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POSTURAL EQUILIBRIUM IN ADOLESCENT IDIOPATHIC SCOLIOSIS

TAGE SAHLSTRAND, ROLAND ÖRTENGREN & ALF NACHEMSON

Departments of Orthopaedic Surgery I and Clinical Neurophysiology,
Sahlgren Hospital and Department of Applied Electronics,
Chalmers University of Technology, Göteborg, Sweden.

Postural equilibrium has been quantified by stabilometry in 57 patients with adolescent idiopathic scoliosis aged 10–16 years. Treatment was required in 39 cases whereof 18 were placed under observation only. The control group comprised 32 healthy children of the same age. An experimental design was made to vary the degree of difficulty of upright standing in four different test situations. The postural sway was analysed in the sagittal and lateral direction as well as in the area of total sway. The scoliotic patients had a significantly poorer postural control compared with the healthy children in all the tests. The difference was most pronounced in tests in which the proprioceptive functions were most important for maintaining the postural equilibrium. The left convex patients had quantitatively more pronounced reactions than the right convex patients. Patients with small curvatures, i.e., patients placed under observation only, had significantly increased postural sway compared with patients with more severe deformity. This fact, together with findings in patients with double primary curvatures, and the results of the study of brace effects, indirectly indicate the possibility of a postural disequilibrium as a contributory causative factor in adolescent idiopathic scoliosis.

Key words: equilibrium; aetiology; posture; scoliosis; stabilometry

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Previous investigations

In the search for a solution to the aetiological problem in idiopathic scoliosis, attention has been focused, in a number of reports, on different factors influencing equilibrium. When investigating righting reflexes, drift reactions and optokinetic nystagmus, Yamada et al. (1969) found equilibrium dysfunction in 57 out of 70 patients in at least one test while only one out of 20 individuals in a control group showed any dysfunction. When they divided the scoliosis patients into groups with differing aetiology, there was no difference between the groups. They also demonstrated significant positive correlations between the extent of equilibrium disturbance and the degree of curvature, the rate of progress of the curvature, and the skeletal immaturity. Yamada & Yamamoto (1972) found, in a field study performed in school children, an increased frequency of scoliosis in children who showed a retarded development of equilibrium function. It has long been recognized that muscular imbalance can produce structural scoliosis (Manning 1974). The possible aetiological contribution of a higher postural tone on the concave side to the idiopathic thoracic curvature has recently been discussed by Hoogmartens & Basmajian (1976). A lateral rotatory curvature of the spine may be a symptom of various diseases engaging different nervous structures, from peripheral nerves up to central structures in the brain (Robin 1975). Another symptom of these diseases may be a disturbed equilibrium function.

Posture and postural control

The equilibrium in upright posture is dynamically controlled, and a slight postural sway is a normal phenomenon. The postural sway occurs both in the sagittal and the lateral plane and represents a complex reflex process, involving acquisition and processing of sensory information as well as execution of motor commands. The input information originates from proprioceptors in the muscles, joints, ligaments and tendons, and from the vestibular and the visual apparatuses. Postural reflex activity can be initiated in the proprioceptive system at the spinal level. Much of the input concerning postural equilibrium is co-ordinated into proper motor commands at supraspinal centres through a continuous integration of impulses from the different receptor systems. The vestibular nuclei, the reticular formation, and the cerebellum form a functional group at the brain stem level which is of vital importance for postural equilibrium control. More demanding sensory processing involves the basal ganglia and also the cerebral cortex (Fredrickson et al. 1966, Guyton 1976, Martin 1967, Nashner 1970, Roberts 1967).

It has often been shown that the complex regulatory process of postural equilibrium can be disturbed by various neurological disorders involving different levels in the central nervous system.

