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**Original Article**

# Management of the technical training process of athletes in cycling sports

POLIANYCHKO, O.M.[1], HOLOVACHI, I.[2], YERETYK, A.A.[3], SPESYVYKHO, O.[4]
[1,2,3,4] Borys Grinchenko Kyiv University, Kyiv, UKRAINE

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**Abstract:**
In cyclic sports, the main indicator that characterizes adversarial activity is the average speed of passing distances. The presence of functional dependencies of speed factors on various indicators of sports activity can determine its dynamics. It allows to simulate the process of competitive activity, and according to the dynamics of speed, to determine the nature of a particular indicator. Cyclists and swimmers defined law of motion, the dependence of the athlete's instantaneous speed and its acceleration ontime, applied forces, resistance forces and forces of inertia, as well as on specific physical and morphological data. The presence of a mathematical model allows us to create an adaptive system for controlling the technical preparedness of athletes in cyclic sports.
**Key words**: mathematical modeling, cyclists, fins, technical training.

## Introduction

One of the important conditions to use effectively the reserve capabilities of athletes in cycling sports (which ensure the maximum realization of the athletes' motor potential in the course of the competition) is the development of methodical bases for technical training management. Modern methods are based on model characteristics, which were obtained as a result of statistical data processing of a specific contingent of athletes. Model characteristics do not take into account the individual characteristics of athletes(Kostiukievich, 2016, Platonov, 2015).

The irrational distribution of accents in the cycle of movements, uneven fluctuations in the internal cycle velocity, disturbances in the spatial and rhythmic structure of movements lead to unproductive energy consumption. In the process of competitive activity, the athlete often can not fully realize the available motor potential. This determines the need to develop a more sophisticated system for managing the process of technical training of athletes. It involves the use of mathematical modeling techniques. These methods allow you to search for optimal variants of the structure of movements of specific athletes, taking into account the variables. Factors should reflect individual peculiarities of special readiness, the specifics of the structure of the training process, the peculiarities of the external environment, the possibilities of using pedagogical means and methods of correction of technology.

The study of objective relationships between sporting results and indicators that characterize the physical and technical fitness of an athlete has particular relevance(Khudolii at al., 2015, Lopatiev at al., 2009, Yang at al., 2015). This is done in order to develop the best options for the structure of competitive activities. This determines the necessity of not only mathematical description of such connections, but also the development of a mathematical model of processes of athletes' competitive activity. It should take into account the influence of all these indicators in the conditions of the action of the shrinking factors of the environment.

A large number of models may fit the same sportsman depending on the purpose of the simulation. These models reflect the different sides of the athlete. A mathematical model of an object or process involves a mathematical description of the relationships between the indicators and the constraints imposed on these changes, provided that the purpose of the functioning of the simulated system or process is known(Shestakov & Averkin, 2003).

The ultimate modeling task is to develop a management algorithm(Kacenelinbojgen, 1970). Management provides a more effective achievement of the goal. In this case, an athlete in a competitive environment is a complex biosystem that interacts with the environment, sports equipment and a number of other mitigating factors that influence on the achievement of sport result. The main purpose of simulating the process of competitive activity under certain conditions of the environment is to find effective ways to perform motor activities. These actions should be aimed at achieving the highest sporting result. This requires: 1) the development of methods for assessing the effectiveness of solutions to motor tasks; 2) assessment of the impact of indicators of physical and technical fitness of athletes on the effectiveness of actions; 3) determining the degree of conditions that affect the completing of these tasks with maximum efficiency(Lames, 2006, Silva at al., 2007).


Corresponding Author: POLIANYCHKO, O.M, E-mail: re_play@3g.ua

The most complete representation of the system's behavior is given by dynamic models. They can be developed as a result of the study of changes in indicators that characterize all aspects of not only competitive activities, but also structures of motor activity, physical fitness, workability, etc. (Lopatiev at al., 2008, Severini, 2014).

In cyclic sports, the main indicators that characterize adversarial activity are the average speed of passing distances. The presence of functional dependencies of speed factors on various indicators of sports activity can determine its dynamics. It allows to simulate the process of competitive activity, and according to the dynamics of speed to determine the nature of a particular indicator(Platonov, 2013, Silva at al., 2007).

Complex methods for evaluating different aspects of specialist preparedness and competitive activities are often based on laboratory testing results. This significantly reduces the objectivity of evaluating the functional characteristics of different systems of the body of an athlete in the competition. Measurement of medium speed dynamics is technically carried out directly in the process of competitive activity. The task of developing a dynamic model can be reduced to the definition of such relationships that would allow, based on the laws of physics and mechanics, to determine the dynamics of the change of instantaneous velocity and the indicators that determine it, according to the dynamics of the change in the average velocity on certain segments of the competitive distance(Namatevs at al., 2016).

The most promising basis for solving this problem is the use of mathematical modeling methods. They allow to synthesize the optimal structure of movements in the variational conditions of sports activities. The starting point for the synthesis of the optimal technique of sports movements and the development of a mathematical model of movements in cyclic sports is the well-known notion that any mechanical system in the most general form can be characterized by the equation of the energy balance and the laws of its motion.

