasons: 86 had died, seven were severely handicapped and 34 could not be traced or the parents did not want to participate in the examination. The 197 children were given a neurodevelopmental screening examination, psychological and articulatory tests. A score of ≧23 in the neurodevelopmental screening examination was noted in 8% of the controls, in 87% of the severely handicapped and in 34% of children without severe handicaps. All psychological test results differed significantly from those of the controls. The articulatory tests showed that the speech problems were more common among the LBW children. According to the teachers' assessments at the age of 9 years, 32% of the LBW children were in need of special education, compared with 12% of the controls. A significant correlation was found between the test results at 5 years and the school achievement at the age of nine.

Key words: Low birthweight - Neurodevelopmental screening - School achievement

Introduction

The study is a part of a prospective research project to follow-up a group of newborn infants selected according to certain high-risk factors from 22217 consecutive cases born in 1971-1974. All children with a birthweight of 2000 g or less were included in the study and the outcome at the age of 5 years is reported.

The aim of the study was mainly to investigate the degree to which minor neurodevelopmental handicaps were present, and whether the results at five could be used to predict school failure at nine. The mortality and the occurrence of severe handicaps is also reported.

Materials and methods

The series comprised 324 children who were born alive in 1971-1974 at the Institute of Midwifery, Helsinki. All the children from 22217 consecutive cases who had a birthweight of 2000 g or less were included in the study series.

The low birthweight (LBW) infants were mainly taken care of at the Institute of Midwifery which apart from the maternity wards has two wards for the newborn, one mainly for prematures and the other for fullterm. Neonates who needed more extensive investigations and treatment were referred to the Children's Hospital, University of Helsinki.

Twelve percent of the LBW children were born at 38-40 weeks of gestation, 32% at 34-37 weeks of gestation and 56% at 33 weeks of gestation or earlier. Thirty-two percent were born small for gestational age. Fifteen percent were born by breech presentation and 15% by caesarean section. The Apgar scores were at 1 min of age ≦6 in 48%, and at 5 min of age ≦6 in 25%. Sixty-six children had in addition to LBW other risk factors in the newborn period; 8% had hyperbilirubinaemia (at least two values ≧340 mmol/l or blood exchange transfusion performed), 7% had hypoglycaemia (at least two values ≦1.67 mmol/l for fullterm and ≦1.21 mmol/l for prematures), 11% had received respiratory care. Ten percent had neurological symptoms, such as convulsions, rigidity or prolonged feeding difficulties.

At the age of 5 years (4 y 10 m-5 y 3 m) the following investigations were made at the Children's Hospital.

Neurological examination. The neurological examination consisted of test items from a neurodevelopmental screening examination developed by Bax and Whitmore [1] and modified by Michelsson et al. [20]. The examination tested gross and fine motor performance, coordination, balance, reflexes, visual and auditory perception, articulation, language skills, short memory, concentration ability, behaviour, vision and squint. Points were given for items which the child failed and the total score demonstrated the impairment of the child's neurodevelopmental state.

The neurological examination was performed by a paediatrician or a paediatric neurologist.

Psychological tests. The Illinois Test of Psycholinguistic Abilities (ITPA) was used [13]. The test was designed to analyse various aspects of childrens' communicative abilities [12], and was standardised for Finnish children [14]. The items of the 12 subtests are: visual and auditory reception, visual and auditory association, verbal and manual expression, visual, auditory and grammatic closure, visual and auditory sequential memory, and sound blending.

The visual-motor tests were made by a psychologist and the auditory-vocal tests by a speech therapist.

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All the children were asked to draw a person, and the performance was scored according to Goodenough [9]. The children also wrote their names, and the writing was scored according to Reimer et al. [21]. The children born in 1973 and 1974 were given the short intelligence test developed by Dubowitz et al. [5]. In the test the children build models with cubes and copy forms (part A), count fingers and cubes, which together with the repetition of numbers consisted of the part B.

Articulatory tests. In the articulation test the children were asked to repeat single vowels and consonants which were scored incorrect if the vowels and consonants were substituted or distorted. Failures were scored normal, slightly or definitely abnormal.

