THE TOTAL AMPLITUDE OF BODY OSCILLATIONS AS AN INDEX OF THE STABILITY OF HUMAN STANDING POSTURE

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In 1951, together with our colleagues, one of us proposed a method of stabilography (study of human standing posture stability) and constructed a stabilograph [1] for recording the body oscillations of a man standing on a rigid nonbalancing platform. These oscillations cause a displacement of the projection of the over-all center of gravity of the body on the bearing surface. The platform, in which were installed transducers for converting mechanical forces into electrical signals, takes into account displacement of the over-all center of gravity.

In the present work, we used a stabilograph built by the Special Design and Engineering Office "Biofizpribor." The platform of the stabilograph is two horizontally positioned square Duralumin plates situated one above the other. Four bronze rings with a diameter of 30 mm and a wall thickness of 4 mm are installed between these plates along their corners. Wire strain gauges of constantan wire with a diameter of 0.03 mm and a resistance of 330 Ω are wound on ruby supports, which are installed along the horizontal diameter of the rings. Two strain gauges are mounted on each of the four rings. One of the strain gauges of each ring is connected to the circuit of one bridge, and the other strain gauge is connected to the circuit of a second bridge. The first bridge circuit is made so that the strain gauges of the two front rings of the platform form two opposing arms of the bridge, while the strain gauges of the two back rings form the arms adjacent to them. In the second bridge circuit, the strain gauges that are on the front and back rings of one side of the platform make up two opposing arms of the bridge, while the strain gauges that are on the front and back rings of the other side form the adjacent arms.

The first circuit is designed for recording body oscillations in the sagittal direction (forward and backward), and the second, for recording oscillations in the frontal direction (to the right and to the left). The bridge circuits

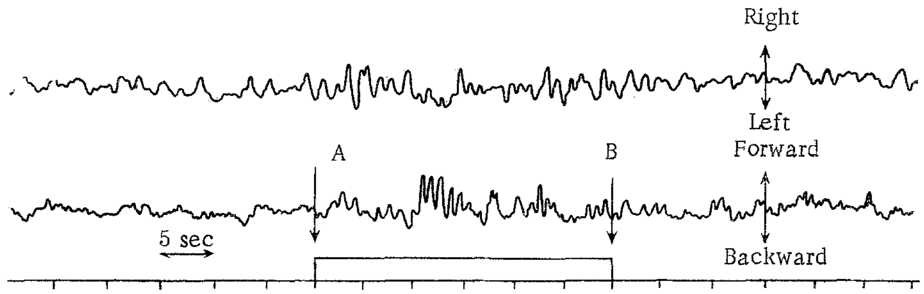

Fig. 1. Sample of stabilogram of healthy person. The upper curve is a recording of body oscillations in the frontal plane; the upper curve, in the sagittal plane. The arrows indicate the closing (A) and opening (B) of the eyes. The time marks equal 5 sec.

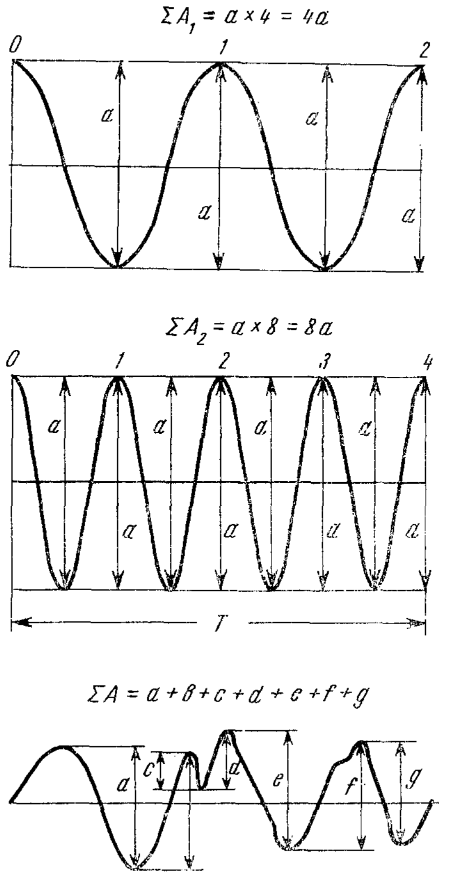

Fig. 2. Diagram explaining the results of operation of the amplitude adder.

are ac powered from a generator with a frequency of 5000 cps. The voltage produced as a result of unbalance of the bridges when the body of the subject oscillates is red to a strain-gauge amplifier. The principle of amplitude modulation of the carrier frequency is used in the instrument. The amplified signal is demodulated by a phase-sensitive detector and is fed through a filter to a dc amplifier, the load of which is a moving-coil vibrator, which records the body oscillations of a subject standing of the platform. Compensators, which eliminate the unbalance of the bridges that arises at the beginning of a study when the subject is placed on the instrument, are connected to the electric circuit (the constant component that is a function of the weight of the body is eliminated).

