System for Biomechanical Study and Simultaneous Improving of the Rowing Cycle

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INTRODUCTION

Studies of the biomechanical characteristics of the rowing cycle began at the end of the past and the beginning of the present century: I. Stock, 1860, W. Gud, 1889, C. Atkinson, 1896, Lefevre / Pailliote, 1904, Alexander, 1927. In more recent time, the biomechanical characteristics, the factors constituting the technical skill of the oarsman and their relation to the physical and the psychological conditioning of the competitor were examined by A. Tsvetkov, K. Boichev, T. Tonev, 1976, T. Ischico, 1976, E. Schneider, 1977, 1979, T. Asami, 1977, 1981, A. Dalmonte, 1979, V. Zatsiorski, N. Jakunin, 1980, F. Angst, 1982, E. Bachert, 1982, V. Mihailov, 1984, F. Nolte, 1985, A. Tsvetkov, V. Bachev, 1986, 1987.

The studies and the applied experience accumulated, allow to formulate an algorithm for carrying out complex up to date investigations and to utilize the results obtained.

PURPOSE AND METHODS

The purpose of the investigation was to draw up the structure of the biomechanical experiment for studying of the rowing cycle, on the basis of the systematized research experience, and to carry it out with a view to elaborate a system for biomechanical study and improvement of the rowing cycle.

The methods applied included study of the literature, designing of an apparatus equipment, tensometric registration of the rowing cycle in real conditions and mathematical treatment of data.

At a competition rowing over a distance of 2000 m with single boats were recorded about 10 000 cycles of 22 scullers. The apparatus equipment we used is shown on fig. 1, and the obtained analogue records can be seen on fig. 2. Each rowing cycle, recorded in analogue mode, was discretized in 45 biomechanical indices. In this way it was possible to analyze thoroughly the structure of the basic unit in rowing.

