The control system for special preparedness of cyclists

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Abstract

Purpose: to develop a system for monitoring the level of special preparedness of cyclists (specialized in individual race for 4 km) on the basis of the indicators of the cardiorespiratory system.

Material: The study involved bicyclists (n=14, age 18-22 years).

Results: The step-increasing load to the full allows to determine the maximum functional opportunities of the body of cyclists. The coefficient of efficiency of the functioning of the cardiovascular system is equal to the ratio of the average distance value of the pulse to the maximum value of the pulse. Using the linear regression equation, it is possible to predict the magnitude of the pulse at a given speed of movement.

Conclusions: It is possible to find out the individual characteristics of athletes with the help of an indicator of the effectiveness of the functioning of the cardiovascular system. One can compare the activity of the cardiovascular system of athletes of different qualifications, different age groups, gender, level of preparedness. The degree of realization of the functionality of cyclists is calculated by a special formula and serves to monitor the training and competitive process. The results of the studies make it possible to predict the result by evaluating the level of special physical preparation.

Keywords: cycling, pulse, control system, prognosis, success.

Introduction

The problem of testing athletes is one of the most urgent in modern sports and should be solved on the basis of achievements in physiology, biochemistry, biomechanics, pedagogy and other sciences [2, 3, 38, 39]. It is impossible to control the process of training athletes without objective criteria for assessing the level of special preparedness [8, 17, 25, 40]. The authors note the need to take into account the functional capabilities of the cardiovascular and respiratory systems of the body.

One of the most informative indicators of the functional state of the body of athletes (specializing in sports for endurance) is the level of maximum oxygen consumption [16, 36]. In studies of foreign authors found that the most informative indicators in assessing the functional readiness of athletes of high qualification is: the magnitude of the oxygen cost of one meter of the path at a standard speed [11, 37]; oxygen consumption level (Vo_2) at speed of movement 85-90% from the competitive; speed of movement along the threshold level of anaerobic exchange.

Hydren J.R. and Cohen B.S. showed the possibility of achieving maximum effectiveness in endurance exercises in highly qualified athletes [19]. Mueller S.M. et al. found that aerobic intensive interval training improves cardiovascular ability, but it can reduce the endurance of cycling [26]. Nakahara H. et al. examined the effects of intensive interval training at a frequency of once a week on cardio-respiratory function at rest and during exercise [27]. The authors found that intensive interval training markedly improves cardiorespiratory function and causes morphological adaptations of the heart.

In cycling the methods of modeling are used in various studies. Caddy O. et al. used computerized planimetry and compiled a reverse integration model to

simulate a 4-kilometer distance [12]. The authors showed the possibility of a small and significant increase in productivity at a distance of 4 km. Childers W.L. et al. compiled a race model for 4 km using the Monte Carlo method [13]. The authors established a relationship between power losses and aerodynamic coefficients. Luth M.T. et al. used modeling techniques to study the relationship between passion, normative orientation and the satisfaction of qualified cyclists [24]. These data show that not all forms of passion are useful for classes. Data helps explain the relationship between passion and satisfaction.

Improving the performance of athletes requires: individual approaches to training [15], proper pedagogical control [14], selection of adequate tests [29], optimization of physical activities [28, 32], observance of rest and training regimes [31], accounting of the body's functional reserves [33], predicting the success of athletes [20, 30], the use of rehabilitation means and readaptation to work [34, 35].

Some researchers [22, 36] notice that during examining a homogeneous group of athletes using standard tests, the maximum oxygen consumption value has a low correlation with the athletic result. In their opinion, testing should be carried out in conditions that are as close as possible to those that are competitive in terms of the structure of the movement and the duration of the task. Under such conditions the factors that limit the availability of work will manifest.

The purpose of the study is to develop a system for monitoring the level of special preparedness of cyclists (specializing in individual race for 4 km) on the basis of indicators of the cardiorespiratory system.

Materials and methods

Participants. The study involved bicyclists (n=14, age 18-22 years). Athletes had sports qualification as

a candidate for master of sports and master of sports. Athletes specialize in individual race at 4 km.

Organization of the study.

To determine the maximum functional opportunities of the cardiorespiratory system of the body of cyclists was used step-increasing load to the full. The cyclists performed work with a pedaling frequency of 90 revolutions per minute using the veloergometer "Monark". The load increased by 2,70 kGm / min. every 2 minutes [21-23]. At the same time an analysis of exhaled air was carried out on the automatic gas analyzer of the company "Beckman". The pulse rate was determined by the electrocardiographic method (electrocardiograph "Salut"). Prior to work and on the 3rd minute of recovery, was dipped blood sampling to determine the acid-base balance (pH).