**Methods**

Methods of computer mathematical modeling were used in this work.

**Results**

In cycling sports, the energy balance equation establishes a functional connection between the work of a cyclist $A(F_t, \varphi)$ spent on the kinetic energy required to change the speed, the forces of inertia in the rotating parts of the bicycle, as well as the forces of friction and air resistance forces of the air flow:

$$A(F_t - \varphi) = \Phi_1 \{mv, ms, (V_i^1 - V_{i-1}^2)\} + \ldots \rightarrow$$
$$\Phi_2 \{I_k, I_{zz}, I_{pz}, I_l, I_r (W_i^2 - W_{i-1}^2)\} + \ldots \rightarrow$$
$$\Phi_3 \{F_v, F_{tr}, F_{vv}, L\},$$

where: mv, ms - mass of bike and athlete respectively; $V_{i,\ i-1}$ is the final and initial value of the linear velocity in the time interval $\Delta t$; $I_k$, $I_{zz}$, $I_{pz}$, $I_l$, $I_r$ - moments of inertia of bicycle wheels, rear sprocket, front sprocket, chain and connecting rod, respectively; $W_{i,\ i-1}$ is the final and initial value of the angular velocity for $\Delta t$; $F_v$, $F_{tr}$ - frictional forces inside the bike and rolling; $F_{vv}$ - resistance to air flow; L is the linear path taken by the cyclist for $\Delta t$; $F_t$ - the value of tangential efforts; $\varphi$ is the angular path for $\Delta t$; i is the transmission number of the chain transmission.

For swimming, a similar equation establishes the connection of the work spent by the swimmer from kinetic energy, which is necessary for changing the speed, the creation of the suppressive forces, the forces of resistance of transverse water flows, as well as the forces of inertia:

$$A(F_{ru}, F_n, L) = \Phi_1 \{ms, (V_i^2 - V_{i-1}^2)\} + \ldots \rightarrow$$
$$\Phi_2 \{\alpha, S, (V_i^2 - V_{i-1}^2)\} + \ldots \rightarrow$$
$$\Phi_3 \{F_{ww}, F_{vw}, F_{pp}, L\},$$

where: $F_{ru}$, $F_n$ - force of traction of hands and feet movements; L is the linear path that was passed by the swimmer for $\Delta t$; ms - mass of swimmer; $V_{i,\ i-1}$ is the final and initial velocity value in the time interval $\Delta t$; $\alpha$ - angle of attack; S - swimmer body meridian; $F_{vw}$ is the strength of the water resistance; $F_{ww}$ - force of wave resistance; $F_{pp}$- is the strength of the resistance of transverse water flows.

We define the law of motion of the cyclist and swimmer, dependence instantaneous speed of the athlete and his acceleration times, the appended motive forces of the resistance and inertia forces, as well as the specific physical and morphological data.

For a cyclist these dependencies may be represented by the following functionalities:

$$L_i = \Phi_L \{(M_t - M_c), \sum I_j, ms, mv, i, V_{i-1}, t_i\}$$

$$V_i = \frac{a_i}{a_t} = \Phi_v \{(M_t - M_c), \sum I_j, ms, mv, i, V_{i-1}, t_i\}$$

$$a_i = \frac{a^2 L_i}{at^2} = \Phi_a \{(M_t - M_c), \sum I_j, ms, mv, i\}$$

where: $M_t$, $M_c$ - moments of motor (tangential) forces and forces of resistance; $\Sigma I_j$ - total moment of inertia of all rotating parts of a bicycle; ms, mv - mass of athlete and bicycle respectively; i - transfer number; t - current time value; $V_{i-1}$ - the value of the linear velocity at the initial moment of time t calculation; $L_i$ is the linear path that the cyclist has overcome in time $\Delta t = t_i - t_0$; $V_i$ - instantaneous velocity at time t; $a_i$ - cyclist acceleration in time $\Delta t$.

Similar dependencies for a swimmer have the form:

$L_i = \Phi_L \ \{(F_d - \sum F_c) V_{i-1}, t_i\}$

$V_i = \Phi_v \ \{(\sum F_d - \sum F_c) V_{i-1}, t_i\}$

$a_i = \Phi_a \ \{(\sum F_d - \sum F_c)\}$,

where: $\Sigma F_d$ - total moving force of the comb movements; $\Sigma F_c$ - total resistance of the water environment; S - mass and meridian swimmer; α - angle of attack; $V_{i-1}$ - instantaneous velocity value at the initial point of time $t_0$; $L_i$, $V_i$, $a_i$ - respectively the path, instantaneous speed and acceleration of the swimmer.

The value of the initial indicators of competitive activity for a particular athlete is determined by the difference between the motor forces and the forces of resistance. The greater the value of this difference over the entire time interval of passing distance, the better sports result will show the athlete.