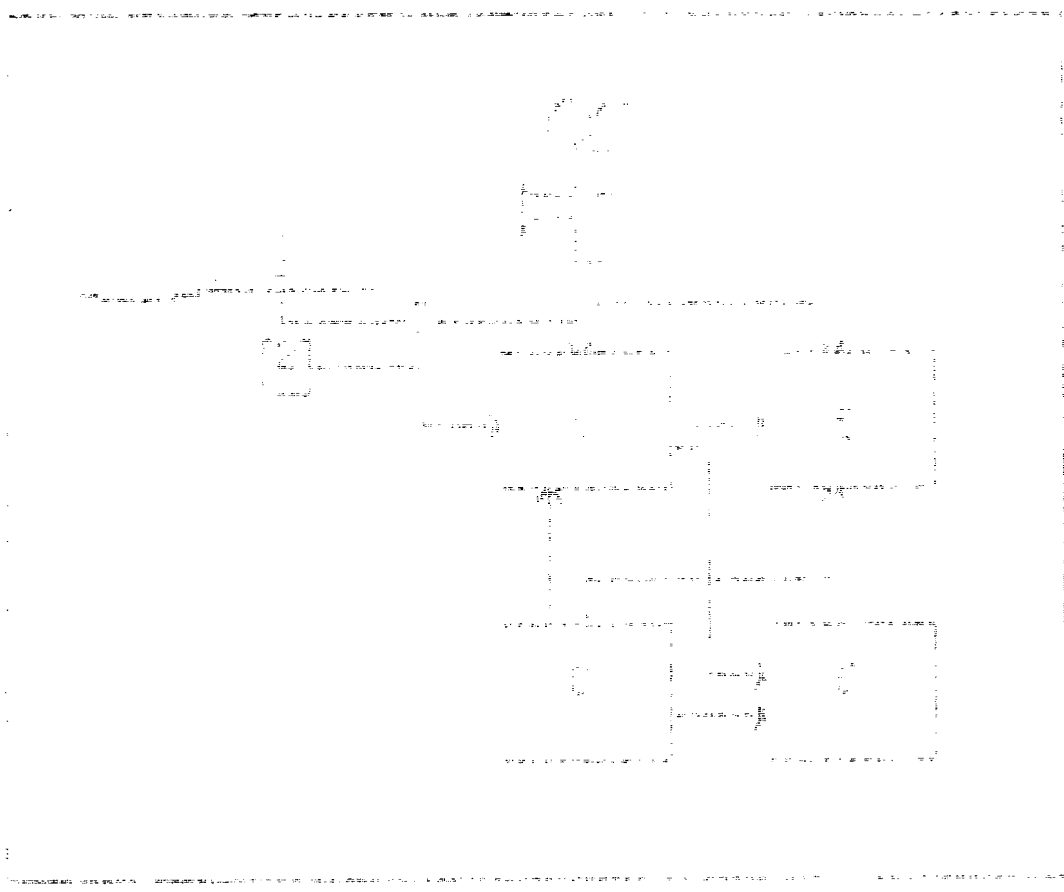

Fig. 1 Apparatus equipment for obtaining an analogue record in a rowing boat: 1. tensometric oar; 2. accelerometer; 3. tensometric leads; 4. amplifier; 5. recording device; 6. magnetograph; 7. synchronous camera; 8. current generator.

By means of the correlation and the factor analysis, the most important indices and factors of the sports performance were mathematically evaluated.

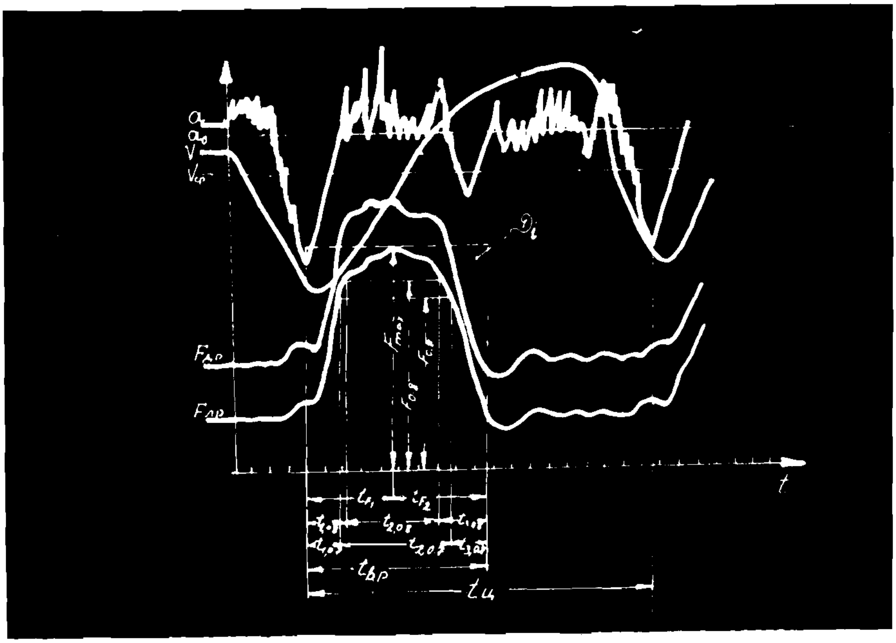

Fig. 2 Analogue record of a rowing cycle on scull. F – applied force; t – time; V – velocity; a – acceleration.

RESULTS AND ANALYSIS

The examination of the investigations on the biomechanics of the rowing cycle showed that the algorithm of a research consisted of:
- designing of methods and apparatus for measuring, collection and storage of the biomechanical information;
- mathematical selection of the most important indices determining the sports performance;
- creating of real possibilities for improvement of these indices in the training process;

When all these complex requirements are satisfied, then a system for biomechanical research and improvement of the rowing cycle is set up.

The system for biomechanical research we designed was based on the data from the mathematical analysis of the rowing cycle for extracting the most important indices and factors of the sports performance (tabl. 1).

TABLE 1

MAIN FACTORS LIMITING THE SPORTS PERFORMANCE IN SCULLERS

No of the indices	Biomechanical indices	Factors 1	2	3	4	5	H^2
5.	Average force of the right hand	914	−68	−125	−189	−122	907
9.	Time of maintenance of the force at 80% r.h.	−55	−522	462	−270	505	818
14.	Time of decreasing of the force below 70% r.h.	−204	61	−891	−93	−171	878
20.	Average force of the left hand	618	198	281	191	533	822
23.	Time of raising of the force up to 80% l.h.	−325	145	335	208	−758	858
25.	Time of decreasing of the force below 80% l.h.	−378	527	−16	618	106	816
32.	Average velocity of the cycle	511	−814	143	−138	−147	986
33.	Difference in the innercycle velocity	368	−814	−43	−13	365	934
38.	Minimum acceleration	−23	−367	−166	−31	−658	597
40.	Coefficient $\frac{a\ min \div a\ max}{V\ av}$	−273	77	−768	−181	140	724
42.	Sum of the average force of the left and the right hand	976	50	48	−42	175	991
43.	Coefficient $C = \frac{F\ av}{V}$	325	931	−18	30	−98	984
44.	Power output of the test	885	−374	115	−101	215	994
45.	Impulses/s during the whole test	499	−377	557	−343	204	860

The first factor was defined as «force factor». It represents the sum of the mean efforts applied by the left and the right hands and it explains 38.9% of the dispersion.

