

A STUDY OF LABYRINTHINE FUNCTION IN PATIENTS WITH ADOLESCENT IDIOPATHIC SCOLIOSIS

I. An Electro-Nystagmographic Study

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An electro-nystagmographic study of labyrinthine function was performed in 56 patients with adolescent idiopathic scoliosis (AIS) aged from 10 to 16 years. Forty-seven patients had major structural single curvatures, and nine patients had double-primary scoliosis and were analysed separately. Treatment was required in 36 cases while 20 were being observed only. Thirty healthy children of the same ages constituted a control group.

Spontaneous nystagmus (SN) and positional nystagmus (PN) were found in 24 out of the 47 patients with single curvatures and in only one subject in the control group ($P < 0.001$). No significant correlation was noted between direction of convexity and nystagmus. Neither did the frequency of SN or PN differ significantly between patients requiring treatment and patients submitted to observation only. Significant differences were observed in the caloric response between right and left scoliotic patients ($P < 0.05$). The right convex patients had a sensitivity dominance in the right labyrinth and the left convex patients in the left labyrinth. There were no significant differences between right- and left-beating nystagmus. A dysrhythmic nystagmus occurred in the scoliotic patients with significantly increased frequency ($P < 0.05$). The results are discussed with special reference to aetiology in AIS. It was difficult, however, to draw any definite conclusion as to whether the findings may indicate a causative factor in relation to the idiopathic curvature or whether they might be a feed-back effect from the deformed spine.

Key words: aetiology; electronystagmography; equilibrium; labyrinth; scoliosis; vestibular function test

Accepted 1.ii.79

The deformity in idiopathic scoliosis can be regarded as a symptom of a disturbance in the dynamic and static equilibrium in the spine. In order to analyse different equilibrium factors which might be of aetiological importance in adolescent idiopathic scoliosis (AIS) a study of vestibular function has been carried out.

The vestibular system is essential for

postural control and interacts intimately with the visual and proprioceptive systems (Roberts 1967). Integration of impulses from these different systems takes place mainly at the brain-stem level (Fredricksson et al. 1966, Guyton 1976, Roberts 1967).

Apart from its more basic and general importance, vestibular function has a more specific effect on the trunk which is of

interest in connection with a study of equilibrium in scoliotics. During vestibular imbalance, caused by stimulation or disease, skeletal muscle tone can be influenced reflexively through afferent tracts, resulting in a deviation and rotation of the body towards the side with least tone (Fukuda 1959, Henriksson et al. 1962, Torok & Kahn 1960, Wodak & Fischer 1923). The abnormal asymmetric posture demonstrated by the spine in these circumstances resembles the characteristics of the scoliotic deformity.

In the light of this observation, it is possible that a functional asymmetry or disturbance at some level in the vestibulospinal reflex-arch, in the labyrinth or in the brain stem, might be a contributory mechanism in AIS.

Nystagmus is often used for studies of disturbances of equilibrium. It is an important sign of various vestibular and neurological disorders (Barber 1975, Norré 1975). Its analysis is important in the diagnosis of these disorders.

Yamada & Yamamoto (1972) have studied some equilibrium factors in a group of scoliotics with various aetiologies. They only tested spontaneous and positional nystagmus using Fresnel's glasses and were not able to demonstrate any significant vestibular dysfunction with these tests.

The main purpose of the present study was to investigate spontaneous nystagmus, positional nystagmus and caloric response in a group of patients with adolescent idiopathic scoliosis, and to compare the results with those obtained in a control group of children with a straight spine. The questions we hoped to answer were as follows:

1. Is there any difference in vestibular function between children with AIS and control children with a straight spine?
2. Is there any correlation between vestibular dysfunction and the convexity of the curvature?
3. Is any vestibular dysfunction primary or is it secondary to the deformed spine?

METHODS

The nystagmus was recorded with the electro-nystagmographic technique (ENG) using an ELEMA direct-writing Mingograph. The paper speed was 5 mm/s. The advantages of this method are well-known (Stahle 1958).