With the same indicators that characterize the level of special training in cycling sports, the end result is largely determined by the level of technical fitness of the athlete. It can be represented by the value and effectiveness of the realization of motor forces. The main task of simulating the process of competitive activity is to determine the optimal change in motor forces that provide (at known resistance values and energy intensity of work) the maximum factors of average speed at a distance. For each athlete in the process of modeling, specific requirements for the technology of movements throughout the course are formulated. At the same time, any deviation of the values of motor forces from the optimal variant is reliably connected with excessive energy costs for standard work, with the manifestation of the disturbing influence of fatigue and the decrease of instantaneous and average speed indicators at certain areas and on the distance in general.

The dynamics of motor forces during the passage of areas of the competition distance is primarily due to the nature of the distribution of these forces from cycle to cycle and with parameters that reflect the internal cycle dynamics. The fulfillment of the requirements for the distribution of motor forces from cycle to cycle determines the conditions for optimization of the internal cycle structure of the motor forces of athletes. In cycling, this reduces to optimizing the angular position of the plane of the pedal to the axle of the connecting rod. In swimming - to optimize the time shift between the rows of the right and left hand and the coefficient of symmetry of pulse forces in the cycle of motion.

**Discussion and conclusions**

The process of optimizing the technical fitness of athletes in cycling sports and defining a certain algorithm is reduced to solving problems at three main levels. On the first of these, based on the data on the athlete's ability to work, an optimal variant of the distribution of energy consumption at a distance is determined. This option ensures their maximum use at the maximum value of the average speed that can be achieved at a distance. At the second level, based on the optimal energy distribution (distribution of work along the distance segments), an optimal change in the values of instantaneous velocities along the distance (optimal movement curve) and the distribution of the motor forces that ensure the execution of this graph is determined. At the third level, optimization of the internal cyclic structure of movements is carried out(Khudolii & Ivashchenko, 2014, Lopatiev at al., 2014).

A distinctive feature of the tasks that are solved at all levels is the difference in the nature and methods of obtaining the source information. In order to solve the problems of optimization of the first level, the data on the athlete's ability to work, based on which (if using the energy balance equation) is used, determines the optimal distribution of energy costs over the distances and the average speed of its passage(Verkhoshanskij, 1985). The obtained distribution allows determining, at the second level, the optimum rates of instantaneous velocities at each particular distance segment and, consequently, optimal motion schedules and the distribution of motive forces. The real distribution of instantaneous velocities and motive forces that allow us to estimate the ratio of optimal and real indicators can be obtained by directly measuring instantaneous velocity in the process of passing the distance or by solving the equation of motion using real data on the distribution of the average velocity during the passage of distances(Kostiukevych & Stasiuk, 2016, Stoggl at al., 2011).

The optimal distribution of motor forces over a distance or its individual sections defines the requirements for the indices of internal cyclic motor forces. Requirements for their distribution from cycle to cycle are defined for ensuring speed (optimal traffic schedule). Thus, the requirements for internal cycle velocity of motor actions are formed(Khudolii, 2005, Shustin, 1995).

It is necessary to evaluate not only the possibility of providing the optimal index of internal cyclic motive forces, but also their significance with the ideal technique of performing motor actions. That is, a possible reserve of achievements in a particular competitive discipline by improving the technical fitness of an athlete. To solve the problems of the third level, additional data of laboratory studies of the real dynamics of the internal cycle structure of the motor forces are needed. Such data can be obtained using special technical means (in conditions that are maximal to real ones).

Different conditions for obtaining primary information at all stages of modeling, as well as its diverse nature, rule out the task of optimizing the structure of motor actions in real time measurement(Khudolii, 2016). They can be performed at the stage of the survey in the competition period (preliminary estimation of the possible sports result) or in the preparatory period (evaluation of the need for correction of the structure of motor actions)(Lopatiev, 2007, Maier at al., 2000).

Control actions in the process of technical training are carried out directly by the trainer according to the prepared decision variants. The prepared recommendations should provide for a certain parameter. This parameter should provide a practical opportunity to control the deviations from the optimum technique of the implementation of movements in the process of training or competitive activities. This parameter can be the value of instantaneous speed when passing the distance or the schedule of passing distances. These parameters are functionally related to motor forces, and therefore - with the technique of movements of athletes.

Particularly important are such recommendations for using the generalization parameter (which is functionally related to the indicators of technical preparedness of athletes), acquired when using special training equipment during training(Khurtyk at al., 2016). For example, in swimming, using a light-lead device in conjunction with a pace leader, guided by the optimum values of the dynamics of changes in indicators during the course, helps the trainer to determine the areas of the distance with the greatest deviations of the real values of these indicators from the optimal ones(Lopatiev, 2008).The analysis of these deviations by simulation reveals the causes of these deviations, identifies the necessary corrective effects on the navigation technique when passing certain areas.

In cycling sports, technical equipment can be used. With them, the functions of comparing the optimal instantaneous velocity value along the distance with the real one are realized. In addition, the functions of controlling the process of dosing of physical activity are implemented. They are selected according to the real forces of resistance during the passage of the race according to the optimal schedule of motion. The presence of a mathematical model allows us to create an adaptive system for controlling the technical preparedness of athletes in cyclic sports.

**Conflict of interest**

The authors declare that there is no conflict of interests.

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