Techniques for studying postural sway

A number of methods for studying the act of standing have been described in the literature, but none is free from criticism. In principal, any method or combination of methods that records information pertaining to the control process and the performance can be used. For obvious reasons, the external recording sites must usually be selected and the methods narrowed down to kinesiological techniques, i.e., methods of studying movements by means of film photography, electromyography, and measurements with accelerometers and force transducers, etc. These methods have recently been reviewed by Grieve et al. (1975). In stabilometry, a force platform of varying design is the most frequent recording instrument (Terekhov 1976). The force platform responds to the projection on the horizontal base plane of the movements of the body's centre of gravity, which are inevitably present while standing. For evaluation, the lateral and sagittal sway amplitudes and centre and size of the sway area (Njiokiktjien & de Rijke 1972) and other statistical signal characteristics, e.g., power spectra, are often estimated (Bensel & Dzendolet 1968, Cernacek et al. 1973, Eklund & Löfstedt 1970, Leroux et al. 1973, Scott & Dzendolet 1972). Other measures, subjective as well as objective, are also frequently used.

The use of force platforms in studies of postural sway has several advantages. The test procedure is simple, and very easy to explain to the subjects. It can readily be adapted to give prominence to specific aspects of the postural control mechanisms (Tourtelotte et al. 1965), and the recorded signals can be evaluated quantitatively by means of electronic signal processing equipment. The mechanical analysis of the results can be involved, however, because of the large number of degrees of freedom of movements of the body (Murray et al. 1967). Since the force platform responds to movement characteristics closely related to those affecting the physiological receptor systems, the test is well suited to an analysis of postural control in terms of control theory and mathematical models (McRuher et al. 1968, Nashner 1970, Paltser & Agashyan 1974).

Aim of the present study

The aim of the present investigation was to study quantitatively, by means of stabilometry, the postural equilibrium in a group of patients with adolescent idiopathic scoliosis and to compare these results with those obtained in a control group. In addition it was of interest to obtain a qualitative measure of the function in the afferent regulatory systems controlling upright posture.

METHODS

Experimental design

The degree of difficulty of standing in the different tests was varied by having the subjects' eyes open or closed and by having a stable or compliant base support. Four tests were used in the recordings in the following sequence:

1. Standing on a stable base support with eyes open.
2. Standing on a stable base support with eyes closed.
3. Standing on a compliant base support with eyes open.
4. Standing on a compliant base support with eyes closed.

The stable base support was identical with the horizontal and rigid surface of the platform and the compliant base support was accomplished by laying a 10 cm thick piece of foam rubber on the platform.

Experimental procedure

The subjects were allowed to become acquainted with the test procedure. All tests were conducted with the subject naked except for underpants. The positioning of the feet on the platform was always the same, with the heels together and the feet at an angle of 30 degrees. In Tests 3 and 4 the piece of foam rubber was fitted to the platform, and the subject was assisted in positioning his feet accurately. For the test conducted with his eyes open, the subject was instructed to fix his gaze upon a 10 × 10 cm reference square placed at a distance of 5 m in front of the platform and adjusted to eye level. The room was artificially illuminated. The subject was also instructed to stand relaxed with equal weight on both feet and with his arms hanging freely along the sides of his trunk. The recording of each test lasted 2 minutes whereupon the subject was asked to sit down on a chair and relax for a period of about 2 minutes before the next test.

As a special study, the effects of brace treatment on postural equilibrium were investigated. The patients participating in this part of the study were tested as follows:

1. As all other patients before any treatment.
2. In a well-fitted brace about 1 week after Test 1.
3. At the same time as Test 2 but without the brace when the brace had been off for 10 minutes.
4. At a routine follow-up about 6 weeks after the brace treatment started.

Recording equipment

The postural sway was recorded by means of a force platform provided with a unit for transducer excitation, and signal processing and display. The equipment was especially made for stabilometry by L'Electronique Appliquée, Montrouge, France (Baron 1964, Barigant et al. 1973). The platform measured 44 × 44 × 17 cm and it had a foot guide directing the foot angle (30 degrees) and also enabling centring of the subject in the forward-backward direction. Force transducers were placed in the middle of the sides of the platform. Each transducer consisted of a dynamometer ring and a differential transformer sensing the compression of the ring caused by a vertical force component. The transducer signals were processed electronically to yield two signals, representing sway components in the forward-backward direction and in the left-right direction, respectively. These signals were connected to an FM-tape recorder (Racal-Thermionic, Store 4) for subsequent analysis, and to an XY-recorder (Houston Instrument, Omnigraph EHR 96 TM) for monitoring purposes during the recordings. The frequency range of the signal channels was from 0 to 10 Hz.

