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RELIABILITY AND INFORMATION CONTENT OF TESTS WITH
CARDIOLEADER IN CYCLIC TYPES OF SPORTS

by

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The nontraditional pedagogical approaches are beneficial not only in training athletes [7], but also in controlling their condition. In particular, to test athletes one can use a portable electronic trainer-cardioleader that makes it possible to maintain the frequency of cardiac contractions on the assigned level. /10**

Until now the cardioleader has been used only for regulating training loads [3,4,5,6,12]. However, at least three arguments speak in favor of tests with the cardioleader:

- 1) stabilization of the frequency of cardiac contractions in the tested athlete is equivalent to standardization of the testing conditions and increases the reliability of the test;
- 2) tests with the cardioleader are more informative since they are made under natural conditions of training (on a running track, ski slope, etc.) and with energy patterns close to the competitive;
- 3) tests with the cardioleader make it possible to evaluate not only the physical, but also the technical-tactical preparedness of the athlete; in particular, they are suitable for searching for the optimal patterns of cyclic movements in an energy relationship.

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** Numbers in margin indicate pagination in original foreign text.

Table 1. Possible Variants of Tests with Cardiolader in Cyclic Types of Sports

No. in order	What is programmed	What is measured	What is computed	What is evaluated
1	Frequency of cardiac contractions and length of distance	Time spent for passage of distance	1. Average rate of advance 2. Pulse cost of meter of path	1. Special endurance 2. Effectiveness of movements
2	Frequency of cardiac contractions during fulfillment of exercises	Distance covered	1. Average rate of advance 2. Pulse cost of meter of path	1. Special endurance 2. Effectiveness of movements
3	Frequency of cardiac contractions	Limit time of fulfillment of exercises with assigned cardiac contraction rate	-	Special endurance
4	Series of values of cardiac contractions and rate of movements; length of distance (two-contour test)	Time spent for passage of distance	1. Average rate of advance 2. Length of step and pulse cost of meter of path	1. Special endurance 2. Comparative effectiveness of different variants of technique of advance

The tasks of the study consist of developing reliable and informative tests designed to control the preparedness of the athletes.

In the cyclic types of sports four variants of tests are possible with the cardiolader (table 1), whereupon the first two of them can be considered equivalent [8]. The article presents information about the reliability and information content of the first and fourth variants of the test. /11

Technique

Ten cardioladers of type AKL-75 and 10 pulse summators type SP-75¹ were used. To increase the interference-resistance the instruments were modified design-wise; the electrodes were equipped with recording stickers. Control of the accuracy of maintaining the assigned level of tachycardia was implemented by the pulse summator or by radio. The technique of programming the cardiac contraction rate did not differ further from that previously used [9].

¹Production of VISTI [All-Union Planning-Technological and Experimental-Design Institute of Athletic and Tourist Items], head of development V. M. Perlov.

In the process of testing the athlete with the cardioleader and pulse summator limbered up until his cardiac contraction rate reached the programmed level, after which he overcame the previously marked segment of distance. The time spent was measured by a stopwatch. At the moment of the start the pulse summator was engaged, and when the finish line was passed it was disengaged. The rate of walking and running (test 4) was programmed with the help of a sound or light metronome.

The testing procedure was repeated no less than four times, which made it possible to exclude from the analysis the results of the first attempt and to evaluate the reliability of tests by the dispersion method, according to the amount of intraclass coefficient of correlation [11]. The number of subjects was not predetermined beforehand. In each series the studies lasted until the obtained data became statistically reliable with level of significance $d < 0.05$. On the whole 97 people were studied. The computations were made on a VANG-2200 computer.

The results² and their discussion concern reliability and information content of tests with the cardioleader. Both named qualities depend on the length of the distance segment on which the testing is done, on the number of attempts in the testing procedure, and on the programmed level of tachycardia. A plan of complete factor experiment was used. Runners, cyclists, ski racers, and untrained people were examined under conditions of walking and running with weights.

Cycling

Cyclists of varying qualification (from novice to expert) on a track covered 5 circles of 400 m each with cardiac contraction rate 110, 130, 150, 160 and 170 beat/min. A measurement was made of the time spent, and the average rate of the passage of each circle and the pulse cost per 1 m of path were computed.

The coefficient of reliability of the proposed test with single repetition of the training procedure lies in the limits 0.48-0.77. With an increase in the number of repetitions of the test procedure (which is attained with an

²V. K. Buller, A. I. Golovachev, A. Yu. Gur'yev, V. A. Zankin, V. V. Zaytsev, S. A. Malakhov and V. V. Tikhonov participated in the collection of experimental data.

increase in the number of circles passed by the athlete with the assigned level of tachycardia) the coefficient of reliability of the tests in complete correspondence with theory [10, 15] rises, reaching the amount 0.82-0.95 with five-fold repetition of the test. The tests with cardioleader with cardiac contraction rate= 170 bt/min possesses the greatest reliability.