In the word articulation test the children were shown 46 pictures which they were asked to identify. Missing or substituted sounds were noted as reversed syllables. We also noted if the child had an abnormal voice, such as hoarseness or nasal speech, or if he stammered.

The motor performance of the tongue and lips was observed. The performance was scored normal, slightly or definitely abnormal.

The articulatory tests were performed by a speech therapist, who—like the physician and the psychologist—knew that the children belonged to a high-risk group, and we studied the children with various risk factors. The examiners did not know the kind and severity of the neonatal risk.

Developmental evaluation. The development of the children was checked at child health centers at the age of 0.5, 1, 1.5, 2 and 4 years.

At the age of 9 y 4 m (±6 m) 120 LBW children born in 1971–1973 were investigated at the Children's Hospital. The results at the age of 9 years of the Stott Test of Motor Impairment [23], WISC intelligence test, ITPA, and the teachers' statements of the childrens' performances were correlated with the results at the age of 5 years.

Control children. The control series comprised 85 children born in 1971–1974 in the same hospital. Sixty children were randomly selected among infants with no complications observed during pregnancy, delivery or the newborn period. The children were fullterm with normal birthweights. Twenty-five children were healthy twin-partners to infants, who because of neonatal risk factors were included in our risk group.

Both the control children and the LBW children have been living in the Helsinki region. There were no significant differences between the groups in sex, order of birth or social status of the family.

Results

Mortality. Of 324 children 26.5% died; 83 during the first week of life and three at the age of 1 month. Of those who died during the first week 25 had a birthweight above 1500 g, and 58 had a birthweight ≦1500 g. Twelve of the children had severe anomalies which can be considered to be the main cause of death. One child died of septic infection and two of paralytic ileus. In all other cases the autopsies revealed a pulmonary or cerebral cause, mainly hyaline membrane disease and/or cerebral haemorrhage. Three children died at the age of 1–4 months; one of biliary duct anomaly, one of cardiac fibroelastosis and one suddenly of an unknown cause.

Table 1. Mortality, occurrence of severe handicaps, and the number of children investigated according to birthweight

Birthweight (g)	Dead	Severe handicaps	Examined for minor handicaps	Not examined	Total
	n	*n*	*n*	*n*	*n*
1760–2000	13	8	82	19	122
1510–1750	14	4	58	10	86
1260–1500	14	7	30	4	55
≦1250	45	3	12	1	61
Total	86	22	182	34	324

Severe handicaps. The number of children with severe mental or neurological handicaps, epilepsy, hydrocephalus and/or retrolental fibroplasia was 22, which is 6.8% of the LBW children and 9.2% of those who were alive after the 1st week.

Three children had hydrocephalus which had developed in the neonatal period. Two of three children with severe mental retardation had an anomaly syndrome. Moderate mental retardation was observed in three children, one of whom also had retrolental fibroplasia. Spastic diplegia was found in one child, spastic hemiplegia in three, spastic tetraplegia in four children and dystonic tetraplegia in one child. Of the children with CP five had additional mental retardation and/or convulsions. One of the children was handicapped because he had been battered at the age of 5 months; the child was also almost deaf. Two more children had retrolental fibroplasia, and two more had convulsions.

Fifteen of the handicapped children were investigated at the age of 5 years. The mean neurodevelopmental score was 63.2. Two children with epilepsy received 8 and 15 points in the examination. Two children with hydrocephalus had scores of 22 and 24. All the others had scores between 40 and 160. The mean ITPA was 30.4. Nine children had speech problems.

Seven children with severe handicaps were not examined; five of these were known to be severely handicapped and therefore were not invited, and two arrived but could not attend in the examinations because of mental retardation.

Thirty-four children were not examined because they could not be traced or the parents refused to bring them (Table 1). However, we have the results of these children from the child health centres and we know that they are not severely handicapped. The minor handicaps cannot be defined precisely from the questionnaires.