Defining a co-ordinate system with its origin at the geometrical centre of the platform, its positive y-axis forwards, and its positive x-axis to the right (Figure 1), calibration of the platform yielded the y-sensitivity (torque about the x-axis) 0.102 V/Nm (0.0100 V/kpcm) and the x-sensitivity (torque about the y-axis) 0.123 V/Nm (0.0121 V/kpcm). The sensitivities were orthogonal and neither of them was affected by the position of the foot guide. The offset and the hysteresis of the platform had a negligible effect on the output signals. The non-linearity was less than 5 per cent in the y-direction and less than 7 per cent in the x-direction.

Evaluation procedure

The signals recorded on tape were played back at a speed four times greater than during recording. The signals were fed to second-order, Butterworth low-pass filters (Hewlett-Packard, 5489 A) the cut-off frequencies of which were 30 Hz (corresponding to the real time frequency 7.5 Hz). The outputs of the filters were connected to the analogue-to-digital converters of a computer (PDP-15). The sampling frequency for each channel was 80 Hz (real time frequency 20 Hz). After digitalization, the data sequences were displayed on an oscilloscope screen and checked for artifacts and equipment faults, and further divided into separate files. In this procedure the recording artifacts between the sequences – caused by starting and stopping the tape recorder – were used as markers. The files were named according to subjects and recording conditions. In total, 770 files were recorded, containing about 12 million data words.

The recorded voltages were converted to equivalent length-co-ordinates through division by the overall calibration factor and the weight of the subject. These co-ordinates indicate the locus of the action point – on the platform surface – of a vertical supportive force having a magnitude equal to the weight of the subject. When the acceleration forces are small compared with the gravitational forces, this point indicates the projection of the centre of gravity of the body on the x-y plane. Considering the time series of the length-co-ordinates thus estimated as realizations of an ergodic bivariate stochastic process, statistical signal parameters characterizing the sway were calculated: mean values and root-mean-square values (rms values). The mean values x_m and y_m indicate the position of the centre of the sway, and the rms values s_x and s_y indicate the sway amplitude in the lateral plane and in the sagittal plane, respectively. In addition, assuming normality, parameters of the confidence ellipse of the joint probability density function of the sway at the level $e^{-\frac{1}{2}}$ of maximum were calculated (Figure 1). At this level the degree of confidence is 39.3 per cent. The area A of the ellipse is a statistical measure of the total sway amplitude, which takes a possible correlation between the x- and y-components into account. The correlation also influences the angle α between the positive y-axis and the major axis of the ellipse (positive direction counter-clockwise), which was calculated to indicate an average direction of the sway. To reduce an effect due to correlation between adjacent samples (Persson 1974), only every third sample was used in all these calculations. All parameters estimated were treated statistically: mean values, standard errors of the means, and 95 per cent confidence intervals were calculated for groups of subjects – the subjects being assigned to one or more groups according to clinical characteristics. To compare the inter-individual variability with the intra-individual variability, the estimated parameters were normalized to their corresponding values in the first test situation. This value was subtracted from the means of co-ordinate and angle values, yielding standard value zero, and it was used as divisor with the sway amplitudes, yielding standard value one.

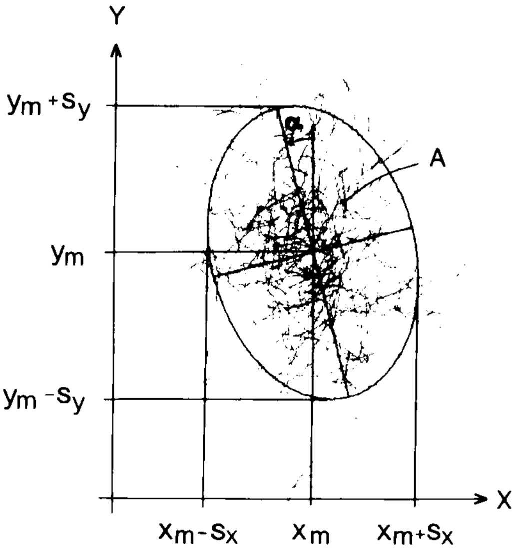

Figure 1. Statistical description of postural sway in the x-y plane. The confidence ellipse of area A has its centre in ($x_m y_m$). The tangents parallel to the coordinate axes yield the standard deviations of the marginal distributions which are equal to the rms values of the sway components s_x and 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.