Before the ENG registration all subjects were examined for neurological disorders and ear, nose and throat diseases according to a special schedule. The children were also asked questions about whether they experienced motion sickness in the various situations which are known to produce vestibular stimulation. They were also asked how they felt at high altitudes.

The recordings were performed in a dark, silent room with the test subject supine and with eyes closed. Electrodes were placed at each outer canthus for recording horizontal nystagmus. Nystagmus, which is a diphasic reflex movement of the eye, has a slow phase as an expression of the reactions in the vestibular apparatus and a rapid phase as a result of extra-vestibular, cerebral correction (Aschan et al. 1956). The direction of nystagmus is indicated in the usual way by the direction of the rapid phase.

Spontaneous nystagmus (SN) is nystagmus unaffected by the position of the head and is constant in all positions (Stahle 1958). Positional nystagmus (PN) is nystagmus that develops only in certain positions (Figure 1 a, b). It can be direction-fixed, i.e. beating in the same direction regardless of the position of the head or it can be direction-changing, i.e. reversing direction when the position of the head is changed, and it can be irregular, i.e. changing direction in a given position (Aschan et al. 1956). Posture tests signify recording of both SN and PN (Stahle 1958).

Registration of nystagmus was performed as follows:

1. Head in 30° flexion before the Mingograph was calibrated.
2. Head in 30° flexion after calibration.
3. Head in rotation to the left side.
4. Head in rotation to the right side.
5. Head in 30° extension.

The recording time in each position was at least 60 seconds. The direction of nystagmus and intensity were registered.

The caloric tests were performed according to the method of Fitzgerald & Hallpike with slight modifications (Fitzgerald & Hallpike 1942). The syringing was done for 30 seconds with a water volume of 100 cc. The registration of eye movements started simultaneously with the syringing and was continued for 210 seconds. The time between two syringings was 10 minutes. The syringings were performed with carefully con-

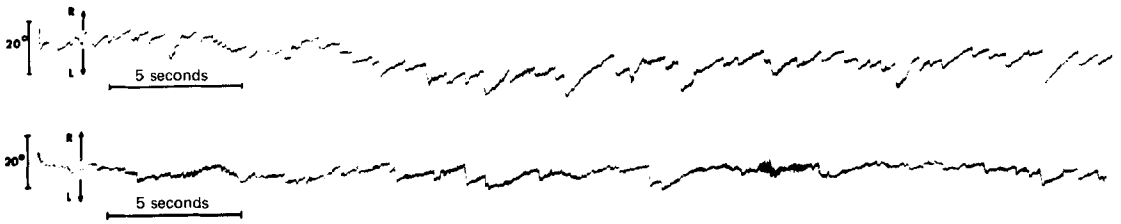


Figure 1 a, b. ENG recording illustrating evaluation in the posture test. In 1 (a) an obvious left-beating positional nystagmus is considered to be present. Figure 1 (b) illustrates a less intensive left-beating positional nystagmus, at the lower limit taken account of.

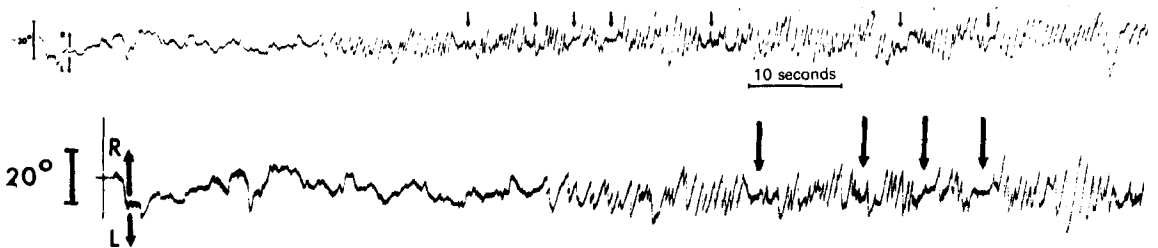


Figure 2 a, b. ENG recording illustrating evaluation in the caloric test (30°, right ear). In 2 (a) the 10-second period that was assessed as being the peak of reaction, maximum intensity (degrees/second), is indicated. Figure 2 (b), which is an enlarged copy of the first part of 2 (a), illustrates periods of dysrhythmia; these are indicated by the arrows.

trolled temperatures, 30° and 44°.

