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THE CONCEPTION OF THE COMPUTER STABILOANALYSERS KCK–4 «STATOKINESIMETRE–STABILAN» DEVELOPMENT AND APPLICATION IN SPORTS AND MEDICINE

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Abstract: The basic characteristics of the computer stabiloanalysers (the devices which measure the parameters of the human vertical posture keeping process) produced by various Russian firms are considered. The problem of strain-gauges choice is discussed. The possibility of combining the stabiloanalysers with the devices which measure other physiological parameters is examined. The examples of the practical applications of the stabiloanalysers are given. The new mathematical methods for stabilographic data processing are discussed.

Key words: stabiloanalyser, human center of pressure, strain-gauge, stabilograms processing

Introduction

The method of comfortable and economical investigation of the vertical posture keeping process is called stabilography. V.S. Gurfinkel, E.B. Babsky, E.L. Romel and J.S. Jacobson developed this method in 1952, i.e. almost 50 years ago. The biomechanical investigations of the movements kinematics, which have become classical owing to the works of N.A. Bernstein [1, 2], necessarily include today the analysis of both the mechanisms of the comfortable vertical posture keeping and the synergetics of arbitrary postures. This analysis is carried out in the course of different tests and arbitrary programmed and guided movements. It should be noted that in several publications the above-mentioned method is called «statokinesimetry», but we use the term «stabilography». The new qualitative level connected with the computer processing of the stabilograms has been achieved by this method only 40 years since 1952.

Several firms in Russia have been developing the techniques and methods for the computer stabilography during the last ten years. But only three firms have reached the level of mass production of the high-quality techniques authorized by the Russian Federation Ministry of Health: the Special Design Office «Rhythm» (Taganrog, Russia), which worked in close co-operation with the Scientific-Medical Firm «Statokyn» (Moscow, Russia) and the Joint-Stock Company «VNIIMP–VITA» (Moscow, Russia).

Each of the above-mentioned organizations took its own path. So it is interesting to compare the completed devices. Table 1 shows the basic technical parameters of the devices.

The computer stabilography has been developed at the Special Design Office «Rhythm» since 1990 (at the Scientific-Medical Firm «Statokyn» - since 1992) as an independent scientific and technological theme. The construction of the first four experimental computer stabilographs CT-1 (the first generation) is referred to the beginning of the investigation. The certificates for the computer stabiloanalysers KCK-4 (the fourth generation) were obtained in 2000.

The great attention is paid to bringing the methodology of the stabilometric study, the mathematical algorithms and the apparatus into line with the international standards Normes 85, which were adopted and published by the Association francaise de posturologie (Paris, 1986).

Stabiloanalysers characteristics

The stabiloanalyser KCK-4 first of all allows one to carry out the static stabilographic investigations (the stabiloplatform is immobile) and also to record and to process the trajectory of the pressure centre (PC) of an examined person in the X- (frontal direction) and Y- (sagittal direction) coordinate plane. The stabiloanalyser produced by the Joint-Stock Company «VNIIMP–VITA» has the same properties. The moments of forces acting on the stabiloplatform surface are not measured because the coordinates of the gravity centre of an examined person cannot be obtained immediately from the values of these moments. The group of scientists guided by B.A. Potyomkin established this fact at the Institute of Machines Science of Russian Academy of Science.

Table 1. The technical parameters of the computer stabilographs, which are mass-produced in Russia.

Firm, Model (year)	PC coord. range, mm	Resolv. power, mm	Coord. precision, %	Patient's mass, Kg.	ADC word length, Digits	Power, W	Number of gauges	Device mass, Kg; Dimensions, mm
«VNIIMP–VITA» Stabilotest-K (1996)	X,Y± 50	0.15… 0.01	±2	Up to 150	10-12	5	4	3; 400?370?50
«Rhythm» and «Statokyn» KCK-123-3 (1997)	X,Y± 160	0.1… 0.005	±5	30… 150	12	5	4	7; 400?350?80
KCK-4.2 (1999)	X,Y± 150	0.006	±2	20… 150	16	5	4	6; 400?350?70
KCK-4.3 (1999)	X,Y± 200	0.006	±1.5	20… 150	16	20	4	8; 480?480?70

The constructors from «Rhythm» and «Statokyn» took the vertical mobility of the stabiloplatform supporting surface into account. This mobility was regarded as a negative factor and an obstacle for the investigation standardization. This factor is usually not mentioned and it depends on the structure of gauges and stabiloplatform. But the examined person feels this mobility rather distinctly. The mobility of the stabiloplatform supporting surface in the stabilograph KCK-2 (second generation) reached 2 mm, and it was mentioned by most of examined persons. In the stabilographs KCK-4 (fourth generation) this displacement was reduced much, but some sensitive persons still felt the vertical mobility.