Using the estimated parameters to characterize the various groups, differences between the groups were investigated by means of Student's *t*-test – assuming equal variances – of the 5 per cent level of significance.

MATERIAL

The study comprised 57 patients with adolescent idiopathic scoliosis (AIS) referred to the Department of Orthopaedic Surgery I, Sahlgren Hospital, during the years 1975 and 1976. The controls were randomly recruited from a material of healthy children previously described by Petersén & Eeg-Olofsson (1971). The reason for this recruitment was that the history and the somatic-neurological status in these children had been carefully studied previously. The controls were of similar age and had the same sex ratio as the scoliotics (Table 1). The 48 patients with single major structural curvatures were subgrouped with regard to the magnitude and convexity of the curvature (Table 2).

Nine scoliotics with double-primary curvatures formed a separate group in this study. These patients had two curvatures of major degree, both with structural changes. The classification of the patients followed the definitions laid down by the Scoliosis Research Society (1976). The scoliotic patients were classified with regard to whether the deformity required treatment or not. All of the patients with double-primary curvatures required treatment. As a rule, the indication for treatment (brace or surgery) was a curvature of more than 20 degrees (Cobb 1948) in a patient still skeletally immature. Two patients, who required a brace and both had a curvature of 17 degrees, were the only exceptions to this rule. Eight of the patients with a single major curvature required surgery. The two different subgroups requiring treatment were analysed together and the patients were investigated before any treatment.

Five of the patients with single curvatures and three of the patients among the double-primary scoliotics participated in the special study of brace effects.

The past history was extensively penetrated in all the subjects and they were given a thorough physical examination with emphasis on the neurological status, according to a special schedule. None of the patients was taking drugs and all abstained from tobacco and coffee on the day of the investigation.

Table 1. Material

	Scoliotics (single curves)	Controls
Number	48	32
Mean age (years ± SD)	13.4 ± 1.7	13.3 ± 2.1
Age range	10–16	10–16
Sex ratio ♂/♀	8/40 (20 % ♂)	5/27 (19 % ♂)

Table 2. Grouping of the scoliotic patients with regard to magnitude and convexity

	Patients placed under observation	Patients requiring treatment	Total
Right convex single curve	8	19	27
Left convex single curve	10	11	21
Double primary curve		9	9
Total	18	39	57

RESULTS

None of the children presented any neurological sign of pathological importance in the clinical examination.

Graphical comparison of the lateral and sagittal sway amplitudes, s_x and s_y, and of the total sway A are presented in Figures 2 and 3.* A summary of the statistical analyses is shown in Table 3.

The average position x_m of the lateral sway is to the right of the centre of the support area for the controls as well as in right and left scoliotics. In the right convex patients the shift is significantly more pronounced than the controls. The left convex patients also have a shift to the right, although they do not differ significantly from the controls. The displacement to the right for all these groups is preserved in Test 2. Patients placed under observation have a more pronounced displacement x_m than patients requiring treatment, in both the right and left convex group. This result is statistically significant ($P < 0.05$) for the left convex patients in Test 2.

The sway in the sagittal plane s_y is more pronounced in the scoliotic patients compared with the controls in all of the tests. A common feature is the almost consistently increased degree of significance for the lateral sway s_y compared with the sagittal sway s_x. The significant difference in the sagittal sway – as well as in the other parameters analysed – between scoliotic patients and controls is most conspicuous in the tests from which visual sensory information is excluded. The patients placed under observation were found to have the most pronounced differences in sagittal sway compared with the controls in

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* Detailed results in table form can be obtained by applying to Tage Sahlstrand.