The second factor indicates the proportion between the mean and the inner-cycle velocity of the boat and was defined as «velocity factor». It explains 17.5% of the dispersion. The third factor relates to the time of the force action during the water phase of the cycle, and it was defined as «time-force factor». It explains 14.7% of the dispersion.

The forth factor is related to the decreasing of the applied force below the level of 0.8 of the maximum up to the pull out of the oar, and it explains 8.9% of the dispersion. It was defined as «efficiency of the pull out of the oar». The fifth factor, related to the efficiency of the stroke of the oar, explains 7.3% of the dispersion. It is limited by the negative acceleration of the boat and it was defined as «efficiency of the stroke».

This factor structure is subject to development, because with the improvement of the sports-technical skills of the competitors, a qualitatively new level of individual biomechanical efficiency is achieved, which determines a new priority of the different factors. Therefore, it is necessary to investigate and to analyse periodically the biomechanical characteristics of the rowing cycle.

The achievements of the technical progress allowed the utilization of apparatus equipment based on computer technique. We developed two apparatus equipments for immediate measuring, evaluation and feed back in rowing in real conditions. The scheme of functioning of the first equipment is shown on fig. 3. It consists of a tensometric measuring system (TMS), a system for data collection (SDC), a microcomputer (MC), a supplying device (SD) and a memory (M). The microcomputer commands on the line «direction» the treatment of data through the SDC, and on the line «memory» the storage of data by M, which can record an information up to 640 kilobits.

The hardware of the computer system weights 2 kg and the consumed power is 10 watts.

The SDC is of 12 bits and the speed of functioning is 100 000 transformations/s in a channel, at a precision of the transformation of 0.025%. The information stored on the disk is treated by means of a personal computer «Pravetz» 16 or IBM PC.

Results from the investigation of a sculler by means of the system are presented on tabl. 2 and fig. 4, and in the concrete example for each rowing cycle four indices are differentiated: maximal force applied on the handle of the oar (F max), average force (F av), the force at 0.8 of the