The reduction of this mobility achieved by the constructors from «Rhythm» and «Statokyn» allows the examined person to keep the natural behaviour and eliminates the disturbances from the measuring device.

The selection of method of the force transformation into the electric signal is very important for the designing the stabiloplatform. This signal provides information for the PC coordinates calculation. There are about twenty methods of the force transformation: contact, rheostatic, strain-gauge, capacitor, piezoelectric, electromagnetic, movable-electrode tube, jet, opto-electronic and so on. The constructors from «Rhythm» and «Statokyn» used the strain-gauge method.

The selection of the resistance strain-gauge elastic element structure is also very important. In recent ten years we have sampled different elastic elements:

- hollow cylinder with the truncated lateral surfaces (according to O.I. Safronov's certificate);
- thin-walled pipe used in the strain-gauges ЛХ-143 and ЛХ-144, which are produced at the Krasnodar strain-gauge devices factory;
- cut rings of our own design.

Stabiloanalysers КСК-4 contain the strain-gauges of parallelogram type, which consist of two cantilever beams. D.V. Kryvets, the senior research officer of Rostov State University and Cogan Scientific Research Institute of Neurocybernetics, has constructed these gauges. The recent achievements in integrated circuit engineering and resistance strain-gauge transducers designing allowed us to obtain the unique dynamic diapason (about 65000 bits over the PC coordinates range) both in sagittal and frontal directions. This diapason allowed us to bring the resolving power of the coordinates determination to less then 0.01 mm over the whole measurements field (400?400 mm), and to reject the scaling of the input signal. This technical decision has sufficiently simplified the stabilographic investigations while there is no risk of information loss and no necessity of repeated observations.

It should be mentioned that the gauges used in our stabiloplatform completely eliminate the unwanted registration of the lateral force component, and record only the vertical component.

The use of the up-to-date achievements in the integrated circuit engineering allowed us to eliminate the tooling components and to automate the preparation of the stabiloplatform for the work. Such problems as the initial strain compensation, the combining of the PC and coordinate system origin, the registration of the gauges individual indices were solved in automatic way. The option of the strain-gauges, which, in contradistinction to the piezoceramic gauges, allow one to measure the constant component of the support reaction, solved the problem of weight measuring. Although the person's weight changes slowly, the weight measuring, combined with some stabilographic indices, is important for the prognosis of the medical treatment process.

A considerable abundance of the dynamic diapason of the stabiloanalyser КСК-4 allows one to evaluate the dynamics of the examined person's weight with high resolving power (7-9 digits), therefore the stabiloplatform becomes the ballistic gauge. The study of this channel significance is only at its beginning, but we can already say that this channel provides information about heart and breathing mechanics (especially when the examined person sits on the stabiloplatform). The spectra of ballistograms in the diapason up to 0.2 Hz are close to those of stabilograms; this phenomenon requires special study.

In 1993 already we faced the necessity of using the additional channels for synchronous transducing of stabilograms and some other physiological signals. The synchronous record of stabilograms and systoles was developed. Those signals were analysed by means of R.M. Bayevsky intervalocardiography (variational pulsometry) method in order to investigate the vegetative homeostasis of the examined person and to evaluate the «power

cost» of such complex locomotion as vertical posture keeping. The photoplethysmographic finger gauge was used in the first variant of the pulsometer channel. That gauge often missed the systoles, especially when the babies with the finger athetoid hyperkinesia and pathological capillary circulation were examined. At present the electrocardiogram is used for the pulsometry. This way of variational analysis is more correct because the precision of the R-R interval measurement in electrocardiogram is higher than that of the systole interval measurement by means of the analysis of photoplethysmographic wave smoothed peak.

The mathematical analysis of the cardiac rhythm variations as a part of the stabilometric investigations is of interest because the vegetative parameters of the cardiac activity can be compared with the patient's ability for softening the vertical body shaking, which is due to systole. These parameters are investigated in the analysis of the oscillation process spectral power in the systole frequency diapason by means of the Fourier transformation.