The following four test situations were studied in the supine position with the subject's head in 30° flexion:

1. Cold water, left ear
— elicits a nystagmus to the right.
2. Cold water, right ear
— elicits a nystagmus to the left.
3. Warm water, left ear
— elicits a nystagmus to the left.
4. Warm water, right ear
— elicits a nystagmus to the right.

The nystagmus was assessed with regard to direction, rhythmicity, and maximum intensity. The maximum intensity is the mean eye speed in the slow phase of nystagmus during a 10-second period at the peak of the reaction (Figure 2). It is often used as the best way to quantify an induced reaction (Riesco-MacClure 1964, Stahle 1958). Only amplitudes of more than 2 mm were counted.

When analysing the registration it is important to determine whether or not symmetry exists in the sensitivity of the labyrinths or between the right-beating and left-beating nystagmus. The isolated reactions are of less importance (Stahle 1958). The following two relationships are therefore compared:

1. Right/left sensitivity (2+4) — (1+3).
2. Right-beating/left-beating nystagmus (1+4) — (2+3).

There is a great normal interindividual variation in the caloric reactions. We therefore determined the difference in sensitivity between the labyrinths and between right- and left-beating nystagmus in relation to the total response, as recommended by Jongkees & Philipszoon (1964). Differences in labyrinthine sensitivity, labyrinth predominance, can be expressed by the formula

$$\frac{(2+4) - (1+3)}{1 + 2 + 3 + 4} \times 100\%$$

A negative value means a predominance of the

left labyrinth and a positive value a predominance of the right labyrinth.

The difference in right- and left-beating nystagmus, directional preponderance, can be expressed by the formula

$$\frac{(1+4) - (2+3)}{1 + 2 + 3 + 4} \times 100\%$$

$$1 + 2 + 3 + 4$$

A negative value means a dominance of left-beating nystagmus (i.e. preponderance to the left), and a positive value means a dominance of right-beating nystagmus.

The registrations from the control children were used for calculation of reference values for the two formulae and were set at $M \pm 2$ SD.

Dysrhythmia was considered to be present when a subject had alternating periods of high and low intensive nystagmus, sometimes being completely absent for several seconds (Figure 2) (Stahle 1958).

In the statistical analysis Student's *t*-test and the chi-square test with Yate's correction has been used (Baily 1973).

MATERIAL

The participants in this study were 47 patients with adolescent idiopathic scoliosis (AIS) with a single major structural curvature. They were referred to the Department of Orthopaedic Surgery I, Sahlgren hospital, during 1975 and 1976. The control group comprised 30 non-scoliotic, healthy subjects in the same age group and with about the same sex ratio (Table 1). The

controls were randomly recruited from a material of healthy children previously described by Petersen & Eeg-Olofsson (1971). The reason for this recruitment of controls was that these children had been very carefully examined earlier regarding their history and their somatic-neurological status.

The patients were subgrouped with regard to the magnitude and convexity of the curvature (Table 2). The magnitude of the scoliosis was classified with regard to whether the deformity required treatment or not. As a rule the indication for treatment (brace or surgery) was a curvature of more than 20° (Cobb 1948) in a patient still skeletally immature. Two patients who required a brace and who both had a curvature of 17° were the only exceptions to this rule. Eight patients required surgery. The two different subgroups requiring treatment were analysed together and the patients participated in this investigation prior to any treatment.

Nine scoliotics with double-primary curvatures constituted a fifth subgroup in this study which was analysed separately. These patients had two curvatures of major degree, both with structural changes. The classification of these patients follows the definition proposed by the Scoliosis Research Society (1976).

