Eur J Pediatr (1986) 145:475–479

European Journal of
Pediatrics

Visual acuity and stereopsis between the ages of 5 and 10 years

A cross-sectional study*

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Abstract. The development of visual acuity and stereopsis was studied in 321 boys and 340 girls aged between 5 and 10 years. Visual acuity was assessed by the E test and a modified version of the STYCAR test, stereo acuity by the Lang-Stereo test [17].

Both vision tests showed an increase in the median visual acuity between the ages of 5 and 10 years. The E test indicated an increase from 1.2 between 5 and 6 years to 1.5–1.7 between 7 and 10 years. The values obtained with the STYCAR test were 0.6–1.3 higher, depending on the test rating used. Visual acuity norms between 5 and 10 years are presented as empirical centile curves.

No significant differences were observed in visual acuity between the left and right eyes, nor between the sexes. The right eye was found to be the leading eye in 54.8% of the boys and 54.5% of the girls ($P < 0.001$).

The Lang-Stereo test was passed by 87.9%–94.3% of all children, and there were no significant differences with respect to age and sex. Children who failed the test had a significantly lower visual acuity than those who passed it. In the former group a significant interocular difference in visual acuity was present ($P < 0.01$).

Key words: Visual acuity – Stereo acuity – Children 5–10 years old

Introduction

Sufficient visual function is a prerequisite for normal overall development in infancy and childhood. In recent years a number of authors [1, 2, 4, 5, 8–10, 12, 14, 15, 24, 27] have been involved with the problems of visual acuity and stereopsis and with the testing of these functions, and a range of new tests and methods has been developed [e.g. 10, 11, 13, 16–18, 21].

Using different methods, the visual development of newborns and young infants has been investigated recently [1, 2–4, 6, 10], and the development of visual acuity from the age of puberty to adulthood has been the subject of several studies [e.g. 9, 19]. Less well documented is visual acuity for children aged between 5 and 10 years, its developmental course and its variability.

There has been a growing interest in the use of stereopsis tests to screen for amblyopia in young children. The testing of stereo acuity and its relationship to visual acuity have been investigated in a series of studies [7, 8, 20, 22, 24, 26], but data on child stereo acuity norms are limited and, for various methodological reasons, often contradictory [26].

In this study the following aspects of visual performance between the ages of 5 and 10 years were investigated. (1) Development and variability of visual acuity; (2) agreement between results shown by a modified form of the STYCAR test and the E test; (3) development of stereo acuity as assessed by the Lang-Stereo test [17]; (4) relationship between visual acuity and stereopsis.

Subjects

Between February and December 1983, 325 boys and 342 girls were tested in public schools (Table 1). In collaboration with the school authority, two school districts in the city of Zurich were chosen, from which 14 kindergarten, 15 first-grade and 11 third-grade classes were selected at random. The mean ages were 5.8 (SD 0.6) years for the kindergarten, 7.3 (SD 0.5) years for the first grade and 9.5 (SD 0.6) years for the third grade of primary school. There was no distinction by sex. The percentage of Swiss (78%) and of foreign children (8.9% Italian, 3.2% Jugoslavian, 1.5% Spanish, 2.0% Greek and others 6.5%) remained the same in all three age categories, and is representative for the city of Zurich.

The proportion of children wearing glasses increased from the kindergarten to the third grade (1.4% in the kindergarten, 6.6% in the first grade, and 10.1% in the third grade).

Methods

The luminance of each examination room was measured with a photographical light meter. The mean of three standardized measurements was 8.4 fc (lumen per square foot) (SD 1.8) in the kindergarten, 8.1 fc (SD 1.1) in the first class and 8.2 fc

Table 1. Subjects

		N	%	Age (years)		
				M	SD	Range
Kindergarten	M	93	43.9	5.8	0.6	4.4–8.1
	F	119	56.1	5.8	0.7	4.4–7.2
First grade	M	120	49.6	7.3	0.4	5.7–8.7
	F	122	50.4	7.3	0.6	6.3–8.5
Third grade	M	108	52.2	9.5	0.5	8.7–11.7
	F	99	47.8	9.6	0.6	8.6–11.3
Total	M	321	48.6	7.6	1.6	4.4–11.7
	F	340	51.4	7.4	1.6	4.4–11.3

