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VESTIBULOSPINAL REFLEX ACTIVITY IN PATIENTS WITH ADOLESCENT IDIOPATHIC SCOLIOSIS

Postural Effects During Caloric Labyrinthine Stimulation Recorded by Stabilometry

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Postural sway has been quantified with stabilometry during caloric labyrinthine stimulation in an erect posture in 49 patients, aged 10–16 years, with adolescent idiopathic scoliosis. Thirty-two healthy children of the same age constituted a control group. The scoliotic patients tended to have an increased postural sway during labyrinthine stimulation on the convex side compared to the effects on the concave side. Significant differences were observed when left and right scoliotic patients were compared with the controls. The results can be explained by an asymmetric sensitivity in the labyrinth or by a dysfunction in the postural control mechanisms at the brain stem level.

Key words: aetiology; equilibrium; posture; scoliosis; stabilometry; vestibulospinal reflex; vestibular function test

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The vestibular system performs an essential function in the control of posture and movements. The regulation is exerted either by direct efferent projections of the vestibular nuclei to the spinal cord, i.e. the lateral and medial vestibulospinal tract, or by collateral activities of reticulospinal neurons (Gernandt 1959, Pompeiano 1975).

During vestibular imbalance, caused by stimulation or disease, an asymmetric tone in skeletal muscles can be distributed reflexively via these tracts (Torok & Kahn 1960), resulting in a deviation and rotation of the body towards the side with least tone (Wodak & Fischer 1923). When the spine demonstrates an abnormal asymmetric posture under these circumstances, there is a resemblance to the characteristics of scoliotic deformity. A functional asymmetry or disturbance at some level in the vestibulospinal reflex arc might therefore be a contributory factor in the development of adolescent idiopathic scoliosis.

Different approaches to the study of the vestibulospinal reflex have been reported. Wodak & Rischer (1923) described "Körperdrehreflex" and "Körperneigungsreflex" in patients exposed to caloric labyrinthine stimulation and estimated the effects qualitatively. A stepping test has been used by Fukuda (1959). Hara et al. (1960) made electromyographic observations on tone shift in m.triceps brachii during rotatory stimulation. Torok & Kahn (1960) described a recording device for measuring rotary falling tendency after rotatory labyrinthine stimulation. Henriksson et al. (1962) described a method for recording vestibulospinal influence on the head with pneumatic balloons placed one on each side of the occiput. Spector

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(1970) published a study using the same method. Galvanic stimulation of the vestibular system with recording of the postural effects using a statokinesimeter has been reported by Njiokiktjien & Folkerts (1971).

The purpose of the present investigation was to study, by means of stabilometry, the effects of caloric vestibulospinal stimulation in an erect posture in a group of patients with adolescent idiopathic scoliosis and to compare the reactions with those recorded in a control group.

METHODS

The effect of caloric stimulation of the labyrinth on postural sway was recorded using a force platform and a tape recorder. The recording equipment and the evaluation procedure have previously been described in detail (Sahlstrand et al. 1978). Briefly, the output signals of the force platform were converted to length coordinates which indicate the movements of the projection on the base plane of the body's centre of gravity when the acceleration forces are small compared to the gravitational forces. The time series of length coordinates describe the postural sway and were used in the calculation of average values x_m in the lateral direction and y_m in the sagittal direction. (Positive directions to the right and forwards, respectively.) The points x_m and y_m indicate the centre of the sway. In addition, the rms-values s_x and s_y of the lateral and sagittal sway amplitudes were estimated regarding the sway as a bivariate normal stochastic process. The area A of the 39.6 per cent confidence ellipse of the bivariate amplitude density function was calculated. This area is a statistical measure of the sway area which takes a possible correlation between x- and y-signals into account. The angle a between the major axis of the ellipse and the positive y-axis, being a measure of the average direction of the sway, was also calculated (positive direction counterclockwise).

All data were treated statistically and mean values, standard errors of the means, and 95 per cent confidence intervals were calculated for each parameter and test situation. To estimate changes in the centre coordinate x_m and the average direction of the sway a, the statistical calculations were also based on the normalized values $x_m - x_{m_1}$ and $a - a_1$ for each subject. Here x_{m_1} and a_1 are the values obtained in the reference test position, i.e. standing relaxed with eyes open.