Before each test, the instrument is calibrated by moving a known weight a certain distance over the surface of the platform. The amplitudes of the body oscillations of the subject, whose weight is known, are compared with the calibration data. Thus, the displacement of the overall center of gravity of the body in the sagittal or frontal directions can be calculated and the amplitudes of these oscillations can be expressed in kg/mm. The smaller these oscillations, the greater the stability of the standing posture.

In order to simplify and unify the analysis of the stabilograms (Fig. 1), we used an automatic instrument: an electronic amplitude adder. This instrument was connected in parallel with the vibrator. This allows the total amplitude of human body oscillations to be determined by means of electromechanical counters for both directions (i.e., forward and backward or to the right and to the left). The results of operation of the amplitude adder are shown schematically in Fig. 2.

The circuit diagram of one channel of the amplitude adder is shown in Fig. 3. The signal picked up from the output of the stabilograph goes through an ordinary 6N15P (T_1) push-pull amplifier stage to a storage system with two 6Zh3Ps (T_2 and T_3) Capacitor C_2 is the plate load for these tubes. When the voltage across the capacitor reaches a value that is sufficient to gate the 6N1P (T_4), the current through the latter begins to increase avalanchwise, and the voltage pulse that is produced at the plate in this case is used to trigger a kipp relay, which uses a 6N1P (T_5). The square pulse generated by the kipp relay is fed to the grids of the amplifier stage, which uses a 6N1P (T_6). Its cathode load is an MÉS-54 electromechanical pulse counter, which also counts the pulses generated by the kipp relay.

The charging rate of the capacitor varies according to the value of the signal fed to the amplitude adder, which causes a change in the number of pulses generated by the kipp relay for a certain time interval and; therefore, a change in the readings of the pulse counter for that same period. An experimental check of the dependence of the counter readings upon the value of the imput signal showed a linear dependence between them. The frequency response of the amplitude adder is from 0.1 to 30 cps.

The total-amplitude counters are calibrated just as the stabilograph is calibrated, by moving a known weight a certain distance along both axes of the stabilograph platform. If we know the weight of the subject, on the basis of the calibration data we can calculate the total amplitude of body oscillations according to the displacements of the over-all center of gravity in kg/mm for 30 sec or for 1 min. In each test, we first determine the readings of the counters for 30 sec or 1 min of stainding of the subject on the stabilograph platform with open eyes, and then readings are taken for the same time with closed eyes, and, finally, readings are again taken for standing with open eyes.

The results obtained in an examination of 32 practically healthy subjects (16 men and 16 women) are given in the table, which gives calculations of the stabilographic index, which reflects the role of the visual analyzer in standing stability. This index is the ratio of the total amplitude of body oscillations (displacements of the overall center of gravity) with closed eyes to the total amplitude of these oscillations with open eyes expressed in percent.

Total Amplitude of Oscillations of Overall Center of Gravity of Body (in kg/cm/min) in Frontal (A) and Sagittal (B) Planes (Average Data of 32 Tests of Healthy Subjects)

		With open eyes		With closed eyes		With open eyes		Ratio of total amplitude of displacements of over-all center of gravity with closed eyes to amp. of displacements with open eyes (in %)	
		A	B	A	B	A	B	A	B
Men	Oscillation limits	3,6—14,6	7,5—18,3	11,6—20,4	12,1—25,2	9,0—15,4	7,7—17,9	128—162	102—176
	M	11,1	12,9	15,7	17,8	11,3	12,8	142	138
	$m\pm$	0,45	0,76	0,63	0,92	0,45	0,86	2,6	5,1
	$\sigma\pm$	1,81	3,03	2,51	3,66	1,82	3,4	10,6	20,5
Women	Oscillation limits	7,0—12,7	8,1—15,7	9,1—20,6	12,7—21,2	8,9—15,4	7,6—15,1	113—204	117—178
	M	10,3	12,0	15,0	18,2	11,3	11,8	153	146
	$m\pm$	0,4	0,6	0,8	0,7	0,4	0,6	6,0	4,4
	$\sigma\pm$	1,7	2,5	3,3	2,8	1,6	2,4	21,0	17,6