To determine the level of cardiovascular system functioning, bicyclists participated in competition, where the pulse was recorded throughout the race using the Puls-6 radiotelemetric system.

To determine the dependence of the pedaling speed from the intensity of the functioning of the cardiovascular system, cyclists performed a special test program on the track in 5 pulse regimes (130, 150, 160, 170, 180 bpm, 4 km distance). The work with the constant value of the functioning of the cardiovascular system was simulated. The time of passage of each half of the circle (166,7 m) and the average speed over the entire distance were measured.

To maintain a certain heart rate in studies was used autocarillary ACL-75, which provided standard testing conditions for all athletes.

Statistical analysis. Average values of indicators and their errors (X±m), degree of difference of means and reliability of differences (t, p) were determined. The amount of dispersion was set – a variant around the mean (σ, CV). The degree of interrelation between the studied indicators (r) was determined.

In carrying out complex pedagogical, biomechanical and biological surveys with the participation of athletes adhered to the legislation of Ukraine on health protection, the Helsinki Declaration of 2000, directive No. 86/609 of the European Society on the participation of people in biomedical researches.

Results

At the carrying out step-increasing load to full, a bicycle ergometer obtained the data (Table 1). The data allow to judge individual characteristics of the activity of the cardiorespiratory system of the cyclists' body.

The values of the obtained indices testify to the maximum stress of the functioning of the examined systems of athletes' organism. The correlation relationship of studied parameters with the results in the individual race at 4 km is unreliable (with the exception of the pulse rate). Therefore, it is impossible to use these data to predict the sports result (Table 2).

Step-increasing load to full allows to determine the maximum functionality of the cyclists' body. The maximum value of the pulse in the test has a negative value of the correlation coefficient and the sports result (r_{tk}=–0,578, p<0.1). This indicates an inverse relationship between the studied indicators. Excessive increase in the pulse when performing work on a veloergometer indicates an ineffective activity of the cardiovascular system. To determine the level of functioning of the cardiovascular

Table 1. The indices of the maximum functional capabilities of the cardiorespiratory system of the organism of cyclists in step-increasing load to full

| Parameters | Indices physiological | | | | biochemical | |
	MMV (l)	Vo_2 max (l)	Vo_2 (ml/кg)	f_h (bpm)	pH before the load	pH after the load
X	151,811	4,441	63,112	198,611	7,381	7,216
б	31,242	0,539	6,941	2,760	0,012	0,076
m	11,811	0,204	2,620	1,040	0,005	0,029

Notes: MMV – maximum pulmonary ventilation (l); Vo2 max – maximum consumption of oxygen (l); Vo2 – oxygen consumption (ml/kg); fh – pulse (bpm)

Table 2. Coefficients of correlation between the investigated parameters of the cardiorespiratory system of the body of athletes and the result in the race for 4 km

Investigated parameters	Vo_2 max, (l/min)	Vo_2 (ml/кg/min)	$f_{h'}$ (bpm)	pH
Speed in race, (m/s)	0,320 unreliable	0,390 unreliable	- 0,578 p<0,1	0,442 unreliable

Notes: Vo2 max – maximum oxygen consumption (l / min); Vo2 – oxygen consumption (ml / kg / min); fh – pulse (bpm); р – level of significance of the correlation coefficient

PEDAGOGICS medical-biological
PSYCHOLOGY problems of physical
training and sports

system of cyclists in conditions of competitive activity, the pulse rate was used during the individual pursuit race at 4 km (Table 3).

Three indicators are calculated that characterize the intensity of the functioning of the cardiovascular system.

1. The average distance of the pulse is 184,9 beats per minute: characterizes the level of functioning of the cardiovascular system of cyclists in the race for 4 km. This value has a negative relationship with the result in the race. The correlation coefficient is equal to $r_{tk} = -0,440$.

2. The value of the pulse at the 1st minute of the work reflects the speed of the cardiovascular system and the entire organism as a whole. It is to the 40-60th second of the work that anaerobic and aerobic energy supply mechanisms are fully activated. In our study, the pulse at the 1st minute of work was 172.1 ± 8.7 bpm.

3. The maximum pulse value reflects the maximum level of functioning of the cardiovascular system. The maximum pulse value is 192 ± 5.29 bpm: correlates ($r_{tk} = 0.78$, p <0.1) with the maximum pulse value that was obtained in the bicycle ergometer test in the laboratory. The maximum pulse value has a negative correlation coefficient with the result in the race ($r_{tk} = -0.515$; p <0.1).