The caloric stimulations in an erect posture constituted the last test in a series of examinations including stabilometry in the standing position and electronystagmography during caloric stimulation in the supine position. These studies have been described elsewhere (Sahlstrand et al. 1978, Sahlstrand & Petruson 1979a,b). The caloric stimulation in a supine position was performed at least 1 hour before the stimulation in an erect position and none of the subjects participating in this study had any remaining vertigo or nausea.

The recordings were performed with the subject standing on the force platform with his head straight forward making the direction of the eye ball axis horizontal, i.e. the horizontal semicircular canal was at an angle of 30 degrees to the horizontal plane. The subjects had their eyes closed and the room was dark. The positioning of the feet on the platform was always the same, with the heels together and with the feet at an angle of 30 degrees. The subjects were instructed to stand with their arms hanging freely beside their trunk. In the event of a subject experiencing marked instability during the stimulation, a surrounding barrier was available for support. The testing started with the left ear and continued 10 minutes later with the right ear. The syringing was performed for a period of 30 seconds using 100 ml of cold water (30°).

The recording from the force platform started when the separate syringing was finished, i.e. after 30 seconds, and lasted 180 seconds. The nystagmus was recorded simultaneously using ENG. These results are presented in another paper (Sahlstrand & Petruson 1979b). During the tests, the subject's subjective reactions, need for support, and visual assessment of rotation of the body were also noted. An account of this evaluation is presented in another paper (Sahlstrand & Petruson 1979b).

MATERIAL

This study included 41 children with adolescent idiopathic scoliosis (AIS), all of them with a single major structural curvature. The material, originally consisting of 48 patients, has been described in a previous paper (Sahlstrand et al. 1978). Seven patients were excluded because they were not able to tolerate continued caloric stimulation in an erect posture due to persisting vertigo or nausea after the previous caloric test in the supine position. The patients were subgrouped according to the magnitude and convexity of the curvature (Table 1).

Table 1. Grouping of the scoliotic patients with regard to magnitude and convexity of the curve

	Patients placed under observation	Patients requiring treatment	Total
Right convex single curve	8	15	23
Left convex single curve	9	9	18
Double primary curve		8	8
Total	17	32	49

Eight scoliotics with double primary curvatures were included as a separate group and are analysed separately. Also in this group one patient was excluded because of persisting vertigo and nausea after the previous caloric test. The control group comprised 32 healthy children of the same age.

All the subjects were given a thorough physical investigation with emphasis on neurological status according to a special schedule. None of the subjects was taking any drugs or had consumed any tobacco or coffee on the day of the investigation.

RESULTS

Comparing the results from right and left labyrinthine stimulation within the different scoliotic groups, there is a tendency towards more pronounced effects when the labyrinth on the convex side was stimulated, whether the right or the left convex patients are analysed (Tables 2 a, b and 3).

Patients placed under observation, in right as well as left convex groups, were noted to have significantly more lateral sway s_x during left labyrinthine stimulation compared to the patients requiring treatment. In the right convex group, the patients placed under observation also showed a significantly more pronounced shift of x_m and a significantly increased total sway A during left labyrinthine stimulation.

There were also more pronounced effects in general in the scoliotic patients compared to the controls. The control children had almost completely symmetric vestibulospinal effects from the two separate stimulations.

Right labyrinthine stimulation seemed to distinguish statistically between the groups to a lesser extent compared to left labyrinthine stimulation. The shift of the centre of the sway $x_m - x_{m_1}$ and the lateral sway s_x tended to be the most decisive parameters.

The double primary scoliotics had an increased lateral sway compared with the controls during vestibular stimulation on the right side. They also differ significantly from the left convex patients regarding the change in angle *a* during left labyrinthine stimulation.

DISCUSSION

To our knowledge, effects of vestibular stimulation have not been investigated previously in patients with adolescent idiopathic scoliosis. The laterotorsion, i.e. lateral twist of the head, neck, and body, that follows vestibular stimulation (Henriksson et al. 1962) has certain similarities with the characteristics of a lateral rotatory deformity in the idiopathic curvature. This observation might be of importance in connection with aetiological factors in idiopathic scoliosis.