Table 3. Summary of statistical analyses. The results of the tests are denoted with ★, ★★, ★★★ and ★★★★, indicating the significance levels 0.05, 0.01, 0.005 and 0.001, respectively

	Test 1 Stable base, eyes open						Test 2 Stable base, eyes closed							Test 3 Compliant base, eyes open				Test 4 Compliant base, eyes closed			
	x_m	s_y	s_x	s_y/s_x	A	α	x_m	$x_m - x_{m_1}$	s_y	s_x	s_y/s_x	A	$\alpha - \alpha_1$	s_y	s_x	s_y/s_x	A	s_y	s_x	s_y/s_x	A
Controls/single curves					●				★★★	★★★★		★★★★						★★★	★★★★	★	★★★★
Controls/patients placed under observation			★						★★★★	★★★★		★★★★		★	★		★	★★★	★★★★	★★★	★★★★
Controls/patients placed under observation right convex	★★★★	★					★★		★★★★	★★★★		★★★★		★	★		★	★★★	★★★★		★★★★
Controls/patients placed under observation left convex			★	★		★	★		★	★★★★		★★★★						★	★★★★		★★★
Controls/patients requiring treatment									★	★★		★★						★	★★★		★★
Controls/patients requiring treatment right convex										●		★★★★							★		
Controls/patients requiring treatment left convex						★			★	★		●						★	★★★		★★★
Controls/right convex scoliotics	★★						★		★★★	★★★★		★★★						★	★★★		★★★
Controls/left convex scoliotics			★			★★			★	★★★★		★★★★						★★★	★★★★	★	★★★
Controls/double primary curves										★★		★★							★		
Patients placed under observation/ requiring treatment										★		★							●		
Patients placed under observation/ requiring treatment right convex																			●		
Patients placed under observation/ requiring treatment left convex							★														
Right convex/left convex scoliotics						★															
Right convex/left convex scoliotics patients placed under observation				★		★															
Right convex/left convex scoliotics patients requiring treatment																					
Single curves/double primary curves																					

Test 3. The right convex patients requiring treatment, on the other hand, did not show any significant differences in sagittal sway compared with the controls in any of the test situations.

The scoliotics also had a clear increase in the lateral sway s_x compared with the controls. Another interesting feature is the very marked increase in lateral sway s_x in the tests from which visual information is excluded (Tests 2 and 4). As previously stated, when the scoliotics are compared with the controls the significance is more pronounced in these test situations for the lateral sway than for the sagittal sway. Significant differences under these conditions were also found for the right convex patients requiring treatment. In the lateral sway the difference between the patients placed under observation and the patients requiring treatment became most obvious. The patients placed under observation had a significantly ($P < 0.05$) increased postural sway in Tests 2 and 4 compared with the patients requiring treatment and in Test 4 the right convex patients of these two groups also differed significantly ($P < 0.05$).

The total sway area A is related to the sagittal and lateral sway. Analysis of this parameter also showed results similar to the other ones. One exception is the comparison between the total group of scoliotics and controls in Test 1. Even in this "easy" test situation a significantly increased sway could be detected in the scoliotic group ($P < 0.05$).

A decreased s_y/s_x quotient compared with the controls, i.e. a lateralization of the sway, was noted in Test 4. This finding was valid for the total scoliotic group ($P < 0.05$) as well as for the patients placed under observation ($P < 0.05$) and left convex patients ($P < 0.05$). In comparisons between the scoliotic groups the only significant finding was that left convex patients placed under observation had a lower quotient compared with right convex patients with the same magnitude of curvature ($P < 0.05$).

The average direction of the sway showed significant differences between the groups only in Test 1. The angle α had a negative value in left convex scoliotics. This value is significantly different from that obtained in the controls ($P < 0.01$). The differences persisted when the left convex patients were subgrouped. The right convex patients and the controls had the same value of α. When these patients were subgrouped, however, the result is obviously a synthesis of a pronounced positive value for the patients placed under observation and a slight negative value for the patients requiring treatment. Statistical comparisons between the scoliotic groups revealed