The coefficient of efficiency of the functioning of the cardiovascular system (CE_p) is equal to the ratio of the average distance value of the pulse ($f_{h\Delta}$) to the maximum value of the pulse ($f_{h\,max}$):

$$CE_p = (f_{h\Delta}/f_{h\,max}) \text{ x } 100\%,$$

$$CE_p = (184,9/192,0) \text{ x } 100\% = 96,3\%.$$

The lower the value of the efficiency factor, the more effectively the cardiovascular system of athletes works. This indicator (CE_p) will be more informative if it is calculated taking into account the average speed. Using the indicator CE_p, it is possible to compare the activity of the cardiovascular system of athletes of different qualifications, different age groups, gender, and level of preparedness. This allows to find out the individual characteristics of athletes.

The level of functioning of the cardiovascular system of cyclists in the race (according to the pulse rate for the 1st minute and the maximum pulse) is close to the limiting level (as in the laboratory). After the period of operation (60-90 s), the pulse curve is practically maintained at the same level – 182,34-189,4 bpm. In this case, there is an insignificant increase in the pulse at the finish: 192,0±5,3 bpm. The dynamics of the speed of movement is more variable. After the initial acceleration on the 30th s the speed reaches 13,47 m/s. Then the speed gradually decreases to 12 m/s and again increases at the end of the 5th minute (11,95 m/s).

The high informativeness and reliability of the pulse rate in the race was used as a basis for the methodology for assessing the level of special functional readiness of cyclists. The obtained data (Table 4) made it possible to determine the dependence of the speed of movement on the intensity of the cardiovascular system during the passage of a distance of 4 km.

The curved line of change in the speed of movement of cyclists, depending on the level of the pulse, can be described by the equation of linear regression of the type $y=a+bX$. For our study, the equation looks like this:

$$V = 0,0536X + 2,354, \tag{I}$$

where V – the speed of movement (m/s)
X – the value of the programmable pulse in bpm.
The coefficients **a** and **b** in the equation are 2,.354 and 0,0536.

Equation (I) allows analytically determine the speed of movement, depending on the selected heart rate. The linear regression equation looks like this:

$$f_h = 17,883X - 35,480, \tag{II}$$

Table 3. Change in the value of the pulse (fh) of cyclists during an individual pursuit race at 4 km

Parameters	Time of race, (s)							
	15	30	60	90	120	180	240	300
X	134,5	159,2	172,1	182,3	184,0	187,1	189,4	192,0
б	12,7	9,8	8,8	7,4	6,8	6,2	5,5	5,3
m	4,9	3,7	3,3	2,8	2,6	2,3	2,1	2,0

Table 4. Change in the speed of the distance 4 km, depending on the pulse

Indices	Parameters	Pulse regimes of work (bpm)				
		130	150	160	170	180
An average	X	9,136	10,497	11,177	11,550	11,733
speed in the	б	0,281	0,162	0,163	0,096	0,104
test, (m/s)	m	0,106	0,061	0,062	0,036	0,039
PS, (bpm)	–	0,237	0,238	0,239	0,245	0,253

Note: f_h – pulse (bpm)

where X – the specified speed of movement (m/s).

The coefficients *a* and *b* in the equation are 35,480 and 17,883.

Using the linear regression equation, it is possible to predict the magnitude of the pulse at a given speed of movement. The disadvantage of this method is to maintain one of the selected parameters (pulse or speed) at a constant level.

In this study, we determined the relationship between the speed of movement at different heart rates (tests V_{130}, V_{150}, V_{160}, V_{170} и V_{180}) and the results that were shown by cyclists in the individual pursuit race at 4 km. In the tests modes of load on the pulse were in the range of various power supply mechanisms.

The speed of cycling in the tests V_{130}, V_{150} and V_{160} is not reliably linked to the results that were shown in the pursuit race at 4 km (Table 5). In these tests, the body of athletes operates in a moderate and high-power zone (approaching the threshold of anaerobic exchange). The result in the race depends not only on aerobic performance. The result in the race is determined by anaerobic performance. This is taken into account by the work itself in the tests V_{170} and V_{180}. Tests have a high reliable relationship (r_{tk}=0,670; $p<0,1$ and r_{tk}=747; $p<0,1$). This allows them to be used in assessing the level of special preparedness of cyclists.