* This work was supported by the Swiss National Science Foundation No. 3988.–1.84
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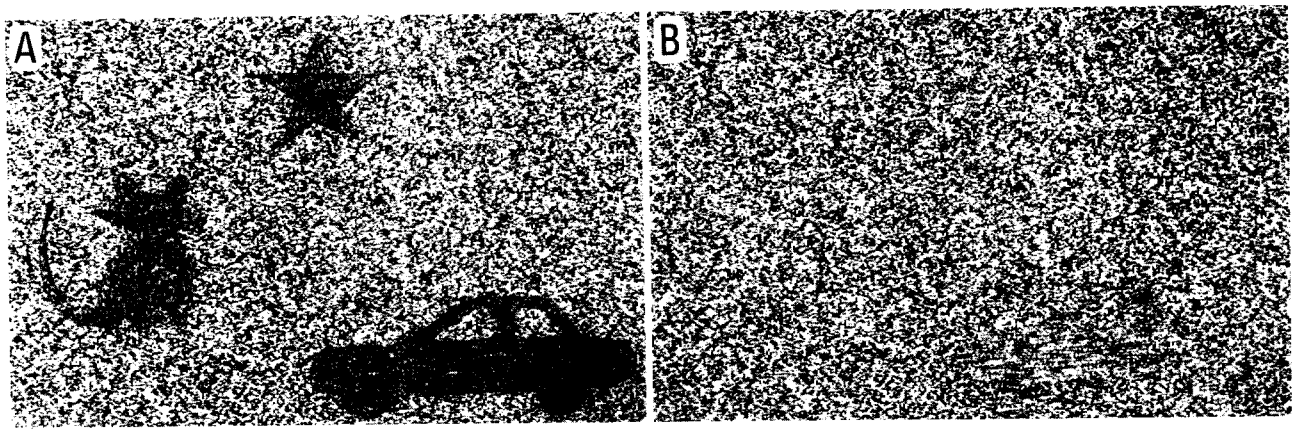

Fig. 1A, B. Lang stereo test. Test card by binocular **(A)** and monocular **(B)** viewing

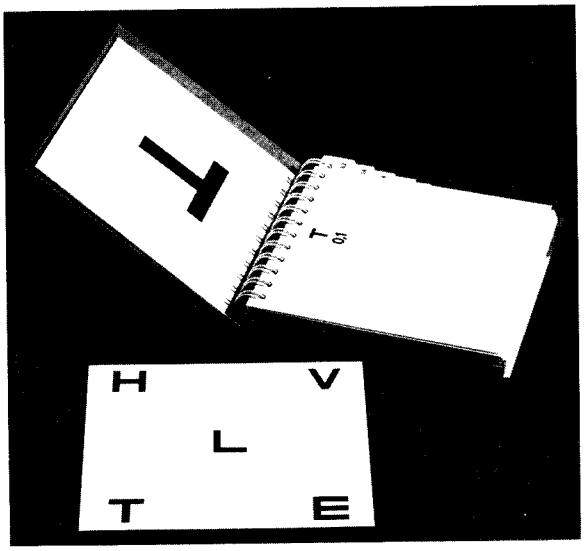

Fig. 2. Stycar test

(SD 1.1) in the third class. All measurements were within the recommended range of illumination of 5–20 fc for visual acuity testing [23]. No significant differences of luminance were found between the examination rooms nor between the different types of measurement and no significant relationships were noted between luminance and visual acuity observed in a particular examination room.

The examination took the following course. First, the presence or absence of glasses was noted for each child and his/her leading eye was determined using a kaleidoscope. Subsequently, the Lang-Stereo test was given to the child, followed, in half of the children, by the E test and then the STYCAR test and, in the other half, by the STYCAR test and then the E test. No significant differences in mean visual acuity were found between these two groups of children. The child's cooperation was estimated during all parts of the examination.

Lang-Stereo test [17, 18]. The child was confronted with a test card, the size of a postcard (9 × 14.5 cm), at a distance of 40 cm (Fig. 1). This card combining the random-dot and cylinder-gratings methods could be used without polarized glasses or red-green spectacles. Binocular stereoscopic viewing of the card allowed the child to see three figures, namely a star (disparity: 600"), a car (disparity: 550") and a cat (disparity: 1200"). By monocular viewing of the card a black mesh-like pattern only was seen. The child's response was scored in the following way: recognizing all three figures clearly, recognizing questionably (did not recognize all three figures or only after guessing many times and looking at them repeatedly), recognizing none of the figures.