Irrigation with cold water diminishes the continuous excitatory impulse flow from the labyrinth towards the vestibular nuclear complex in the brain stem (Richter 1943, Wodak & Fischer 1923). At the same time the tone in axial muscles decreases, and the subject develops laterotorsion towards the stimulated side. All the subjects in the present investigation showed this effect to a greater

Table 2a. Postural sway after caloric stimulation. Mean values and standard errors of the means. For explanation of the symbols see Figure 1

	s_y cm		s_x cm		s_y/s_x	
	Left lab stim	Right lab stim	Left lab stim	Right lab stim	Left lab stim	Right lab stim
Controls	1.11 ± 0.07	1.14 ± 0.07	0.93 ± 0.08	0.92 ± 0.07	1.30 ± 0.08	1.31 ± 0.06
Right convex scoliotics	1.19 ± 0.08	1.31 ± 0.12	0.99 ± 0.07	1.05 ± 0.09	1.25 ± 0.05	1.28 ± 0.08
placed under observation	1.34 ± 0.18	1.50 ± 0.24	1.21 ± 0.15	1.24 ± 0.21	1.13 ± 0.06	1.26 ± 0.10
requiring treatment	1.12 ± 0.08	1.21 ± 0.13	0.86 ± 0.06	0.94 ± 0.06	1.31 ± 0.07	1.30 ± 0.12
Left convex scoliotics	1.44 ± 0.15	1.26 ± 0.09	1.11 ± 0.09	1.10 ± 0.08	1.31 ± 0.10	1.18 ± 0.07
placed under observation	1.58 ± 0.24	1.26 ± 0.12	1.28 ± 0.14	1.13 ± 0.10	1.21 ± 0.09	1.14 ± 0.08
requiring treatment	1.30 ± 0.16	1.26 ± 0.15	0.95 ± 0.10	1.07 ± 0.13	1.40 ± 0.17	1.22 ± 0.11
Double primary scoliotics	1.16 ± 0.11	1.39 ± 0.15	0.94 ± 0.09	1.28 ± 0.15	1.28 ± 0.16	1.13 ± 0.11

Table 2b. Postural sway after caloric stimulation. Mean values and standard errors of the means. For explanation of the symbols see Figure 1

	A cm^2		α degrees		$\alpha - \alpha_1$* degrees		$x_m - x_{m_1}$* cm	
	Left lab stim	Right lab stim	Left lab stim	Right lab stim	Left lab stim	Right lab stim	Left lab stim	Right lab stim
Controls	3.58 ± 0.62	3.62 ± 0.60	15.8 ± 5.8**	− 9.1 ± 4.9	11.2 ± 8.0	−13.8 ± 7.0	−0.67 ± 0.14	1.08 ± 0.14
Right convex scoliotics	3.99 ± 0.53	4.75 ± 0.79	11.2 ± 6.4	− 5.9 ± 7.0	5.5 ± 8.6	−11.6 ± 9.0	−0.93 ± 0.17	0.80 ± 0.18
placed under observation	5.59 ± 1.19	6.67 ± 1.85	18.0 ± 10.5	− 6.6 ± 12.0	− 2.3 ± 18.3	−26.9 ± 8.2	−1.48 ± 0.26	0.53 ± 0.38
requiring treatment	3.14 ± 0.40	3.73 ± 0.61	7.6 ± 8.1	− 5.5 ± 9.0	9.7 ± 9.2	− 3.4 ± 12.8	−0.63 ± 0.19	0.94 ± 0.19
Left convex scoliotics	5.15 ± 0.87	4.55 ± 0.61	1.3 ± 9.1	−13.0 ± 9.4	25.1 ± 13.5	8.9 ± 14.2	−1.29 ± 0.22	1.06 ± 0.19
placed under observation	6.34 ± 1.51	4.49 ± 0.66	3.6 ± 13.8	− 5.1 ± 14.9	19.8 ± 20.2	6.2 ± 21.1	−1.34 ± 0.33	1.25 ± 0.24
requiring treatment	3.97 ± 0.16	4.61 ± 1.03	−1.0 ± 12.8	−20.1 ± 12.0	30.4 ± 18.8	11.2 ± 20.4	−1.23 ± 0.30	0.88 ± 0.30
Double primary scoliotics	3.39 ± 0.56	5.69 ± 1.36	−3.1 ± 11.2	9.5 ± 15.8	−21.1 ± 13.9	− 7.4 ± 18.0	−1.19 ± 0.27	0.70 ± 0.15

* x_{m_1} and α_1 are values obtained in a reference test position, i.e. standing relaxed with eyes open before caloric stimulation.