The obtained data (the correlation between the speed in the race and the speed in the tests V_{170} and V_{180}) can be described by the linear regression equation:

$$V_{170}=766X+3,616, \qquad (III)$$

$$V_{180}= 1,471X − 4,796, \qquad (IV)$$

where V – the predicted speed in the race (m/s),

A – the speed of movement in the tests V_{170} and V_{180} (m/s).

The coefficients *a* and *b* in the equation are as follow 4,796 and 1,471.

Equations III and IV allow to predict the result in the race and perform an analysis of the degree of realization of the functional capabilities of the organism, depending on the shown result. The degree of implementation of the functionality is understood as the ratio of the displayed speed in the race (V_t) to the predicted speed for the selected test V_{170} and V_{180}.

Lets consider this on the following example: rider A (P-us) in the test V_{180} developed a speed of 11,645 m/s. On the basis of equation III, the speed in the race must be 12,33 m/s (V_d=1,471x11,645−4,796). In reality, athlete *A* showed in the race speed of 12,49 m/s. Hence the degree of implementation of the functionality is:

$$SR = (V_t / V_d) \text{ x } 100\%,$$

where V_t – the real speed in the race (m/s),

V_d – predicted speed in the race (m/s).

For the rider A (P-us), the degree of realization of the functional capabilities (SR=12,49:12,33)x100%=101,3. This figure is higher than the average for the group. For the rider *B* (Sh-ko): in the test V_{180}, the speed of movement is 11,634 m/s; the speed in the race according to equation IV must be 12,32 m/s. Really, the athlete showed 12,16 m/s. Consequently, the degree of realization of its functional capabilities (SR=12,16:12,32)x100% is 98,7%. Athlete B (Sh-ko) has not realized its potential functionality.

Discussion

The data obtained by us coordinate with the results of studies of the cardiorespiratory system of cyclists by other investigators [4, 25, 37]. In the experiments [11, 17], the obtained data indicated a low efficiency of the cardiovascular system. This is due to the increase in the pulse when doing work on a veloergometer. It is known that the magnitude of the pulse reflects not only the adaptation of the human body to the load [6, 7]. Pulse is an important indicator of the cardiovascular system. The pulse affects the amount of minute blood volume. According to the data of [7], the magnitude of the minute volume of blood is mainly increased due to the increase in the pulse rate.

Beattie K. et. al. investigated the effect of a 20-week maximum and explosion-force training effect on explosive force, VO (2) max, body composition of cyclists [9]. The study demonstrates that 20 weeks of such training can significantly improve the maximum strength, the specific explosive force of a bicycle and the maximum oxygen consumption of cyclists. Borges N.R. et. al. studied autonomic cardiovascular modulation in well-trained masters and young cyclists after a high-intensity interval training [10]. The authors found that the physical training of qualified athletes has a significant effect on the autonomous function. These data are confirmed by our research.

The data obtained by us are confirmed in the works of other researchers, who also simulated various versions of the distribution of the athletes' efforts in an individual

Table 5. Correlation of the speed of movement of cyclists in the tests and results in the individual pursuit race at 4 km

| Indices | The speed of movement in the test (m/s) | | | | |
	130	150	160	170	180
The size of correlation coefficient (r_{tk})	0,390 unreliable	0,420 unreliable	0,510 unreliable	0,670 p<0,1	0,747 p<0,1

Note: *p* – level of significance

pursuit race at 4 km [1]. A similar character of the dynamics of the pulse and the power of pedaling was obtained earlier [2]. The authors modeled the speed for individual pursuit at 4 km on a bicycle ergometer for cyclists of different age groups. Hittinger E.A. et. al. determined the effect of the MOC (maximum oxygen consumption) on peak loads, submaximal and peak cardiovascular hemodynamics, and the saturation of peripheral capillary oxygen under simulated conditions in experienced cyclists [18]. The authors found that ischemic pre-conditioning can improve blood flow and oxygen delivery to tissues (including skeletal muscles) and has the potential to improve intense aerobic exercise.

However, the predicted result in the race according to equation (IV) based on the test V_{180} reflects only the contribution of the functional readiness of cyclists. This result does not take into account the influence:

- moral-strong-willed qualities and mental properties of personality [5];
- the level of tactical preparedness [2].

Conclusions

1. Using the indicator CE_p, it is possible to compare the activity of the cardiovascular system of athletes of different qualifications, different age groups, gender, and level of preparedness. This allows to find out the individual characteristics of athletes.

2. The degree of realization of the functionality of cyclists is calculated by a special formula. The formula serves to control the training and competitive process.

3. The results of the research allow to predict the result by evaluating the level of special physical training.

Conflict of interest
The authors state that there is no conflict of interest.

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