All the subjects had been extensively investigated as regards past history and had a thorough somatic investigation emphasizing the neurological status according to a special schedule. None was taking any drugs and all abstained from using tobacco or coffee on the day of the investigation.

Table 1. Material

	Scoliotics <i>Single curves</i>	Controls
Number	47	30
Mean age (years \pm 50)	13.4 \pm 1.6	13.5 \pm 2.4
Age range	10–16	10–16
Sex ratio ♂/♀	8/39 (17% ♂)	4/26 (13% ♂)

Table 2. Subgrouping of the scoliotics with regard to magnitude and convexity of the curve

	Patients placed under observation	Patients requiring treatment	Total
Right convex single curves	9	16	25
Left convex single curves	11	11	22
Total	20	27	47

RESULTS

History and clinical investigation

There was no difference between the scoliotic patients and the controls when the answers to the questions about motion sickness were analysed. The scoliotic patients with nystagmus in the posture test or values outside the reference values in the caloric test did not differ from the other patients in this respect. The frequency of a history of otitis media was the same in the scoliotic patients as in the controls.

Posture tests

Spontaneous nystagmus was observed in seven cases. Positional nystagmus was present in 17 patients and in all of them the nystagmus was direction-fixed. The only exception was one patient who had nystagmus beating towards the left in positions 1, 3 and 5 and changing between left and right in position 4. All of the patients with PN, except one patient with nystagmus only in position 1, had nystagmus in at least two positions. The total frequency of patients with nystagmus in the posture test was 51

per cent.

In the control group there was only one subject with PN and it was direction-fixed. None had SN. The difference between the scoliotics and the controls is significant ($P < 0.001$).

The frequency of patients with nystagmus in the posture test was statistically independent of the convexity or magnitude of the scoliosis (Table 3). No correlation was found between the convexity of the curvature and the direction of nystagmus in posture tests (Table 4). When nystagmus was present in posture tests in patients with left convex scoliosis the nystagmus reaction was, however, directed to the left in 12 cases out of 14.

Caloric test

Differences in sensitivity between right and left labyrinths. In the control group the mean difference in the sensitivity between the right and left labyrinths was 3.7 per cent.

The mean difference in patients with convex curvatures was 8.6 per cent and with left convex curvatures it was -4.0 per cent. There was no significant difference between

Table 3. Number of patients with nystagmus in the posture test in relation to magnitude and convexity of the scoliosis. + denotes presence of nystagmus, — absence of nystagmus

	Right convex		Left convex		Total	
	+	-	+	-	+	-
Patients placed under observation	3	6	6	5	9	11
Patients requiring treatment	7	9	8	3	15	12
Total	10	15	14	8	24	23

Table 4. Relation between convexity of the curve and direction of nystagmus in the 24 patients with nystagmus in the posture test

	Nystagmus-direction	
	Right	Left
Convexity		
	Right	4
	Left	6
	Right	2
	Left	12

the patients and the control subjects as regards peripheral sensitivity. However, the right convex scoliotics differed significantly from the left convex scoliotics (Tables 5 and 7). These tables also show that the magnitude of the curvature did not significantly increase the observed difference. Ten patients had values outside the reference values.

Differences between right- and left-beating nystagmus. In the controls the mean value of the difference between right- and left-beating nystagmus was -3.3 per cent (Table 6). There was no difference between right- and left-beating nystagmus when patients with right or left convex scoliosis were compared with the controls (Table 7). Neither

Table 5. Caloric response from right and left labyrinth in scoliotics and controls. Mean values (M) and standard errors of the means (SEM) are expressed in degrees/second and differences in percentage of the total reaction are calculated according to Jongkees & Philipszoon (1964)