Neurodevelopmental examination. Altogether 182 children without severe handicaps were examined at the age of 5 years. The mean score in the neurodevelopmental test was 20.3±12.9 (Table 2). The mean score for the control children was 11.8±7.4. The difference was statistically significant.

A significant difference was also observed between the scores of the 103 girls (mean 16.9±9.4) and the 79 boys (mean score 24.5±15.5, $P<0.001$). There were no significant differences noted if the children were divided according to birthweight, social class or if they were small or appropriate for gestational age.

Sixty-six children had in addition to LBW other high-risk factors in the newborn period, such as hyperbilirubinaemia, hypoglycaemia or neurological symptoms. The mean score for these children was 22.1, while 116 children with no high-risk factors had a mean score of 21.0.

Table 2. Results of the neurological, psychological and articulatory tests in LBW children and controls

Examination	LBW children	Controls	*P*
Neurodevelopmental examination, mean ± SD	20.3 ± 12.9	11.8 ± 7.4	<0.001
ITPA, mean ± SD	34.5 ± 4.0	37.0 ± 2.8	<0.001
Lip movements (%)			
Normal	81.9	97.2	
Slightly abnormal	17.5	2.8	<0.001
Definitely abnormal	0.6	0	
Tongue movements (%)			
Normal	53.8	75.0	
Slightly abnormal	38.0	22.2	<0.001
Definitely abnormal	8.2	2.8	
Articulation of single sounds (%)			
Normal	47.5	68.6	
Slightly abnormal	41.0	29.6	<0.001
Definitely abnormal	11.5	1.8	
Word articulation (%)			
Normal	45.4	63.9	
Slightly abnormal	38.2	33.3	<0.01
Definitely abnormal	16.4	2.8	
Draw-a-person test, mean ± SD	120.9 ± 25.6	137.8 ± 30.3	<0.001
Name writing test, mean ± SD	11.6 ± 2.1	13.1 ± 1.4	<0.001
Developmental test, mean ± SD			
Part A	13.5 ± 3.5	15.6 ± 2.5	<0.001
Part B	18.6 ± 7.4	23.8 ± 4.9	<0.001
Part A + B	32.2 ± 9.6	39.4 ± 6.8	<0.001

The significance levels were determined by the *t*-test, difference between means, and the χ^2-test

A score of 23 or more was recorded for 8% of the control children and 34% of the LBW children without severe handicaps; the occurrence was 32% in children with a birthweight of 1510–2000 g and 39% in those weighing ≦1500 g at birth.

Psychological tests. The mean ITPA among the LBW children without severe handicaps was 34.5 ± 4.0 (Tables 2 and 3). The mean ITPA for control children was 37.0 ± 2.8; the difference was statistically significant.

The results of the ITPA subtests are presented in Table 3. The differences compared with the control series was statistically significant in 9 of the 12 subtests.

The results of the drawing test [9], the name writing [21], and the developmental test by Dubowitz et al. [5] are given in Table 2. The differences between the LBW children and the controls were statistically significant in all the tests.

We noted that 22% of the LBW children did not draw a person at 5 years, versus 4% of the controls. The same was true of the name writing; only 2% of the control children refused while 37% of the LBW children refused. The refusals were excluded from the scoring.

Articulatory tests. Articulation errors in both single sounds and words were significantly more common in the LBW children

Table 3. Results of the ITPA subtests in LBW children and controls, means ± SD

ITPA subtest	LBW children	Controls	*P*
Reception			
Auditory reception	38.4 ± 7.3	40.6 ± 7.8	<0.001
Visual reception	33.0 ± 5.2	34.8 ± 5.0	NS
Organisation			
Auditory association	35.6 ± 6.7	39.1 ± 5.1	<0.001
Visual association	34.8 ± 7.5	36.2 ± 5.2	NS
Expression			
Verbal expression	35.6 ± 6.9	36.2 ± 5.1	NS
Manual expression	32.5 ± 6.2	35.3 ± 3.9	<0.001
Closure			
Grammatic closure	36.0 ± 7.1	39.3 ± 7.6	<0.001
Visual closure	34.5 ± 5.8	38.2 ± 6.2	<0.001
Sequential memory			
Auditive memory	34.3 ± 6.3	36.8 ± 5.4	<0.01
Visual memory	34.3 ± 6.5	35.7 ± 3.6	<0.05
Supplementary tests			
Auditory closure	33.8 ± 7.3	37.5 ± 4.1	<0.001
Sound blending	31.0 ± 4.9	35.1 ± 4.5	<0.001
Total score	34.5 ± 4.0	37.0 ± 2.8	<0.001