The information content of the tests with cardioleader in cycling (as in other cyclic locomotions) is provided by the fact that the power developed by the athlete with the assigned level of tachycardia rises with an increase in his degree of training [2]. This fact is based on the economy of functional shifts in response to the dosed load, and second, increase in effectiveness of movements in the trained people as compared to the untrained. At the same time for any type of cyclic locomotion there exists a certain optimal velocity at which the greatest efficiency of movements is attained [14, 16]. Tests with cardioleader make it possible to reveal the level of tachycardia corresponding to the optimal velocity. For this it is sufficient to compute the number of cardiac contractions per 1 m of path:

$$PC = \frac{CCR_0 \Delta t}{60 L} = \frac{CRR_0}{60 V},$$

where PC--pulse cost in 1 m of path, 1/m; CRR_0 --programmed pulse rate, bt/min; Δt --time for fulfillment of test assignment, s; L--length of distance on which the testing is done, m; V--average velocity of advance, m/s.

The magnitude of the pulse cost depends on the type of locomotion, level of tachycardia and qualification of the athlete (fig. 1 on third page of cover).

Running and Walking

Testing of 18 runners--from second class to experts--was conducted on segments of length 400 and 800 m with CCR-170 bt/min. The criterion of the information content was the best results at distances 800 and 1500 m shown by the subjects in competitions a month from the day of the last test.

The coefficient of reliability of the test was equal to 0.78 with testing on the 400-meter section and 0.86--with testing on the 800-meter section of distance.

The magnitude of the coefficient of information content depends, first, on the method of processing the results, and second on the selection of the criteria for information content (table 2).

For theoretical considerations [13] we assumed that the reliability of the tests with the cardioleader is increased if during the testing both the level of tachycardia and the rate of movement were stabilized. To verify this hypothesis the runner-stayers were tested under conditions of two-contour regulation of the speed of running. At the 400-meter distance the following were programmed: CCR-170 bt/min and rate of running 90 cycles per minute. The findings indicate that the transition from the one-contour test with cardioleader to the two-contour does not increase the reliability of the test, but increases its information content ($r_{tk}=0.93$). To verify the information content of the two-contour test the correlation coefficient was computed between the results of the testing and the results of running 5000 m. The two-contour tests, in addition, make it possible to find the individually optimal patterns of movement in an energy relationship [13]. The technique of such a search was worked out in the laboratory study. The cardioleader programmed the level of tachycardia (from 80 to 150 bt/min every 10 bt/min) and a metronome assigned the level of walking (from 20 to 100 cycles per minute with interval of 20 l/min). The rate of advance and the pulse cost of 1 m of path were determined in each of the 40 combinations of pulse rate and rate of walking. On the obtained graphs the zone of the optimum is clearly visible near which the pulse cost of 1 m of path is the minimum (figure 2 on the third page of the cover). In the unfatigued subjects the rate of walking and the length of the pace corresponding to the optimal zone are highly stable and close to those that man arbitrarily selects under conditions of free walking. /12

Ski Races

Study of tests with the cardioleader in ski races occurred in two stages. At the first the time of passage of flat sections of distance 250, 500, 750 and 1000 m long with pulse rate 160, 170 and 180 bt/min were measured. At the second stage the time for passage of 100-meter segments was measured on a plain and on elevations with steepness 4 and 7° with pulse rate 160, 170, 180 and 190 bt/min. In both cases the average respiration rate and the pulse cost of 1 m of path were computed.

The interest in testing skiers on elevations is explained by the fact that elevations comprise up to 45% of the modern ski route. The values of the steepness of the elevation selected 4 and 7° were found as a result of the statistical analysis of the route profiles on which the major international competitions were made in recent years.

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Table 2. Coefficients of Information Content of Tests with Cardioleader in Running Average Distances (with CCR=170 bt/min)

Length of section of distance on which testing was done	Method of processing testing results	Criterion of information content of results of running for:	
		800 m	1500 m
400 m	Mean arithmetical (of three attempts)	0.82	0.72
800 m	Best result	0.85	0.56
	Mean arithmetical (of three attempts)	0.86	0.81
	Best result	0.81	0.83

The coefficient of reliability of simple (consisting of one component) tests designed to control the special physical preparedness of the ski racer, in the majority of cases exceeds 0.95, and in testing on the 100-meter sections equals 0.99.

A peculiarity of the tests with cardioleader in ski races consists of the fact that their reliability does not rise with an increase in the extent of the testing stretch. Moreover, the greatest reliability of the test is reached at the shortest, 100-meter segment, in particular, in testing skiers on elevations. Analogous results were also obtained in controlling the condition of men whose occupational activity is linked to carrying weight. If the threshold pulse rate was programmed and the weight of the load was not great (15 kg), then with an increase in the distance the reliability of the test rose. However, during testing in the MPK zone and during carrying of a heavy load (30 kg) it is more suitable to implement testing on short segments (100-125 m); in this case the reliability of the test with the use of the cardioleader is the highest.