	Right labyrinth $M \pm SEM$ degrees/second	Left labyrinth $M \pm SEM$ degrees/second	Difference $M \pm SEM^*$ per cent
Right convex scoliotics	33.4 ± 1.6	29.2 ± 1.7	8.6 ± 1.9
Placed under observation	32.2 ± 1.3	29.3 ± 2.1	6.1 ± 2.3
Requiring treatment	34.0 ± 2.6	28.9 ± 2.3	10.0 ± 2.9
Left convex scoliotics	30.8 ± 2.0	33.3 ± 2.1	-4.0 ± 2.7
Placed under observation	26.7 ± 2.7	28.1 ± 2.9	-2.5 ± 4.5
Requiring treatment	34.9 ± 2.7	38.6 ± 2.7	-5.6 ± 3.4
Double primary scoliotics	32.1 ± 6.4	29.3 ± 4.3	2.9 ± 5.6
Controls	35.9 ± 3.0	32.5 ± 2.2	3.7 ± 1.8

* Positive value means right sensitivity dominance and negative value means left sensitivity dominance.

Table 6. Right- and left-beating nystagmus in scoliotics and controls. Mean values (M) and standard errors of the means (SEM) are expressed in degrees/second and differences in percentage of the total reaction are calculated according to Jongkees & Philipszoon (1964)

	Right-beating $M \pm SEM$ degrees/second	Left-beating $M \pm SEM$ degrees/second	Difference $M \pm SEM^*$ per cent
Right convex scoliotics	30.7 ± 2.8	31.5 ± 3.1	-4.6 ± 4.0
Placed under observation	27.7 ± 2.7	32.9 ± 2.6	-8.7 ± 4.3
Requiring treatment	32.4 ± 4.1	30.7 ± 2.5	-2.7 ± 5.8
Left convex scoliotics	31.6 ± 2.9	32.5 ± 2.9	-0.6 ± 4.0
Placed under observation	27.7 ± 3.5	27.2 ± 3.8	2.4 ± 5.9
Requiring treatment	35.5 ± 4.5	39.9 ± 4.0	-6.4 ± 4.4
Double primary scoliotics	28.5 ± 4.9	33.0 ± 5.9	-6.6 ± 6.9
Controls	32.5 ± 2.4	35.8 ± 2.9	-3.3 ± 2.6

* Positive value means right-beating dominance and negative value means left-bearing dominance.

Table 7. Summary of statistical analyses*

	Posture test	Caloric test		
		Right/left labyrinthine sensitivity	Right/left-beating nystagmus	Dysrhythmia
Controls/single curves	$P < 0.001$			$P < 0.05$
Controls/right convex scoliotics	$P < 0.01$	NS	NS	$P < 0.01$
Controls/left convex scoliotics	$P < 0.001$	NS	NS	NS
Controls/double primary curves		NS	NS	
Right/left convex scoliotics	NS	$P < 0.05$	NS	NS
Patients placed under observation/patients requiring treatment				
single curves	NS			NS
right convex curves		NS	NS	
left convex curves		NS	NS	

*Differences between the groups were investigated by means of Student's t-test at the 5 per cent level of significance.

NS = Not significant

was there any difference between the patients with right and left convex scoliosis.

Eight patients had values outside the reference values and nystagmus was noted in seven of these in the posture test. Nystagmus, that was present in both of these tests, always had the same direction.

Dysrhythmia. Dysrhythmia was observed in 13 scoliotics (28 per cent) and in 2 controls (6 per cent). The difference is statistically significant ($P < 0.05$). No difference in the frequency of dysrhythmia was found in relation to the magnitude of the curvature. Ten of the patients with dysrhythmia had a right convex and three a left convex scoliosis; this difference is not statistically significant.

Nine patients with double primary curvatures

In three patients nystagmus was noted in the posture test. There was no difference between the control subjects and patients

with double primary curvatures regarding sensitivity between right and left labyrinth or right- and left-beating nystagmus. Dysrhythmia was only present in one patient.

DISCUSSION

Yamada & Yamamoto (1972) have previously studied vestibular function in scoliosis. About 100 patients with scoliosis of varying aetiology were given a vertical writing test and spontaneous or positional nystagmus was measured using Fresnel's glasses. However, Fresnel's glasses are considered a rather insensitive means of testing nystagmus (Aschan et al. 1956). Yamada & Yamamoto's tests did not include any caloric stimulation. From their results they concluded that the scoliotics did not have any demonstrable peripheral vestibular dysfunction.