STYCAR-test. A modified form of Sheridan's STYCAR Vision Test (1974), constructed according to Snellen principles (Fig. 2), was used. A card with the five letters H, V, T, L, E was handed to the child, who was asked to point at the letter which corresponded to that shown by the examiner out of the test book at a distance of 3 m, (some of the older children preferred to name the letter). The right eye was always tested before the left eye, and the eye not under test was covered by a black eye-flap. The child was shown two different letters per visual acuity step – the magnitude of the steps being 0.1 up to visual acuity 1.0 (3/3), and 0.2 between visual acuities 1.0 (3/3) and 3.0 (3/1). Two scores were marked down for each eye: the last visual acuity at which the child recognized both letters pertaining to that step of visual acuity (STYCAR 1), and the visual acuity of the last-recognized letter followed by three mistakes (STYCAR 2).

E-Test. A whole-line chart presentation was used which consisted of steps of 0.1 for visual acuity between 0.1 (5/50) and 1.0 (5/5) and of 0.25 for visual acuity between 1.0 (5/5) and 2.0 (5/2.5). The test distance was set at 5 m. The child was given a card with the letter E in four orientations – up, down, right and left – and was asked to indicate the orientation of the letter E held up by the examiner by pointing to the letter of the same orientation on this card. The visual acuity of the last correctly recognized Snellen E followed by two mistakes was recorded. The other conditions of the test were the same as those of the STYCAR test.

Statistical analysis of the test ratings was performed by means of the two sample Wilcoxon test and Spearman rank correlations. Six children had to be excluded from the analysis because of insufficient cooperation.

Results

Means, standard deviations and empirical centiles of visual acuity for the *E* test, STYCAR 1 and STYCAR 2 tests are given in Table 2. The distribution of visual acuity according to the *E* test is shown in Fig. 3. Since nationality and sex did not

Table 2. Means, standard deviations and empirical centiles of visual acuity according to the *E* test, STYCAR 1 and STYCAR 2 tests

		N	M	SD	3%	10%	25%	50%	75%	90%	97%
Kindergarten											
E test	M	93	1.2	0.4	0.3	0.6	1.0	1.2	1.5	1.7	2.0
	F	119	1.2	0.4	0.4	0.6	1.0	1.2	1.5	1.7	2.0
STYCAR 1	M	93	1.8	0.6	0.7	1.0	1.4	1.8	2.2	2.6	2.7
	F	119	1.8	0.5	0.7	1.1	1.4	1.8	2.2	2.6	3.0
STYCAR 2	M	93	2.1	0.7	0.7	1.1	1.7	2.1	2.6	3.0	3.0
	F	119	2.1	0.6	0.8	1.4	1.6	2.1	2.6	3.0	3.0
First grade											
E test	M	120	1.6	0.4	0.5	1.0	1.3	1.7	1.7	2.0	2.0
	F	122	1.5	0.4	0.4	1.0	1.2	1.5	1.7	2.0	2.0
STYCAR 1	M	120	2.3	0.6	0.7	1.6	1.9	2.3	2.7	2.8	3.0
	F	122	2.1	0.6	0.5	1.3	1.7	2.2	2.6	2.8	3.0
STYCAR 2	M	120	2.6	0.6	1.0	1.8	2.2	2.7	3.0	3.0	3.0
	F	122	2.4	0.7	0.6	1.4	2.1	2.6	3.0	3.0	3.0
Third grade											
E test	M	108	1.7	0.4	0.6	1.0	1.5	1.7	2.0	2.0	2.0
	F	99	1.5	0.5	0.4	0.9	1.2	1.7	2.0	2.0	2.0
STYCAR 1	M	108	2.4	0.6	1.0	1.6	2.1	2.6	2.9	3.0	3.0
	F	99	2.3	0.7	0.7	1.3	1.7	2.4	2.8	3.0	3.0
STYCAR 2	M	108	2.7	0.6	1.1	1.8	2.5	3.0	3.0	3.0	3.0
	F	99	2.5	0.7	0.7	1.5	2.1	2.8	3.0	3.0	3.0