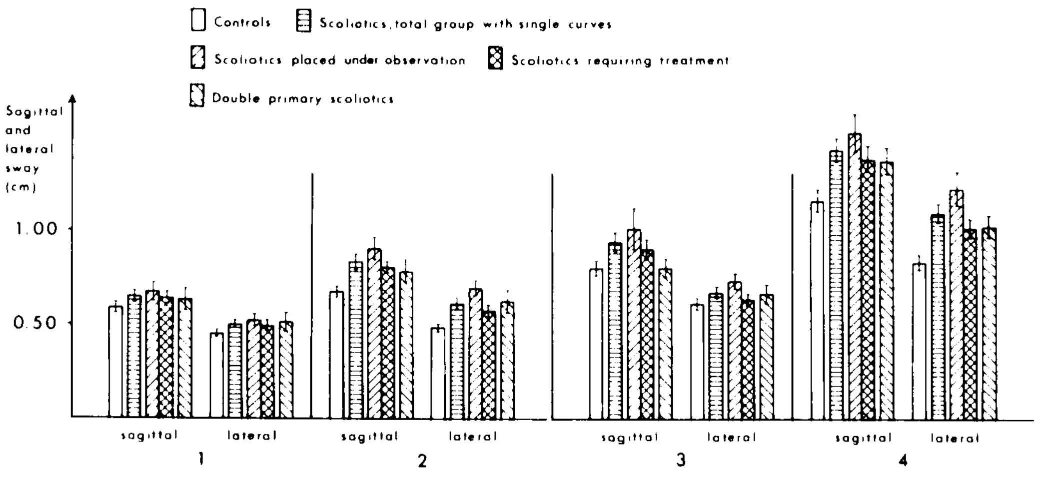

Figure 2. Graphical comparison of sagittal sway s_y and lateral sway s_x. Mean and SEM (cm) for each of the four tests.

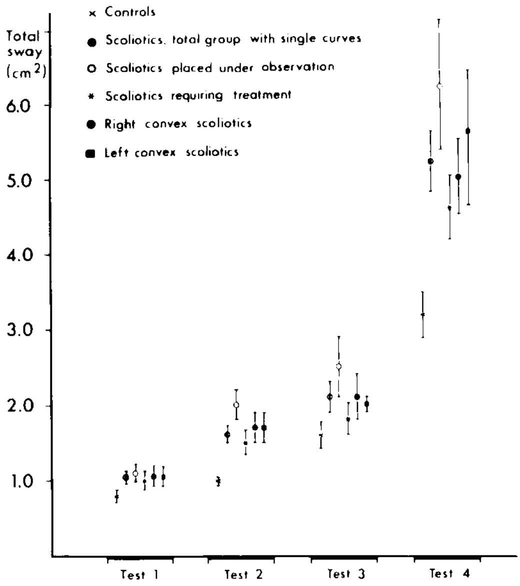

Figure 3. Graphical comparison of total sway A. Mean and SEM (cm²) for each of the four tests.

a difference between the right and the left convex patients as total groups as well as between the patients placed under observation.

For the double-primary scoliotics a significantly increased lateral sway was noted in Tests 2 and 4. The total sway was also increased in Test 2. No significant difference was noted in any other test or parameter.

When investigating the effect of wearing a brace, using the total sway area A as a criterion, there were no statistically significant differences either for the test in a well-fitted brace at the start of the treatment or for the test after 6 weeks of treatment.

DISCUSSION

Maintenance of upright posture is a complex mechanism and investigation and clinical assessment are rather subjective and non-reproducible. Factors such as amplitude and latero-pulsion are hardly registered by the clinician (Njiokiktjien & de Rijke 1972). Small, and perhaps subclinical, disturbances may not be detected unless a suitable method and investigation design are available.