In this study we have used ENG to find out whether the vestibular function differs in

a group of children with idiopathic scoliosis and a group of control children without deformed spines.

The vestibular function was tested with caloric bithermal stimulation, which is currently a principal method for testing labyrinthine function. This is an important basic test and is superior to the rotary test because it enables each labyrinth to be tested independently (Stahle 1958). It has also been suggested that the value of rotatory testing is slight, since it rarely provides information that can not be obtained by the caloric test (Stahle 1958).

The registration of the nystagmus using the ENG is a well-known method with obvious advantages (Stahle 1958). The nystagmus reaction after caloric tests can be evaluated with regard to duration and intensity parameters, i.e. frequency, total amplitude, and maximum intensity. The intensity parameters are a more sensitive means of diagnosing labyrinthine dysfunction than duration (Stahle 1958). The frequency, total amplitude, and maximum intensity usually give similar results and an investigation can therefore be simplified to include analysis of only one of these parameters (Stahle 1958). For our investigation we chose the maximum intensity, i.e. velocity in the slow phase at the peak of the reaction, as it is the most frequently used intensity parameter.

In order to analyse the results of our study we had to compare the responses of the patients with those of a control group consisting of subjects of the same age and sex as the scoliotics.

Differences in vestibular function between children with AIS and control children

Twenty-four of the 47 patients had nystagmus in the posture test compared to only one of the control subjects.

The observation of this nystagmus indicates the presence of a vestibular dysfunction (Norré 1975, Stahle 1958). As the frequency of nystagmus in the posture test was significantly increased in the scoliotics compared to the controls it may be taken as

evidence of a vestibular imbalance in the scoliotic patients.

A dysrhythmic nystagmus reaction was found significantly more often in the scoliotics. An analysis reveals that it is mainly the right convex patients who have these reactions. The interpretation of this disturbance in nystagmus rhythm may be difficult (Henriksson & Nilsson 1975). Stahle (1958) observed this phenomenon only exceptionally in cases with peripheral lesions. Dysrhythmia may indicate either a low level of alertness or a disorder in the brain stem (Henriksson & Nilsson 1975). It is difficult to understand why our scoliotics should have been more sleepy than the controls, as the conditions and test procedure were the same for all subjects participating in this study. Thus, the right convex patients may possibly, for some unknown reason, have a disorder in the brain stem.

Relationship between convexity of the curvature and vestibular asymmetries

In the posture test there was no statistical relationship between the direction of the convexity and the nystagmus reaction. Twelve patients out of fourteen with left convex scoliosis, however, also had a left-beating nystagmus in the posture test.

It is interesting to note that the right and left convex scoliotics had significantly different patterns in the caloric test. The patients with the convexity to the right had a sensitivity predominance in the right labyrinth and the left convex patients had a sensitivity predominance in the left labyrinth. We can therefore establish that they differed in their pattern of reaction to a caloric stimulus and that there is a clear side correlation between the convexity and the predominant labyrinth.

These findings indicate the possibility of an asymmetric postural tone in the trunk during conditions when the labyrinths are exposed to stimulation. The presence of nystagmus in the posture test suggests this possibility even at rest.

Is the vestibular dysfunction primary or is it secondary to the scoliosis?

Yamada et al. (1969) suggested the presence of a positive feed-back mechanism between the proprioceptors of the trunk and the equilibrium centre in the brain stem in scoliosis. They observed an improvement of a disordered optokinetic nystagmus after active correction of a scoliotic curvature or after a change of posture, from standing or sitting, to the supine position.

In our patients a significantly higher frequency of nystagmus was found in the posture test. During and after labyrinthine dysfunction nystagmus can be observed in the posture test. When the dysfunction is compensated for the nystagmus often disappears. A unilateral peripheral vestibular lesion can be compensated for by a specific vestibular phenomenon called accommodation and a non-specific vestibular phenomenon (Pfaltz & Kamath 1970). Spontaneous nystagmus after labyrinthectomy, however, may persist for many years, even in young individuals (Aschan et al. 1956). Spontaneous and positional nystagmus can also be a symptom of a central vestibular disorder (Uemura & Cohen 1972).