Definition see Methods

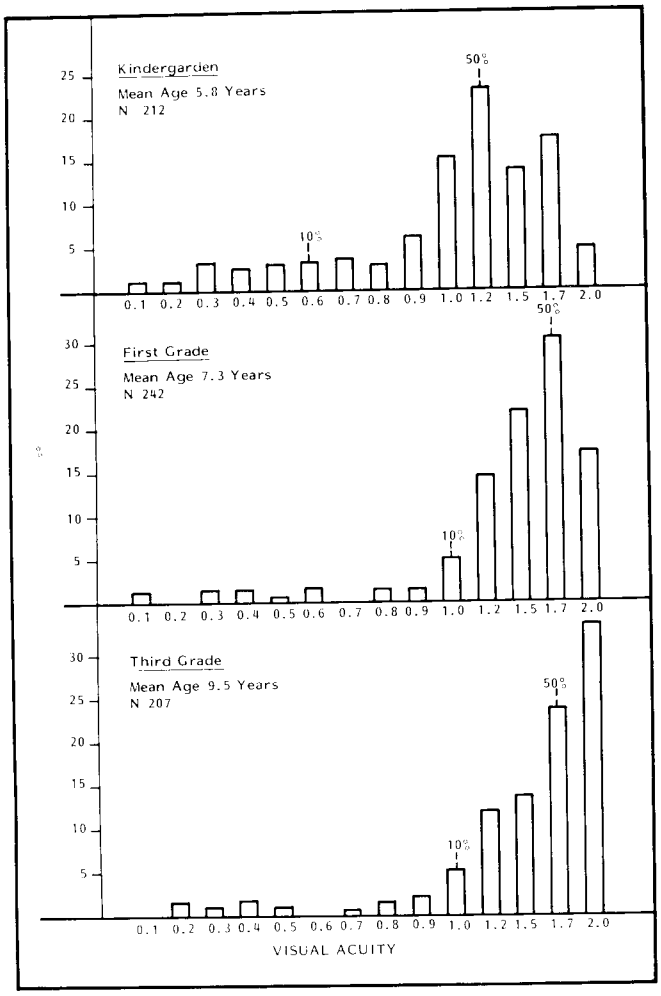

Fig. 3. Visual acuity according to the E test

have a significant influence on any of the test results, the results given include children of all the nationalities involved and of both sexes.

Figure 3 clearly demonstrates that visual acuity was not normally distributed at any of the three test ages and, therefore, mean and standard deviation values are of limited significance. The results are discussed below mainly with respect to empirical centiles, in particular to median values (50th centile).

Using the E test, an increase in median visual acuity was noted between the ages of 5 and 10 years in both sexes (Table 2): starting at 1.2 at kindergarten age, it increased to 1.7 in boys and 1.5 in girls of the first grade, remained steady at 1.7 for boys and increased for girls to 1.7 in the third grade. Thus, the median visual acuity improved by 0.5 for both boys and girls between the mean ages of 5.8 and 9.6 years. At the age of 5.8 years 25% of the children had a visual acuity of 1.0 or less, 10% of these were below 0.7. At the median ages of 7.3 and 9.5 years, visual acuity of less than 1.0 was noted in 8% of the children.

The median visual acuity values of the STYCAR 1 test showed a similar increase between kindergarten and the third grade: from 1.8 for both boys and girls at kindergarten age, they increased to 2.3 for boys and 2.2 for girls in the first grade, and showed a further increase of up to 2.6 for boys and 2.4 for girls in the third grade. The corresponding values for the STYCAR 2 test for boys and girls were 2.1 in the kindergarten, 2.7 and 2.6 respectively in the first grade, and 3.0 and 2.8 in the third grade.

A ceiling effect was noticed in all three tests, particularly in the E test. No significant difference in visual acuity was observed between the left and the right eye in any test or at any of the tested ages. Most median values of the right eye and those of the left eye were equal, a few differed from each other by no more than 0.2.