The significance levels were determined with the *t*-test, difference between means

than in controls (Table 2). Severe articulation errors in single sounds were observed in 11.5% of the study group and in 1.8% of the controls. Severe errors in word pronunciation, i.e. wrong articulation of multiple sounds or repeatedly wrong syllables occurred in 16.4% of the LBW children and 2.8% of the control children.

Articulation errors were more common in children weighing ≦1500 g; the difference from those with birthweights of 1510–2000 g was statistically significant both for sound articulation ($P<0.001$) and for word articulation ($P<0.01$).

There was a statistically significant difference in the muscle movements of the lips and tongue between the LBW children and the controls. While 2.8% of the control children did not manage to perform lip movements correctly, 18.1% of the prematurely born had this failure. Difficulties with tongue movements occurred in 25.0% of the controls and 46.2% of the LBW children. There were no significant differences between the children according to birthweight.

Two of the LBW children and one control child had a stammer. Eight of the LBW children had an abnormal voice pitch and three had a nasal speech; none of these faults were established in the controls.

School achievement. Children born in 1971–1973 were re-examined at the age of 9 years in 1980–1982. On this occasion, we asked the teachers to fill in a questionnaire about the childrens' abilities in reading, writing, arithmetic, handicrafts, drawing and gymnastics. The teacher's opinion on each of these abilities were scored 0 if the child's performance was reported as very good, 1 if it was fairly good, and 3 if the child managed badly. Thus, a maximum of 18 points could be given for a very bad school performance.

According to the teachers' statements, the best scores, 0–4, were achieved by 45 children. A score of 5–8 was received by 46

Table 4. The correspondence between the neurodevelopmental scores at the age of 5 years and the teachers' assessments at the age of 9 years

Neurodevelopmental scores at 5 years	Teachers' rating of school achievement		
	Good (score 0–4)	Fair (score 5–8)	Bad (score ≧9)
0–22	42	29	8
≧23	3	17	16

Table 5. Correlation of the test results at the age of 5 and 9 years

Age 5 years	Age 9 years	*n*	*r*	*P*
Neurodevelopmental screening	Teacher's rating	115	0.565	<0.001
Neurodevelopmental screening	Test of motor impairment	120	0.499	<0.001
Name writing	Teacher's rating	90	0.528	<0.001
Draw a person	Teacher's rating	90	0.485	<0.001
Neurodevelopmental screening	WISC	82	0.548	<0.001
ITPA	Teacher's rating	82	0.239	<0.05
ITPA	ITPA	90	0.388	<0.001
Dubowitz developmental test	WISC	34	0.685	<0.001

children, and 24 had a score of ≧9. Table 4 shows that children with high neurodevelopmental scores at the age of 5 years more often failed in school compared with children with low neurodevelopmental scores.

The teachers assumed that special education was needed by 32% of the LBW children compared with 12% of the control children.

The WISC intelligence test was performed on 82 children, i.e. all LBW children investigated in 1981 and 1982. The mean score was 111±12. Three children had scores <90; all three had a mean ITPA of 27 at the age of 5 years. One of the children had been operated on for hydrocephalus in the newborn period, one had spastic hemiplegia, and one was considered to be mentally retarded at the age of 5 years. They had received 83, 91 and 77 points in the neurodevelopmental examination of 5 years.

The correlation between the test results at age five and the results at age nine is shown in Table 5 and is seen to be highly significant for most items.