** A positive mean indicates a counter-clockwise direction (α) and a direction to the right (x_m).

Table 3. Summary of statistical analysis. Left and right labyrinthine stimulation (significance in right labyrinthine stimulation underlined)*

	s_y	s_x	s_y/s_x	A	α	$\alpha - \alpha_1$	x_m/x_{m_1}
Controls/Right convex scoliotics							
placed under observation				$\underline{P<0.05}$			$P<0.05$
requiring treatment							
Controls/Left convex scoliotics	$P<0.05$						$P<0.05$
placed under observation	$P<0.05$	$P<0.05$					
requiring treatment							
Controls/Double primary scoliotics		$\underline{P<0.05}$					
Right/Left convex scoliotics							
placed under observation							
requiring treatment							
Scoliotics placed under observation / Scoliotics requiring treatment							
right convex		$P<0.05$		$P<0.05$			$P<0.05$
left convex		$P<0.001$					
Right convex scoliotics/Double primary scoliotics							
Left convex scoliotics/Double primary scoliotics							

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

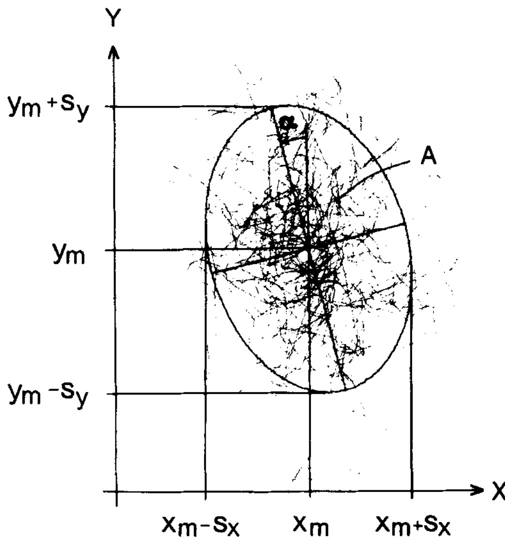

Figure 1. Statistical description of postural sway in the x-y plane. The confidence ellipse of area A has its centre in $(x_m y_m)$*. The tangents parallel to the coordinate axes yield the standard deviations of the marginal distributions which are equal to the rms values of the sway components* s_x *and* s_y *in the lateral and sagittal directions, respectively. The scale of the locus trace has been reduced by a factor of two to increase clarity.*

or lesser extent. Visual estimation of the torsion revealed no difference between the scoliotic patients and the controls (Sahlstrand & Petruson 1979b). The force platform provides an objective measure that enables quantitative estimation of laterotorsion to be performed.

There was a common tendency for the scoliotic patients to have an increased postural sway after stimulation on the convex side compared to the effects on the concave side. The differences were not statistically significant, however. Significant differences as regards effects on the convex side were obtained when left and right scoliotics were compared to the controls, especially for the left convex group. The vestibulospinal reflex was activated with the same stimulus on the two labyrinths but the reaction measured from the force platform was different. An explanation for this could be an asymmetric processing of input information taking place at some level. A previous study in the supine position (Sahlstrand & Petruson 1979a) has shown a functional asymmetry in the labyrinthine function, with a convex side dominance. It seems reasonable to assume that the cause of the more pronounced sway during stimulation on the convex side is an effect of a vestibular imbalance at the labyrinthine level, i.e. differences in labyrinthine sensitivity.

In the supine position the imbalance in the labyrinthine function was found to be more pronounced in patients with more severe scoliosis compared to those with smaller curvatures (Sahlstrand & Petruson 1979a). This observation makes it difficult to explain why calorization induced more pronounced postural effects in patients with smaller curvatures in the erect position as seen in this study. Obviously the postural sway effects cannot be explained only by an imbalance in the labyrinthine function. An EEG study by Petersén et al. 1979 has demonstrated EEG pathology in patients with idiopathic scoliosis. The type and localization of the abnormalities indicated involvement of brain stem structures, where important centres for postural regulation are located. The abnormalities were significantly more frequent in the group with smaller curvatures. The efficiency in processing different afferent impulses might therefore explain the difference in postural control between these groups. The observed differences are also in accordance with the results found in a study of postural effects in other test situations (Sahlstrand et al. 1978).

The results of this study indicate a dysfunction in the labyrinths or in the efficiency with which the scoliotic patient succeeds in counteracting a vestibular imbalance with his postural control mechanisms. A combination of these factors seems even more probable. The observed dysfunction might be of aetiological importance in idiopathic scoliosis.

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