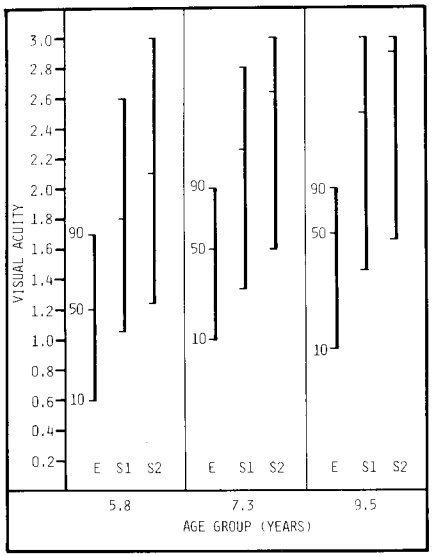

Fig. 4. Comparison between the E test (E), STYCAR 1 (S1) and STYCAR 2 (S2) tests (10th, 50th and 90th centile)

Table 3. Lang stereo test, visual acuity and interocular difference of visual acuity (assessed by the *E* test) for all children

	Clearly recognized	Questionably recognized	Not recognized
Lang stereo test (%)	90.6	3.0	6.5
Visual acuity (M/SD)	1.5/0.5***	1.0/0.6	1.0/0.5
Interocular difference (M/SD)	0.18/0.20**	0.30/0.26	0.25/0.27
N	596	19	42

** $P < 0.01$; *** $P < 0.001$

Figure 4 demonstrates that the median values and ranges differed considerably between the *E*, STYCAR 1 and 2 tests. The *E* test and the STYCAR 1 test showed an average difference for median visual acuity of 0.6–0.9 at corresponding ages. In comparison with the STYCAR 1 test, the median values of the STYCAR 2 test were higher by 0.3–0.4. The ranges are considerably larger in the STYCAR tests, particularly in the STYCAR 2 test, than in the *E* test.

The Lang-Stereo test was passed by 87.9%–94.3% of all children recognizing all three figures (Table 3), and there were no significant differences noted with respect to age, sex or nationality. In 1.6%–5.0% of the children, the test results were questionable; 4.1%–10.1% of the children did not recognize the figures at all. Children who recognized all three figures clearly showed a significantly higher visual acuity than those recognizing the figures only questionably or not at all. In the latter group significant interocular differences in visual acuity were observed ($P < 0.01$).

The right eye was found to be the leading eye in 54.8% of the boys and 54.5% of the girls, a difference in favour of the right eye that was highly significant ($P < 0.001$). A significant acuity difference was also found in favour of the leading eye ($P < 0.01$), but the mean differences were so small (less than 0.1) that they are of no practical relevance.

Discussion

From a recent study by Atkinson and Braddick [1], it is known that there is a rapid increase in visual acuity from birth to 6 months, from about 0.03–0.25 (measured with preferential looking). After that it seems that development of visual acuity to the adult level follows an asymptotic curve. The value of 1.0 is passed at the age of about 3–4 years, as proved by the majority of examinations [3, 4, 8, 24, 25]. In an unselected population, Largo and Largo [19] showed that distance vision decreased considerably between the ages of 10 and 16 years for approximately 15% of the children studied. This increase in the incidence of myopia is probably caused by accelerated physical growth during puberty. Frisen and Frisen [9], in a study involving subjects with normal ophthalmological findings only, reported a monotone growth of visual acuity up to the age of 25 years, after which it slowly decreased.

In our study we have concentrated on visual acuity between the ages of 5 and 10 years. During this age period acuity was found, by means of the E test, to improve by 0.5, without excluding children with possible visual defects. In agreement with some authors [8, 9, 19, 25], we noted that median visual acuity increased from 1.2 at the age of 5 to 1.7 at the age of 10 years. These values are considerably better than 1.0 which is usually considered normal.

Figure 3 clearly demonstrates that visual acuity is not normally distributed. The asymmetric distribution of our results was partially caused by the fact that the upper range for the *E* test, and to a minor degree, that for the STYCAR test, was too limited, resulting in a 'ceiling effect'. This effect could be eliminated by the development of test tables extending to a visual acuity of at least 3.0 (5/1.7) for the *E* test and 4.0 (5/1.25) for the STYCAR test.