Discussion

Previous long-term studies on low birthweight infants indicate that about one-fifth of the children need special education on reaching school age [2, 7, 8, 22] often despite a normal intelligence [10] and no clearly detectable handicap [3, 4, 17]. The need for early recognition of learning difficulties has therefore gained emphasis [4, 7].

School problems have previously been found to be more common in children with neurological symptoms and signs at pre-school age. Jaffa [11] found that learning disorder in young school children could be identified by neurodevelopmental screening, to promote early diagnosis and remediation. She investigated 132 children aged 76–90 months, and found that learning disabled children had a significantly higher incidence of abnormal minor signs. Köhler et al. [15] found that children with minimal brain dysfunction symptoms at 4 years run a risk of having trouble in school, both regarding behaviour, learning, slight neurological disturbances, and visual disorders.

The aim of our research project was not only to follow-up a high-risk group of newborn infants but also to develop methods that would enable early recognition of school difficulties.

In addition to the LBW children we have followed-up children with other neonatal high-risk factors [19, 20]. The results showed that among 845 risk children neurodevelopmental impairment was most common at the age of 5 years in children who neonatally had had neurological symptoms; the scores, however, were almost as high in children who were born with LBW or who had had severe respiratory problems. The lowest scores were recorded for children with neonatal hyperbilirubinaemia, but even these scores were significantly higher compared with the controls. In all risk groups the scores were higher if the child had had multiple risk factors concomitantly [20].

A significant correlation of the neurodevelopmental screening examination with the teachers' questionnaires showed that neurological "soft" signs were more common in children who failed in school, which indicates that the reason for school failure can be an organic lesion. Thus the neurodevelopmental screening examination clearly stresses the need for further examination of children with high scores.

A majority of the control children were able to draw a person and to write their name. About every fifth LBW child refused to draw a person and every fifth refused to write their name. Even if we thought the reason could be an inability to draw and write, the refusals were excluded from the scoring. In spite of this, the results of the LBW children who did draw and write were significantly worse than the results of the controls.

Hertzig [10] found that children who were born prematurely and who showed neurological symptoms at the age of eight years had difficulties in school more often than those who had no neurological symptoms. Nine children out of 20 with neurological symptoms were reported to do poorly in school, against only 4 of 33 neurologically normal children. Psychiatric consultations were also more common; 15% in the neurologically normal group were referred for psychiatric consultations versus 50% of the children with "soft" signs.

We chose the ITPA psychological test as it was designed to assess specific functions that were assumed to underly learning proficiency [13]. Scores that are more than 6 points (1 SD) below the mean scaled score for the individual are considered to be significant areas of deficit [16]. The significantly worse results of the LBW children stresses the need for remedial efforts in areas of deficit. However, there are divergent opin-

ions on whether the subtests are reliable enough as a guide for remedial action [16, 18, 24]. As we found an obvious correlation between the results of the ITPA at five, and school achievement at nine some kind of habilitation seems to be indicated according to the results of the ITPA subtests.

The difference in the ITPA subtests between the LBW children and the controls were more often significant in the auditory-vocal subtests. The same trend was found by Ehrlich et al. [6] who stressed that more attention should be focused on the auditory and verbal function of prematurely born children.

Severe articulation errors were often combined with difficulties with motor function of the lips and tongue. The articulation errors were considered severe if the pronunciation of many sounds was faulty and speech therapy was considered to be indicated. Slight articulation errors, mostly "r" or "s", were common in both LBW children and controls, and were not considered to be substantial errors but rather due to the development of the child at this age, and were considered to disappear without treatment as the child became older. Dargassies [2] has found speech problems in 7% of prematurely born children, and noted that articulation problems predominated.

In conclusion, the results indicate that the neurodevelopmental impairment at the age of 5 years is more common among LBW children than among healthy controls with no perinatal high-risk factors. The results also indicate that school problems were more common among those who had had neuro-developmental impairment at the age of 5 years, which indicates that the cause of school failure can be due to minor organic brain dysfunction. The results also show that it is possible to find children who will fail at school before starting school, as there existed a significant correlation between the results at age 5 and 9 years. This enables early remedial treatment in areas of deficit.

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