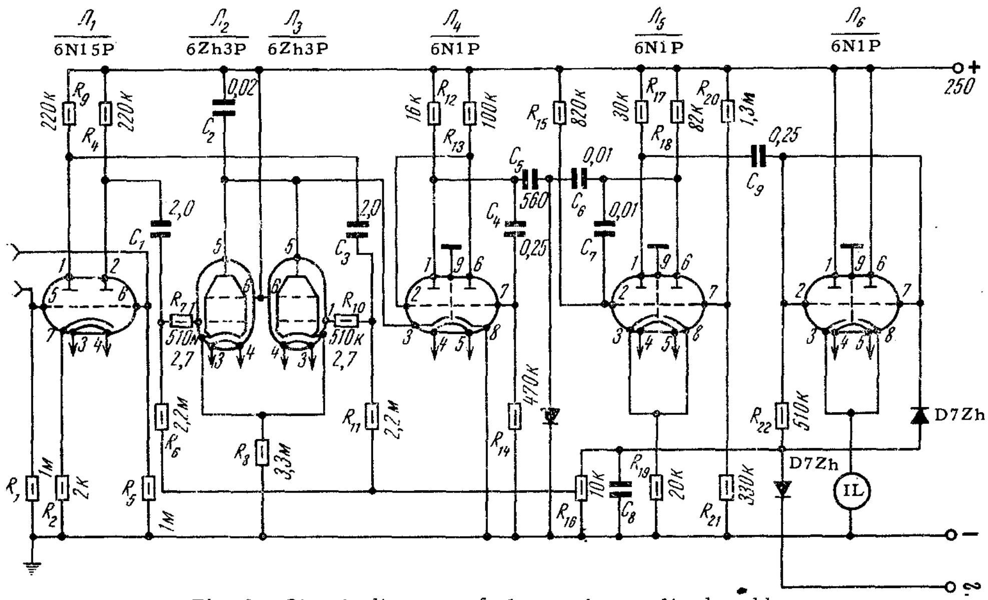

Fig. 3. Circuit diagram of electronic amplitude adder.

Some of the following Russian abbreviations may be found in the figure: Л = tube, Д = diode, Тр = transformer, Др or др = choke, Вк = switch, в = V, М = MΩ, к = kΩ, мк = μF or μH, п = pF or pH, and н = nF or nH.

The average values of the displacement of the overall center of gravity of the bodies of the men and women in the sagittal and frontal directions with open and closed eyes determined with the amplitude adder were 1 to 8% greater than the values calculated by graphical analysis of the stabilograms. This discrepancy can apparently be explained by the fact that the adder takes into account single minute body oscillations, which are not always calculated in graphical analysis of the curves.

The amplitude adder was used to determine the standing stability of neurologically ill subjects. The study was made by Yu. V. Terekhov jointly with E. A. Morozova at the Clinic for Nervous Disorders No. 1 of the Moscow Order of Lenin Medical Institute. Without dwelling here on the data obtained, let us point out that the total amplitude of oscillations of the overall center of gravity of patients with tumors of the cerebrum and cerebellum, and with scattered sclerosis in standing with open and closed eyes in almost all cases exceeded not only the average values, but also the upper limits of the values observed in practically healthy subjects. These observations serve as a basis for assuming that the method of determining the total amplitudes of human body oscillations in standing can be of value in the neurological clinic.

SUMMARY

The article describes the use of the electron amplitude adder for determining the degrees of displacements of the common center of gravity of the body per unit of time (the patient standing on the stabilograph platform). The measurements are taken with the patient having his eyes open and closed. The values obtained present the characteristics of the patient's standing posture stability.

LITERATURE CITED

1. E. B. Babskii, V. S. Gurfinkel' and É. L. Romel' et al., Fiziol. zh. SSSR, 41, 3 (1955), p. 423.

All abbreviations of periodicals in the above bibliography are letter-by-letter transliterations of the abbreviations as given in the original Russian journal. ***Some or all of this periodical literature may well be available in English translation.*** **A complete list of the cover-to-cover English translations appears at the back of this issue.**