

Individualization tailoring the development of functional fitness for cyclists

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Abstract

Purpose: This study investigated the feasibility of implementing principles of individualized training processes for highly proficient road racers. **Material and methods:** The study involved 26 road racers, classified as international master of sports, aged between 19 and 26 years. Assessments were conducted during the competitive phase of the yearly training regimen. A comprehensive methodology was employed to evaluate functional fitness. Levels, encompassing the registration of key parameters related to gas exchange, external respiration, blood, and cardiovascular performance across varying exertion levels. In the process of testing athletes, the changes in the indices of ventilatory and gas exchange components of reactions of the respiratory and circulatory system functional manifestations in response to the given testing loads were examined. Instrumental methods of research - chronometry, ergometry, spirometry, gas analysis, pulsometry, methods of mathematical statistics - were used to determine the athletes' body response to their impact. **Results:** A high level of functional fitness is achieved by different combinations of the presented factors of its structure. The same high level of functional fitness in a skilled cyclist is provided by different combinations of functional fitness structural factors in each individual case. All pulsometric criteria are actually based on a clear interaction between pulse and oxygen consumption. The pulse range in the process of sports activity is divided as follows: 1) the recovery or "non-training" zone; 2) the "aerobic load" zone; 3) the "aerobic-anaerobic transition" zone; 4) the "aerobic-anaerobic load" zone; and 5) the "anaerobic load activation" zone. However, individual differences in pulse, which correspond to different energy criteria, are very large in highly skilled cyclists. **Conclusions:** Our data indicate the existence of significant individual differences in the structure of functional fitness and the various opportunities to achieve the maximum effect in the development of the system of work capacity energy supply. The results of the research allow specifying the possibilities of differentiating the training loads by intensity zones and methods of their measurement by pulse indicator criteria. This permits to approach the development of an individualization method for the practical application of the specified zones of load intensity by widely available parameters of radiotelemetric pulse measurement.

Key words: cyclists, oxygen transport system, respiratory system, pulse zones, radiotelemetric system

Introduction

Immeasurably increased requirements to the level and reliability of fitness of highly skilled athletes, huge volumes of training and competitive loads, and enhanced competition with the use of ethically and valeologically unacceptable ways to improve sports performance have largely caused the need to find new ways in the theory and methodology of training in recent years. At the same time, from the methodological positions of modernity, an urgent need arose in fundamental studies that are associated with the complex individualization of training and competitive activity of high-level athletes, which allows constructively increasing their preparation efficiency. The prerogative of obtaining individually programmed motor actions and training effects, rather than the drive to perform unreasonable (mainly aimed at the maximum) parameters of the given loads should underly the design and practical implementation of athletes' training programs.

The priority way to solve the problem of increasing the efficiency of high-level athletes' preparation systems and the growth of their sports results lies in determining those specific and set training impacts that take into account the condition of the athlete, his individual characteristics and adaptability of responses of different urgency, manifestation, and direction (Kolumbet et al., 2022).

Athlete preparation system realization in modern conditions is ineffective without knowledge of manifestation peculiarities of athlete's body functional capacities in the process of training and especially competitive load impacts. This provision is the most relevant for cyclic sports events with a predominant manifestation of endurance. In cyclic sports events, the volume and intensity of training impacts have now reached their maximum possible limit (Bolotin & Bakayev, 2016). In these sports events, one of the most important factors in achieving high sports results is the body functional capacities in terms of the level of manifestation of athletes' respiratory and circulatory systems. The use of a system of training impacts is primarily focused on their expedient formation in the process of preparation (Araujo et al., 2004).

Due to the deficiency or absence of objective and complete information about the state and capacities of the athletes' bodies, the coaches try to compensate for this situation by unsystematic or objectively unreasonable use of different in their target impact on the body training means. This approach to planning preparation does not always deliver the desired results.

This becomes especially urgent in relation to skilled athletes who are either at the stage of preparation for the highest achievements or at the stage of maximum realization of individual capacities (Monogarov & Bratkovsky, 1979; Pereira et al., 2010). A significant disadvantage of the haphazard approach to training design is that it lacks accurate quantitative information about the peculiarities of athletes' functional capacities. There is no clear and specific substantiation for the choice of targeted training impacts on the body.

To determine the athletes' fitness level regular monitoring of their functional abilities according to the manifestations of the respiratory and circulatory systems in the course of training is necessary. The use of such control in the process of long-term preparation provides opportunities for its objectivization and efficiency of implementation (Coffey et al., 2017). