Stabilometry as a diagnostic tool in clinical medicine

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Stabilometry, a method of measuring stability of stance or postural equilibrium in man, consists of transforming the mechanical oscillations of man's "physiologic gravicentre" into electric signals, then amplifying, recording and analysing the signals. The frequency, duration and mean and maximum amplitudes of oscillations, and coefficients reflecting the influence of vision, differ in patients with various neurologic diseases and from values in healthy subjects. The method is highly sensitive and accurate, simple and rapid to use, lacks danger and discomfort and permits screening of a large number of people in a short time.

La stabilométrie, une méthode servant à mesurer la stabilité de la posture ou de l'équilibre postural chez l'homme, consiste à transformer les oscillations mécaniques du "centre de gravité physiologique" de l'homme en signaux électriques qui sont alors amplifiés, enregistrés et analysés. La fréquence, la durée et la moyenne ainsi que le maximum des amplitudes d'oscillation, de même que les coefficients répercutant l'influence de la vue, diffèrent chez les patients atteints de diverses maladies neurologiques, ainsi qu'avec les valeurs retrouvées chez les sujets sains. La méthode possède un haut niveau de sensibilité et de précision, elle est simple et rapide d'emploi, elle est dépourvue de danger ou d'inconvénient et elle permet de faire en peu de temps du dépistage chez un grand nombre de gens.

Stabilometry, or posturography, is a relatively new method for investigating man's stability of stance and is thus related to both the physiology of the central nervous system (CNS) and medical cybernetics. The complexity of man's upright standing position is determined by the complexity of its control by the CNS, whose function is based on the laws of a self-regulating, multifaceted cybernetic system using feedback principles.[1-3]

The study of man's postural equilibrium has interested clinicians and scientists for decades, and recently the interest has grown. Each year a greater number of papers on stabilometry and posturography appear in international journals and are presented at scientific meetings.[4-9]

In stabilometry the mechanical oscillations of the centre of gravity of the human body, or the "physiologic gravicentre", while the individual is standing are measured. The method can be applied in various disciplines, including clinical medicine, otorhinolaryngology, industrial medicine and sports physiology.

Physiologic aspects of upright posture

Standing represents a complex reflex process that ensures the maintenance of body equilibrium. It is controlled by the uninterrupted flow of impulses reaching the CNS from muscle and tendon proprioceptors, skin exteroceptors and the vestibular and visual apparatus. When the body equilibrium becomes upset, impulses originating in these receptors activate reflex contractions in the muscular fibres to restore the equilibrium. Thus, reflex contractions in the musculature cause continuous body oscillations that maintain the dynamic equilibrium of the upright posture.

The body of an apparently motionless, standing man undergoes continuous micromotions of which he is unaware. These motions occur as both front-to-back and side-to-side oscillations — that is, in the sagittal and frontal planes. These compensatory movements of the physiologic gravicentre ensure the maintenance of posture through the complex reflex mechanism of the CNS. The amplitude and frequency of these oscillations vary from subject to subject and for a given subject in accordance with its normal or pathologic condition.

Romberg,[10] a German neuropathologist, was the first to observe that in some neurologic diseases the patient's body undergoes relatively pronounced, visually detectable oscillations. Later he devised a test that became known as the Romberg test. In clinical neurology the physician still uses the Romberg test to evaluate stationary stance by comparing visually the degree of steadiness when the patient's eyes are open and closed.

Method and equipment of stabilometry

The stabilometric method consists of transforming the mechanical oscillations of man's physiologic gravicentre into electric signals, then amplifying, recording and analysing the signals.

The main component of the device is the transducer, or electronic platform, which consists of two square metal plates (39 x 39 cm) placed horizontally one over the other, and between them, at each corner, load elements. Designed to operate under a load of up to 200 kg without permanent deformation, these elements assure sensitivity, linearity and axis symmetry of the platform. Each is fitted with two strain gauges, which have a built-in mechanism for temperature compensation. The gauges are connected to form two bridge circuits, one of which registers load changes in the sagittal plane, and the other, in the frontal plane.

Several versions of these platforms have been designed and tested by the department of bioengineering of the University of Texas Health Science Center. The basic equipment is shown in Fig. 1. The equipment is calibrated by moving a known weight a certain distance over the surface of the platform, first in the direction of one axis and then in the direction of the other axis.

The test procedure is simple. The patient is asked to stand still on the platform in his natural posture for 30 seconds with his eyes open. At a signal from the operator he is asked to close his eyes for 30 seconds, then to reopen them for 30 seconds. The entire test lasts about 2 minutes and the patient experiences no discomfort. At the end of the test the operator obtains two tracings or stabilograms.

Analysis of stabilograms

A stabilogram of a healthy subject is shown in Fig. 2.

In our analyses of the stabilograms we studied the following baseline parameters of the stability of stance in both sagittal and frontal planes (Fig. 3): (a) frequency of oscillations per minute; (b) duration of one oscillation in seconds; (c) mean amplitude of oscillations in millimetres; (d) maximum amplitude of oscillations in millimetres; and two coefficients reflecting the degree of

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visual influence on the stability of stance: (e) coefficient A (C_A), or Romberg's coefficient, obtained by dividing the mean amplitude with the eyes open at the start of the test by the mean amplitude with the eyes closed; and (f) coefficient B (C_B), or the after effect, obtained by dividing the mean amplitude of the final eyes-open phase by the mean amplitude with the eyes open at the start of the test.

These parameters can be evaluated from the stabilograms by a manual method or with the help of electronic equipment. Either way the mean body oscillation amplitude is calculated by dividing the total amplitude per minute by the oscillation frequency per minute.

We obtained values for the baseline parameters in 52 healthy subjects, 23 men and 29 women aged 24 to 58 years. The average oscillation frequency of the physiologic gravicentre and the oscillation periods were 36.8 and 38.3/min and 1.6 and 1.5 s, respectively. Mean and maximum amplitudes for men and women were 3.5 and 3.2 mm and 9.2 and 7.8 mm, respectively. The average C_A was 1.37 and 1.34, and C_B, 1.07 and 1.05, respectively. These values can be used in demonstrating changes in the stability of stance in different pathologic or experimental conditions.

Application of stabilometry to clinical medicine

Stabilometry has not yet found wide clinical application. However, the high sensitivity of this method in determining changes in man's stability of stance in functional and pathologic conditions indicates its possible application in various fields of medicine, mainly neurology and neurosurgery.

We assessed the clinical value of stabilometry by studying 103 patients, 44 men and 59 women aged 26 to 64 years: 13 had cerebral tumours; 15, cerebellar tumours; 12, tumours of the spinal cord; 19, multiple sclerosis; 17, hypertension and cerebral atherosclerosis; 21, lumbosacral radiculitis; and 6, Parkinson's disease. Sets of values given below are for men and women, respectively; data for the sagittal plane with the patients' eyes open are depicted in Fig. 3.

In patients with cerebral tumours the oscillation frequency was noticeably less in both planes for both opened and closed eyes than in healthy subjects, at 29.9 and 31.2/min. The period of one oscillation was greater, at 2.1 and 1.9 s, the mean oscillation amplitude in both planes with opened and closed eyes was greater by 1.5 to 2 times and the maximum amplitude was considerably greater. In comparison with the values for healthy subjects C_A was low, at 1.18 and 1.21, and C_B was somewhat high, at 1.11 and 1.13.

In patients with tumours of the cerebellum the oscillation frequency was less than in healthy subjects but somewhat greater than in patients with cerebral tumours, at 34.2 and 35.6/min, and the oscillation periods corresponded, at 1.8 and 1.7 s. The mean oscillation amplitude exceeded that for healthy subjects but was less than that for patients with cerebral tumours. The maximum oscillation amplitude was considerably greater than that for healthy subjects. Both C_A and C_B were high, at 1.55 and 1.64, and 1.15 and 1.17.

Patients with tumours of the spinal cord had a small reduction in oscillation frequency and a corresponding in-

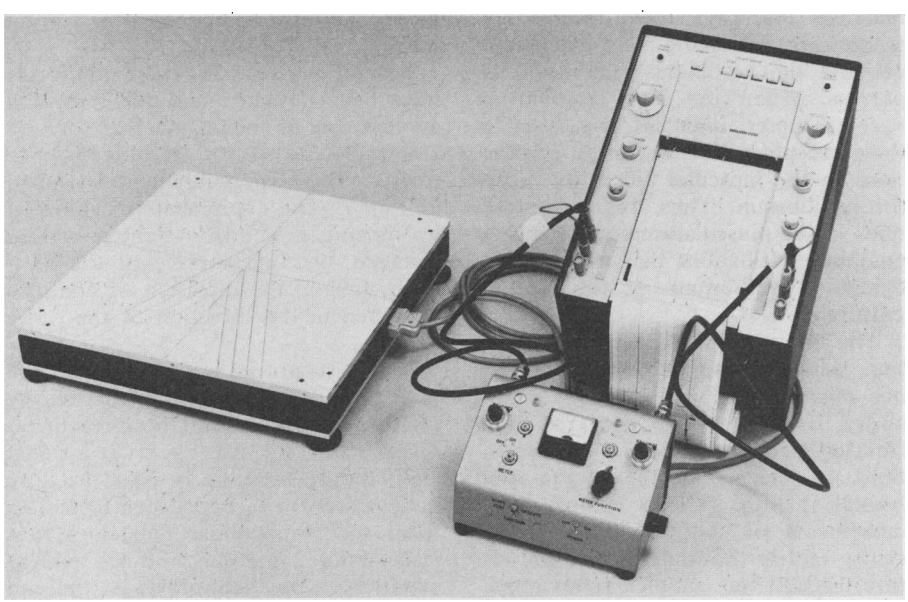

FIG. 1—Basic equipment for recording stabilograms.

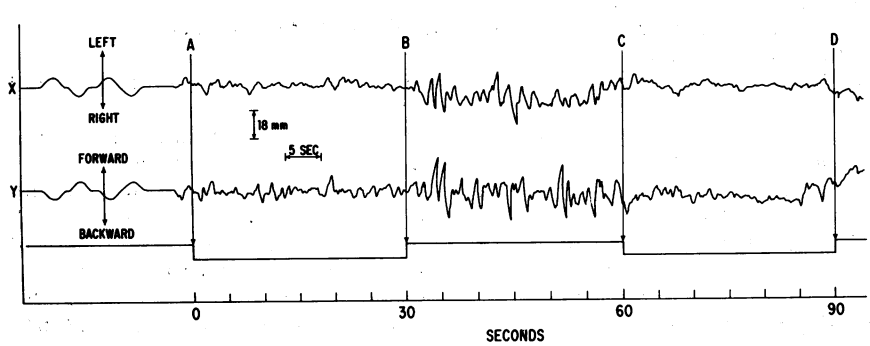

FIG. 2—Stabilogram of healthy subject. A = start of recording; AB = subject's eyes open; BC = eyes closed; CD = eyes open again.

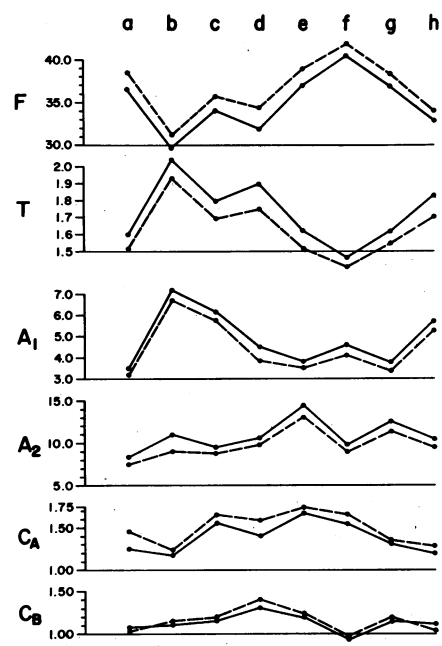

FIG. 3—Mean values for basic stabilometric parameters in healthy subjects (a) and patients with the following conditions: cerebral tumours (b), cerebellar tumours (c), tumours of the spinal cord (d), multiple sclerosis (e), hypertension and cerebral atherosclerosis (f), lumbosacral radiculitis (g) and Parkinson's disease (h). Data for males represented by solid lines, and for females, by dotted lines. F = oscillation frequency (/min); T = oscillation period (s); A_1 = mean oscillation amplitude (mm); A_2 = maximum oscillation amplitude (mm); C_A = coefficient A (mean amplitude with eyes open at start of test ÷ mean amplitude with eyes closed); C_B = coefficient B (mean amplitude of final eyes-open phase ÷ mean amplitude with eyes open at start of test).

crease in the period of one oscillation. Their mean and maximum oscillation amplitudes were higher than those of healthy subjects but lower than those of patients with tumours of other areas of the CNS. C_A was greater than in healthy subjects but less than in patients with cerebellar tumours, at 1.41 and 1.58; C_B was greater than in patients with all other disorders, at 1.31 and 1.37.

In patients with multiple sclerosis the oscillation frequency and period were nearly the same as those in healthy subjects. Conversely, the mean and maximum oscillation amplitudes were much greater in the patients. The highest values of C_A, 1.68 and 1.72, were calculated for these patients; C_B was higher than for healthy subjects, at 1.18 and 1.21.

In patients with hypertension and cerebral atherosclerosis the oscillation frequency was somewhat greater than in healthy subjects, at 40.8 and 42.1/min, and the oscillation period was accordingly less. The mean and maximum oscillation amplitudes were increased. C_A was high, at 1.55 and 1.67, especially in the frontal plane; the lowest values of C_B, 0.93 and 0.99, were recorded in these patients.

In patients with lumbosacral radiculitis the oscillation frequency and period were almost the same as those in healthy subjects. The mean and maximum oscillation amplitudes were somewhat greater. C_A was somewhat lower than in healthy subjects but was higher in the frontal plane. C_B was much higher than in healthy subjects, at 1.14 and 1.16.

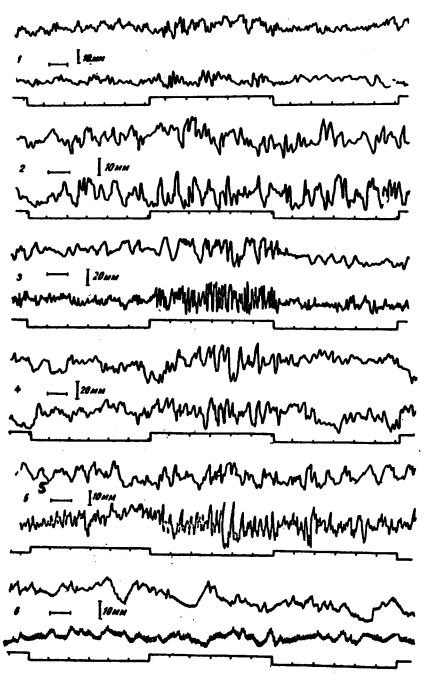

FIG. 4—Stabilograms from healthy subject (1) and patients with brain tumour (2), spinal cord tumour (3), multiple sclerosis (4), hypertension and cerebral atherosclerosis (5) and Parkinson's disease (6). Time intervals marked, 5 s.

In patients with Parkinson's disease there were pronounced changes in the stabilograms. Oscillations of high frequency (in some instances 180 or 190/min) and low amplitude appeared as tremors superimposed on the usual oscillations; the latter had an average frequency of 34/min — somewhat less than in healthy subjects. Oscillation amplitude exceeded the normal but, when the eyes were closed, it was less in these patients than in healthy subjects.

The data we obtained for patients with various diseases showed clearcut differences between the groups, and values for all parameters different from those recorded in healthy subjects. Similarly, the stabilograms differed clearly. Typical examples of a normal stabilogram and those of patients with a brain tumour, a spinal cord tumour, multiple sclerosis, hypertension and cerebral atherosclerosis, and Parkinson's disease are shown in Fig. 4.

Discussion

The Romberg test,[10] devised many years ago and offering only a qualitative evaluation of man's stability, is still being used today. Quantitative assessment of the complex parameters of postural equilibrium characterizing all aspects of standing is a significant step forward; the data obtained from the Romberg test cannot compare with those yielded by the stabilometric method. This method affords new and valuable information about the function of the CNS of man. Disorders of CNS function, regardless of their cause, are reflected in the altered values for the parameters of man's stability of stance. Each parameter is useful in diagnosis, as are the coefficients, because each has a different value in each disease we have investigated; hence, in analysing stabilograms one must include all the data obtained in both the frontal and the sagittal planes with eyes open and closed.

The stabilometric method has several important advantages, such as high sensitivity and accuracy, simplicity and speed of operation, and lack of danger and discomfort to the patient. In addition, it is possible to screen a large number of patients by this method in a short time and identify those requiring more detailed investigation.

Stabilometry promises to be a useful aid in diagnosis.

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