We do not know whether any compensatory mechanisms are operating in our patients or whether a vestibular imbalance can be compensated for to a certain degree. There might be some peripheral vestibular imbalance remaining which caused a nystagmus in the posture test. We must, however, consider both a central and a peripheral origin if the observed vestibular dysfunction is primary and a contributory factor to the idiopathic curvature.

Patients with disorders of the neck can have a very slight spontaneous nystagmus or pure positional nystagmus (Jongkees 1969). These patients also have other symptoms such as tinnitus, variable deafness and symptoms from the cervical spine, such as stiffness and pain. None of our scoliotic patients presented with these clinical symptoms. Moreover, patients with cervically

induced nystagmus in the posture test hardly ever show any significant differences in the caloric test (Jongkees 1969). In the scoliotics we found significantly different asymmetries in the sensitivity of the labyrinth.

Anatomical observations have shown that spinovestibular pathways originate mainly from the lumbo-sacral level of the spinal cord and terminate in the medial and descending vestibular nuclei (Pompeiano 1972). The spinal influence on the vestibular nuclei is mainly an excitatory one. This response is rather generalized, since it involves the neurons of the vestibular nuclei complex on both sides.

A feed-back from the proprioceptors in the intervertebral joints and in the soft tissues surrounding the deformed spine might therefore be possible. In that case, one would expect a higher frequency of nystagmus in the posture test among the scoliotics who had a more pronounced curvature, i.e. among patients requiring treatment. However, there was no difference between patients with curvatures requiring treatment and those not requiring treatment. Neither was there any consistent and statistical correlation between the direction of the deformity and the nystagmus. Nor did the magnitude seem to influence the results of the caloric tests, although there is a non-significant tendency towards a more pronounced mean difference between right and left labyrinthine sensitivity for patients requiring treatment.

An analysis of the double primary curvatures did not elucidate the question of cause and effect. The patients in this group did not differ from the controls in right- and left-beating nystagmus. The peripheral sensitivity was exactly the same as in the controls. The explanation for this result may be that the impulses from their two structural curvatures, which are of equal size but in different directions, counterbalance each other when the afferent information from the proprioceptors in the trunk reaches the brain stem. If the vestibular dysfunction were primary in these cases, the disturbance must

obviously already have been compensated for.

It is also possible that a vestibular imbalance, of hitherto unknown origin, acted initially as a trigger mechanism for the idiopathic curvature. After a period this imbalance might be compensated for and the curvature continues to progress for other reasons. This might cause an equilibrium disturbance calling for a change in central vestibular mechanisms. If this development is possible, we have to consider at what stage in the scoliosis disease we are investigating the vestibular function. An injury to the peripheral vestibular end organ may be a complication in connection with delivery due to anoxia, icterus neonatorum, and rubeola-embryopathy (Stahle 1977, personal communication). When delivery files were studied in the subjects participating in this study two patients were found to have had vacuum extractions and one patient had had icterus neonatorum. No rubeola-embryopathy was revealed. In these three patients signs of vestibular dysfunction were observed. Thus, there was a possible explanation for a vestibular imbalance in these few patients. In the other patients who showed signs of vestibular dysfunction there is nothing obvious in the past history to explain a primary vestibular imbalance. The control children did not have any of the mentioned complications in connection with birth, nor any other disease in the past known to affect the vestibular apparatus.

To sum up, it is difficult to draw any definite conclusions as to whether a vestibular imbalance may be a contributory factor to adolescent idiopathic scoliosis or whether the vestibular findings are secondary to the deformity of the spine.

ACKNOWLEDGEMENT

This investigation was supported by grants from: The Swedish Medical Research Council (Proj. B76-29X-04553-02), Greta och Einar Askers Stiftelse and Stiftelsen Sigurd och Elsa Goljes Minne.

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