The additional channels based on the strain-gauges are embedded into the KCK-4 for transducing the perimetric breathing, hand and stance force signals.

The KCK-4 computer stabiloanalyser channels for transducing the electromyograms envelopes are of interest at present. Four channels usually suffice. Accelerometric channels based on two- and three- coordinates gauges and the goniometer channels are being developed now.

The additional channels for the physiological signals are synchronous with the stabilograms, and these channels include the possibilities of signals viewing, the simple data processing and the exposure of correlations between the different physiological processes. Such approach is realized only at «Rhythm» and «Statokyn». Thus, the computer stabilography can be effectively used in the following fields:

- fundamental investigations in biomechanics and medicine;
- pre-run control of the transport vehicle drivers;
- professional selection and career guidance;
- achievement of high results in sports;
- rehabilitation of the patients' stability disturbances by means of the biological feedback.

The second generation of the KCK computer stabilographs is characterized by the monocoque variant of the stabiloplatform structure. All the electronic groups are placed inside the device frame. We succeeded in eliminating the necessity of six-wire linkage of resistance strain-gauges. It is important for the broadening of the dynamic measurement diapason.

We also succeeded in keeping the masses of the four generations of stabiloplatforms in the limits of 4-8 Kg. Thus the high platforms mobility was provided. Even the auxiliary lower force plate is absent in the fourth generation of stabiloanalysers. Such plate is typical of the most well known devices, their masses being usually in the limits of 15-30 Kg.

Conclusions

After ten years of the computer stabilography development, one can establish that the technical level gap between Russian and foreign firms has been eliminated. Moreover, the Russian firms have left behind the foreign ones in the field of the programs and methods for evaluation of human psychological and physiological condition and pre-run control of the transport vehicle drivers.

The technical basis of the computer stabilography has been constructed. Engineers and scientists should now make every effort at the search of the new methods of data processing. The usual stabilographic indices, which are based on the traditional statistical methods, are not satisfactory. The statistical methods of spectral-correlation analysis and wavelet analysis are having prospects. The approach of Professor V.I. Finayev (Taganrog Radio Engineering

University) is also promising. According to this approach, the concept of «guided random process with the independent increments in three- and two-dimensional space» corresponds as well as possible to the problems of human center of gravity and pressure centre movement approximation.

It is clear today that the stabilograms processing should be based on the new principles and concepts of the modern nonlinear dynamics and synergetics such as chaos, strange attractors, parameters of order, nonlinear oscillations, space dimensions and so on. Learning to handle new methods of data processing brings the computer stabilography to the new level. For example, the analysis of the vectors of PC velocity and acceleration has provided the new method for integral evaluation of human psychological and physiological condition and pre-run control of the transport vehicle drivers. The synergetic approach is developed at the Department of Automatic Control Systems of Taganrog Radio Engineering University by the group of scientists under the leadership of the Head of the Department, Professor A.A. Kolesnikov. This approach is based on the fundamental premise that «biomechanical human movements are high regulated processes, which are possible only as a result of an information interchange between the body parts and the hierarchic levels of biomechanical systems» [3]. In the new synergetic approach the biological phenomena (including biomechanical movements) are regarded as the different self-organized processes. According to A.A. Kolesnikov, «Namely the self-organizing plays the principal role in the biosystems information treatment processes». The new type of information arises, which is connected with the collective variables – the parameters of biosystems order. The application of these parameters provides the sufficient information compression, because not the individual micro-movements but the global properties of the biomechanical system are considered as the system of connected attractors.

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КОНЦЕПЦИЯ РАЗРАБОТКИ КОМПЬЮТЕРНЫХ СТАБИЛОАНАЛИЗАТОРОВ ТИПА КСК–4 «СТАТОКИНЕЗИМЕТР–СТАБИЛАН» И ИХ ИСПОЛЬЗОВАНИЯ В МЕДИЦИНЕ И СПОРТЕ

С.С. Слива, И.В. Кондратьев, Д.В. Кривец, В.И. Доценко, Н.А. Коротаев
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Рассмотрены основные характеристики стабилоанализаторов (приборов, измеряющих параметры процесса удержания человеком вертикальной позы), выпускаемых различными предприятиями России. Обсуждается проблема выбора тензодатчиков. Исследуется возможность объединения стабилоанализаторов с приборами, измеряющими другие физиологические параметры. Приведены примеры

практического использования стабилоанализаторов. Обсуждаются новые математические методы обработки стабилограмм. Библ. 2.