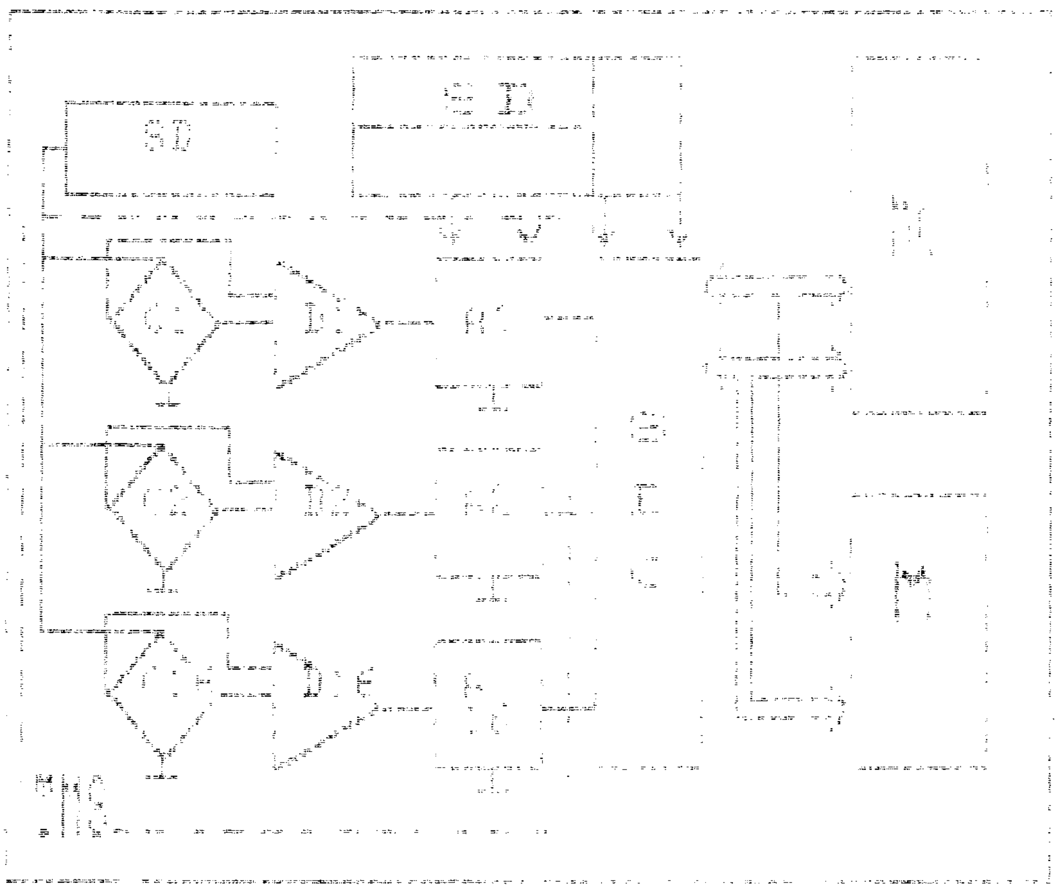

Fig. 3 Functioning block-scheme of a computer system for investigations in a rowing boat; tensometric measuring system (TMS); C_1, C_2, C_{16} – initial tensometric converters; DA_1, DA_2, DA_{16} – differential amplifiers; A_1, A_2, A_{16} – voltage amplifier; MC – microcomputer;

TABLE 2

DATA RECORDS FROM THE ROWING BOAT COMPUTER SYSTEM

N	Fmax	Fcp	Fopt	Topt
	[kg]	[kg]	[kg]	[ms]
1	30.58	19.96	24.46	500
2	27.19	17.11	21.75	450
3	30.76	19.29	24.61	450
4	29.50	19.90	23.60	500
5	29.19	19.91	23.35	500
6	31.66	20.50	25.33	450
7	28.91	18.22	23.13	450
8	30.33	18.15	24.27	400
9	28.61	18.71	22.88	450
10	30.55	20.33	24.44	500

	MAXIMUM	- HOMEP	MINIMUM	- HOMEP	AVERAGE
Fmax	31.66	6	27.19	2	29.73
Fcp	20.50	6	17.11	2	19.21
Topt	500.00	1	400.00	8	465.00

maximum (F opt) and time of its maintenance (T opt). Below the table are given the calculated maximum, minimum and average values of the incices. The number of the respective rowing cycle when they were measured is indicated too.

The computer system and the program allow a considerable extension of the number of indices in a range of 1 to 200 rowing cycles of 8 oarsmen.

On a colour display it is possible to follow up the integrated data graphs (fig. 4).

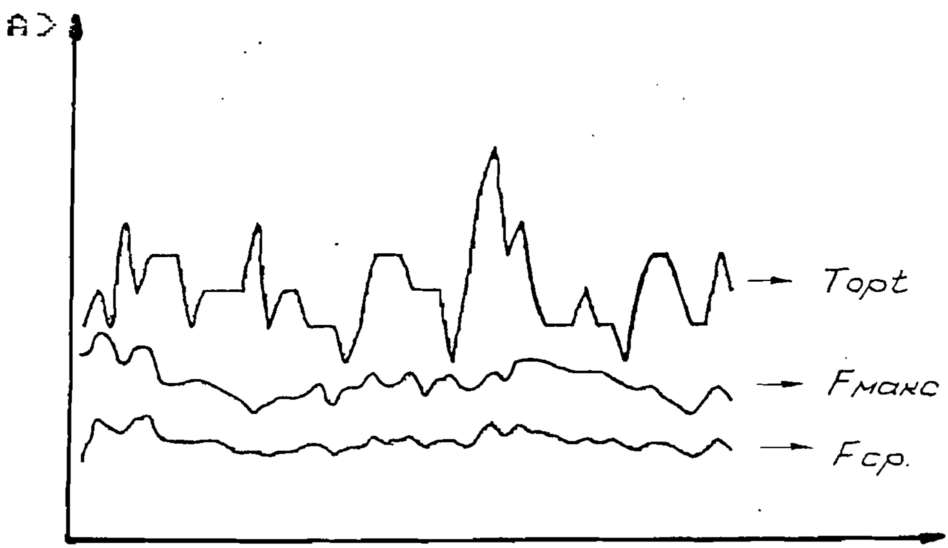

Fig. 4 Graphic computer record of the changes in the studied indices: time of maintenance of the force at a level of 0.8 of the maximal force – topt; maximal force applied on the handle of the oar – F max; average force applied on the handle of the oar – F av.