Children at all ages and of both sexes showed a significantly higher median acuity with the STYCAR test compared with the E test, a factor which has been noticed by other authors [2–4, 8, 11, 27]. In our opinion, a connection with the sequential arrangement of the letters in the STYCAR test can be excluded. The letter E was used in our STYCAR test book at randomly different visual levels. In many cases the children did not recognize E letters at low visual levels although they still recognized the other letters at much higher visual levels. Since in the *E* test the letters were shown in complete lines, whereas the optotypes of the STYCAR test were in single letters, the 'crowding phenomenon' might have exerted an influence. Several authors have stated that single optotypes are more easily recognized than letters of the same size arranged in lines. We agree with Sheridan [25] that children of this age are likely to be confused by letters standing in lines and thus give a wrong impression of their true visual competence. The E test was carried out at a distance of 5 m, the STYCAR test at 3 m. Since visual acuity varies slightly with distance, even though the visual angle remains constant, this difference in the test distance might also have a minor impact on the test results [23]. However, these phenomena can only partially be responsible for the considerable difference between the results of the E test and those of the STYCAR test. In agreement with Hedin and Nyman [11], we believe that the easier legibility of the letters *H, T, V, L* in comparison with *E*, together with the greater attraction of the STYCAR letters are likely to be the major reasons for higher visual acuity results with the STYCAR test. Finally, our STYCAR 1 and 2 test results demonstrate that median values and ranges of visual acuity are considerably influenced by the test rating used.

What ratio of visual acuity should be called abnormal in childhood? Approximately 20% of the kindergarten children (mean age 5.5 years) showed a visual level of less than 1.0 for

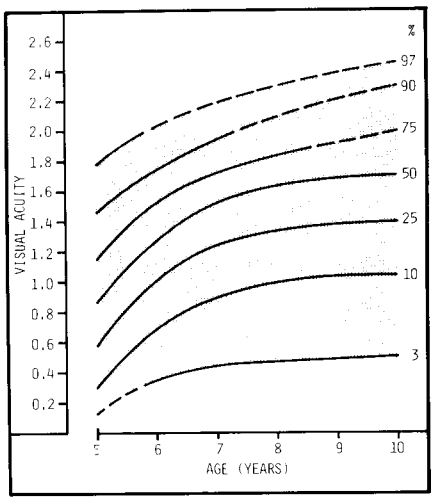

Fig. 5. Centile curves of visual acuity according to the E test from 5 to 10 years of age

both eyes. Sheridan [25] reported 21.9% in this age group, Schirm and Sadowsky [24] reached a slightly lower figure of 15%, whilst Ismail and Lall [15] noted 10%. The number of children in the first and third grades with visual acuity below 1.0 for both eyes decreased to approximately 8%.

Our results advise against using one single norm of 1.0 for kindergarten and school-age children. As for growth parameters, the use of centile charts may allow a more appropriate judgement of normal visual functioning by taking into account the developmental course and variability of visual acuity (Table 2, Fig. 5). If, for example, one takes the 50th percentile, and considers its median as the norm ratio, this would result in a norm for the E test of kindergarten age children of 1.2 and of 1.5–1.7 for children of the first and third classed in primary school. Using the 10th centile, for kindergarten a visual acuity of 0.6, and for the first and third classes of 1.0, would be the cut-off values for ophthalmological examination.

There are several tests available for the examination of stereo acuity (Frisby, Random dot *E*, TNO, Randot circles, Titmus [26]). Various studies have attempted to lay down norm ratios for these tests, and it thus became apparent that for each of these tests different ratios have to be given [8]. Stereo acuity has been reported to be reduced in proportion to the unilateral visual acuity decrement and to be less sensitive to bilaterally symmetric decrements [20]. Some authors suggest that stereo acuity examination should be made part of each child's screening test, as it is a more refined indicator of a disturbed visual function than is the visual acuity test. On the other hand, Friendly [8], after his critical comparison of several visual studies, came to the conclusion that, in terms of current knowledge, stereo tests are of no higher value than are the traditional visual acuity tests.