In designing an equilibrium investigation it is necessary to include tests sufficiently difficult to challenge the nervous system and its neural processing of signals from different afferent sources (Stribley et al. 1974). To obtain information about how these different reflex activities are functioning and to obtain a measure of the relative importance of the participating afferent systems, specific experimental situations can be designed. In these the afferent information can be enhanced, weakened, or excluded (Eklund & Löfstedt 1970, Gantchev et al. 1972, Kapteyn 1972, Le & Lishman 1975, Murray et al. 1975, Stribley et al. 1974). Visual input is considered important in the maintenance of postural equilibrium (Gantchev et al. 1972, Guyton 1976). Lee & Lishman (1975) even postulated that vision can provide more sensitive information than the proprioceptive system. Nashner (1970) found that information from the visual system can be more accurate than that from the vestibular system, with a lower threshold for detection of spatial changes of the body in comparison with vestibular sensors. Although visual signals seem to dominate, they co-ordinate with labyrinthine receptors in postural control and do not replace them (Nashner 1970). An indirect measure of the importance of visual information for postural control may be obtained by noting changes in postural sway when vision is excluded and included in the test situation.

The characteristics of the base support determine to what extent the vestibular system is involved. With an increasing unevenness in the ground the labyrinthine activity becomes relatively more important (Lee & Lishman 1975, Martin 1967, Njiokiktjien 1971, Stahle, personal communication 1977).

The importance of the proprioceptive system increases when visual information is excluded (Gantchev et al. 1972, Roberts 1967). Most authors agree that proprioception dominates over the vestibular system as long as the individual is standing on a stable and firm surface (Martin 1967, Njiokiktjien & de Rijke 1972). The orientation of the body is accurately reflected by the angles of the ankles and from mechanoreceptors that signal the pressure between the feet and the base support. Under these conditions the level of processing can to a greater extent be dealt with at the spinal level in the central nervous system through spinal reflexes (Nashner 1970). However, when the individual is standing on a compliant or unstable surface the proprioceptive information becomes unreliable (Lee & Lishman 1975, Nashner 1970). For maintenance of postural equilibrium under these conditions supraspinal processing is needed to a greater extent. In this mechanism vestibular and visual sensors are involved, integrated mainly at the brain stem level with upwards radiating proprioceptive impulses.

Thus, in the present investigation it may be assumed that the afferent systems have been tested schematically as follows:

Test 1. Proprioception, mainly at spinal levels, the visual system and to a slight extent the vestibular system.
Test 2. Proprioception, mainly at spinal levels, and the vestibular system possibly more than in Test 1.
Test 3. Proprioception, mainly at supraspinal levels, the visual and the vestibular systems.
Test 4. Proprioception, mainly at supraspinal levels, and the vestibular system to a greater extent than in the other tests.

The most striking result of this investigation is the increased postural sway in the scoliotic patients compared with the children with straight spines. This is most conspicuous in the two tests in which the individuals had their vision excluded and had to rely on the proprioceptive and vestibular functions.

With visual input the postural equilibrium is dramatically improved. Whether a stable base support is used or not, the visual information seems important for the scoliotic patients for improving their postural stability. This finding contradicts a hypothesis that the decreased postural control in the scoliotic group is caused by any important disturbances in the visual system.

There are differences of opinion in the literature about the role of the vestibular system in the test situations used here (Kapteyn 1972). There is general agreement, however, that the vestibular system is involved to some extent in all the tests in the present investigation and that it must be most important in Test 4, i.e., when the subject is standing on a compliant surface with his eyes closed. The statistical analysis did not reveal any difference between the results of Test 2 and Test 4. All the different scoliotic groups had a significantly increased sway, totally as well as in the lateral and sagittal direction. Of course, the importance of a more significant contributory vestibular factor in Test 4 may be missed when there are already such clear differences in Test 2. Apart from a disturbed proprioceptive process at the spinal as well as the supraspinal levels, a defective vestibular sensoring cannot be ruled out, especially as the scoliotic patients had a lower quotient between the sagittal and lateral sway, i.e., they demonstrate the lateralized pattern in the postural sway. This phenomenon has earlier been recognized as a possible sign of vestibular disturbance (Njiokiktjien & de Rijke 1972).

The differences between the scoliotic patients and the control children cannot be explained by the composition of the material. The age and sex pattern as well as constitutional factors such as weight and height are about the same in the two groups. The investigation was carried out under the same conditions for the patients and the controls. The only exception was that the patients requiring treatment were participating in this study as inpatients. If this circumstance had constituted a "stress" factor influencing the result, these children would have been expected to have a greater postural sway than the patients placed under observation. But, on the contrary, the patients placed under observation participating as outpatients had a poorer equilibrium performance compared with the patients requiring treatment.