This kind of objective feed back is of great help for the coach, and it offers precise measures, evaluation and analysis of the level of the followed up biomechanical indices and technical skills of the oarsman. It is also a very efficient instrument for research and training control. The competitor however can make use of the information for corrections only in the next training session, and not immediately.

In order to overcome this disadvantage, a second apparatus equipment was designed. The block-scheme of it is given on fig. 5.

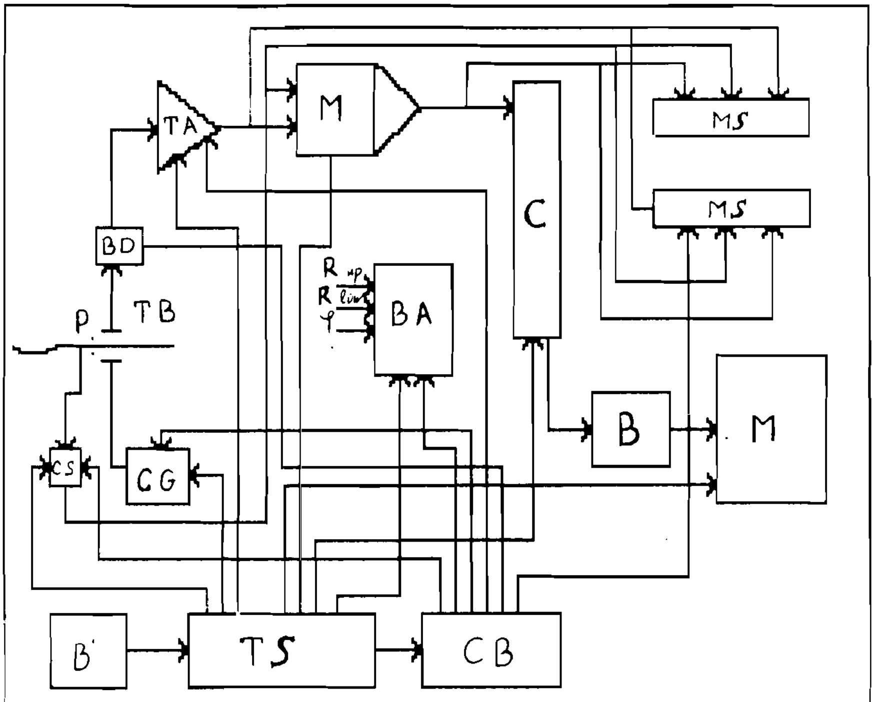

Fig. 5 Block-scheme of the tensoleading system for a rowing boat: pivot for the oar – P; tensometric measuring bridge – TB; current generator – OG; balance device – BD; tensometric amplifier – TA; multiplier – M; comparator – C; buffer – B; monitor – M; upper range of the effort – R up; lower range of the effort – R low; range of the angle –   ; measuring system – MS; batteries – B; tension stabilizer – TS; command block – CB; cosine sensor – CS.

It consists of a measuring block-scheme, a light or sound indicator, a cosine sensor, and a tensometric oar. The weight of the hardware equipment is 1.8 kg, so that it can be placed in every boat. It enables the coach and the competitor to measure and control immediately the force applied on the handle of the oar in a range of 100 to 1000 newtons. For obtaining a feed back in the process of the simultaneous improvement of the rowing cycle, an effort in the range of 30 or 60 newtons, a rotation angle of 40° or the product of its cosine and the force applied are put in the indicator.

Outputs for recording of each of the measured parameters on a high capacity recorder are provided.

The accuracy of the treatment by the indicator is ± 3 N, and the shifting for an hour is smaller than 5 N.

CONCLUSIONS

1. The system for biomechanical investigation of the rowing cycle is based on an algorithm including designing of methods and apparatus equipment for studying, mathematical selection of the most important indices and factors, and creating of objective possibilities for their improvement.
2. The most informative biomechanical factors of the rowing cycle can be mentioned as follows: the force factor, the velocity factor, the time-force factor, the efficiency of pull out of the oar and the efficiency of the stroke of the oar, which explain 87.3% of the total dispersion.
3. Two computer systems for evaluating and improvement of these factors were designed and applied with success.
4. The complex methodical approach allows an optimization of the guidance of the rowing cycle in the dynamics of the training process.

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