In our examinations we made use of the Stereo test recently published by Lang [17, 18]. Combining two methods, namely the random-dot and cylinder-gratings method, a test card was developed which could be used without polarized glasses or red-green spectacles, a major advantage when testing children's eyes. This test showed an extremely low ratio of uncooperative children in comparison with other studies [8, 26] which makes it a useful test for children of and below kindergarten age [17, 18]. The number of "conspicuous" children, about 5%–8% in all three age categories, was relatively low in comparison with other testing methods [8, 26], which may partly be due to the fact that some other tests show lower disparities than the Lang testing method. Children who fulfilled the Lang-Stereo test only questionably or not at all showed a significantly lower visual acuity (see also Simons [26]). Finally, the Lang-Stereo test proved to be sensitive in detecting significant interocular differences of visual acuity.

Acknowledgement. We thank Dr. L. Molinari for his statistical assistance.

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Received December 23, 1985 / Accepted March 11, 1986

Eur J Pediatr (1986) 145:480–484

European Journal of
Pediatrics

A comparison between the neurological and intellectual abnormalities in children and adults with congenital hypothyroidism

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Abstract. Standardised intellectual, motor and behavioural tests have been undertaken in a group of 73 children and 43 adults with congenital hypothyroidism in a regional study in the north of England. These provide comprehensive data with which to compare the results of studies of children diagnosed by screening and indicate the degree of abnormalities persisting into adult life in those patients diagnosed before screening was introduced. The mean IQ scores of the hypothyroid children and adults were 1–2 standard deviations (SD) below the population means.

Longitudinal IQ data indicate persistence of intellectual abnormalities, though there was an increase in IQ score in several patients. The mean motor scores were reduced by 1–2 SD in the children and 1–3 SD in the adults. Behavioural problems and personality difficulties mainly of a neurotic nature also persisted into adult life.

Key words: Congenital hypothyroidism – Development – Longitudinal assessment

Introduction

The mean IQ and motor scores of groups of children with congenital hypothyroidism diagnosed before neonatal screening have been found to be 1–2 standard deviations (SD) below the mean, and behaviour problems, predominantly of a neurotic type, occur in 25%–50% of them [2, 9]. In this study the results, some of which have already been published [2], of standardised developmental assessment of children with congenital hypothyroidism in a defined geographical region are compared with similar tests of hypothyroid adults from the same population in order to determine whether abnormalities persist.

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Abbreviations: WISC-R = Wechsler intelligence scale for children-revised; FIQ = full intelligence quotient; VIQ = verbal intelligence quotient; PIQ = performance quotient; RAQ = reading age quotient; AAQ = arithmetic age quotient; GATB = general aptitude test battery; SD = standard deviation; WAIS = Wechsler adult intelligence test

Methods

Subjects

All children and adults up to 40 years of age with congenital hypothyroidism living in the Northern Health Region[1] were identified by contacting all regional paediatricians, endocrinologists, community physicians and general practitioners and by scrutinising the records of the Regional Statistics Department and the Handicap Registers. They had clinical, biochemical and in some cases bone age and radio-iodine uptake evidence of hypothyroidism beginning before the age of 10 years;

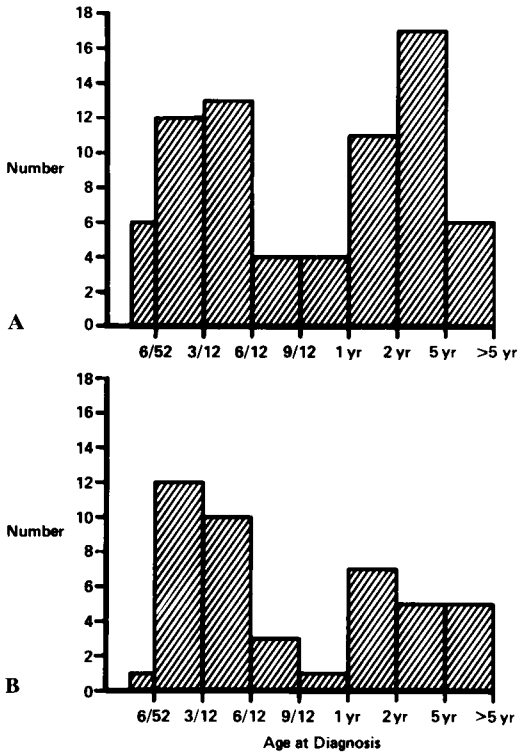

Fig. 1. A Age at diagnosis of the hypothyroid children. **B** Age at diagnosis of the hypothyroid adults

[1] This comprises of the five northern counties of England, with a total population of about three million