The information content of the proposed tests was evaluated according to the magnitude of the correlation coefficient between the results of testing and the best result of a skier in a season for the 15-km race. Data were analyzed that were obtained at a distance of 100 m. From figure 3 (see third page of cover) it is apparent how the information content of the tests with cardioleader rises with an increase in the programmed pulse rate and steepness of the elevation. This fact agrees with the published reports [1] on the high information content of the critical (corresponding to the MPK) speed of the ski racer. According to our data, the greatest information content ($r_{tk}=0.81$) is found in the skier on the 100-meter elevation with steepness 7° with CCR=190 bt/min. Such information content is evaluated as good, but can be insufficient for individual

prediction of the result.

In order to increase the information content it is necessary to unite into a unified evaluation the results of simple tests with the cardioleader. In the simplest case the result of the composite test is formed as a linear function of the type:

$$\Phi(q) = \sum_{i=1}^m c_i q_i.$$

where m --number of simple tests united into a composite; q_i --results of simple tests; c_i --weighted coefficients.

In order for the thus-formed composite test to possess the maximum possible information content it is necessary to select the weighted coefficients c_i such that the difference between the results of testing the group made of n athletes and the results of measuring the selected criterion of information content in the same athletes is minimized. For example, one can strive to reduce to the limit the sum of squares of the individual deviations in the testing results Φ_j from the criterion of information content Q_j :

$$\sum_{j=1}^n |Q_j - \Phi_j|^2 \rightarrow \min$$

As a result one can solve the long-standing problem of sports of the synthesis of highly-informative tests made of low-informative components.

Of the 11 simple tests with cardioleader (see fig. 3 on the third page of the cover) one can comprise 55 two-component and 165 three-component tests. On the VANG-2200 computer equations were solved of multiple regression; as a result the potential information content was defined of all variants of the composite test. Of the two-component tests only one test reached the level $r_{tk} = 0.95$ during which the travel time of a skier of a 100 m in an elevation with steepness 4° and 100 m with elevation 7° was measured with pulse rate 180 bt/min. The special preparedness of the skier in this test was evaluated by the regression equation¹:

$$-62.5t_{180}^{4,7} + 87.6t_{180}^{7,4} - 1360:0.98:0.91 + .$$

¹The subscript designates the level of tachycardia, the superscript--the steepness of the elevation; for example $t_{180}^{4,7}$ --time shown by the skier on a 100-meter section of elevation with steepness 4° with CCR-180 bt/min; the isolated numbers are equal to the coefficient of information content and the reliability of the composite test.

The equation makes it possible in the limits of the studied contingent of first-class athletes and experts to predict their results in a race of 15 km. But since the absolute time in the ski race depends not only on the preparedness of the athlete, but also on the weather conditions, route peculiarities etc., it is expedient to reflect the weighted coefficients in the results of simple tests in dimensionless units; there the equation will look like:

$$-0.42t_{180}^0 + 0.58t_{180}^7.$$

Forty-two of the three-component tests proved to be highly informative ($r_{tk} > 0.95$). For some of them we will write the dimensionless regression equations from which one should evaluate the special preparedness of the skier:

$$\begin{aligned} 0.35t_{170}^0 - 0.34t_{170}^1 + 0.31t_{170}^7 &: 0.96; 0.92 \\ 0.12t_{180}^0 - 0.37t_{180}^1 + 0.51t_{180}^7 &: 0.97; 0.92 \\ -0.30t_{180}^0 + 0.67t_{180}^1 + 0.02t_{180}^7 &: 0.97; 0.83 \\ -0.38t_{180}^0 + 0.34t_{180}^1 + 0.28t_{180}^7 &: 0.98; 0.90 \end{aligned}$$

As is apparent from the cited data, the reliability of the composite tests is lower than the reliability of the simple.

To restore the reliability one can recommend multiple conducting of the testing procedure. The number of its repetitions in which the reliability of the test reaches the required level is easily determined from the graph given in fig. 4 on the third page of the cover.

Conclusions

1. Testing of athletes under conditions of regulated tachycardia makes it possible to objectively evaluate the special physical preparedness and to determine the most economical patterns of cyclic movements.

2. Special approaches were tested whose use in cyclic types of sports result in an increase in the reliability and information content of the tests with cardio-leader to the limit level, including:

--synthesis of highly informative composite tests (homogeneous and heterogeneous) made of low-informative components;

--testing under complicated conditions--for example, on elevations of varying steepness;

--control of the accuracy of maintaining the programmed level of tachycardia with the help of a pulse summator or radiotelemetric system;

--selection of the optimal length of the testing distance;
--use of two-contour tests (in addition to the GDR any biomechanical index is programmed).

3. Tests with the cardioleader do not interfere with the course of training; their main purpose is to have operational and current control over the athletes.

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