This leads us to the question of whether these findings might be of aetiological importance or whether the disequilibrium reflects a phenomenon that is secondary to the deformed spine. If a dysfunction in the postural equilibrium is secondary to the idiopathic curvature, it seems reasonable to assume that a patient with a more severe curvature will have more dysfunction. However, this study has shown a clear-cut tendency in all the analysed tests for the patients requiring treatment to have a decreased postural sway compared with the patients placed under observation, i.e., the children with small curvatures. The tendency becomes statistically significant in Test 2 and Test 4 for the lateral sway and in Test 2 also in the total sway. The superior equilibrium performance of the patients given treatment was also evident when these two subgroups were compared with the controls (Table 3). This result is difficult to interpret. It does not, however, support any theory of a postural dysfunction as an effect of a crooked spine.

With a feed-back theory as background, the double-primary curvatures are interesting to study. Like the patients with single structural curvatures, they turn out to have a significantly increased postural sway compared with the controls in Test 2 and Test 4 and they do not differ from these in the between-group comparison among the scoliotics.

It might be possible that the patients placed under observation and those requiring treatment have been studied in different situations at the time of the development of the disease. The cases placed under observation might have been investigated in an earlier and perhaps more sensitive phase of the disease. This possibility has been considered and a separate analysis reveals that the deformity had been recognized for the same length of time in the two groups. A brace is considered to stabilize the spine and we know from radiograms that it diminishes the curvature. However, the special study of the brace effect on postural equilibrium did not seem to support the theory that the disturbed postural equilibrium in these patients was caused by the scoliosis. In the tested patients improvement and aggravation were about equally frequent. It seems reasonable to assume that the existence of an active feed-back mechanism of any importance would have resulted in a more clear-cut tendency towards improvement of postural equilibrium when the patients received their braces.

In summing up the discussion of what is cause and what is effect, we must begin by stating, like so many investigators who have approached idiopathic scoliosis from an aetiological point of view before us, that once a curvature is established it is difficult to say what came first: the different signs or symptoms or the deformity? However, the comparison between the findings in patients with small and more severe curvatures, the results in the double-primary group and the findings in the brace study do not support the theory of the crooked spine as the cause of the disequilibrium in the scoliotic patients. On the other hand, the observations in these patients are not direct evidence that the significant differences in postural equilibrium between the scoliotics and the controls are of aetiological importance. Elucidation of this point requires further study of the outcome for the patients placed under observation in this study. This measure will not be enough, since our material is too small to clearly elucidate this issue adequately. A longitudinal study in a larger group of patients with smaller idiopathic curvatures, still not requiring treatment, is needed to study this issue more thoroughly.

On the whole there are no significant differences in angle values between right and left convex patients except in Test 1. The angle α is a measure of the average direction of sway, and this parameter may reflect such phenomena as rotation and laterotorsion of the body. This assumption is supported by findings in this comparison, bearing in mind that in the characteristics of the deformity in idiopathic scoliosis rotation is included. When starting from the assumption that the angle α might be a measure of rotation and laterotorsion, the left convex patients seem to have a more pronounced feature of such phenomena than the right convex patients and they also seem to react to a great extent regarding such phenomena when closing their eyes. A different reaction pattern is also found in the s_y/s_x-quotient when left and right convex patients are compared. When the patients are subgrouped according to the magnitude of the curvature, the left convex scoliotics also turn out to have a different pattern in the quotient between sagittal and lateral sway, with a clear lateralization of the sway compared with the right convex patients. It is known (Njiokiktjien 1971) that the majority of people have their projection of centre of gravity to the right, as had our controls and right convex scoliotics. An unexpected and somewhat surprising finding is that the left convex patients also had their centre of sway in the lateral plane directed to the right.

Summarizing the comparison between the right and left convex groups, the left convex patients had quantitatively more pronounced reactions than the right convex patients.

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Correspondence to: Tage Sahlstrand, M.D., Department of Orthopaedic Surgery, Ostra Sjukhuset, University of Göteborg, S-41685, Göteborg, Sweden.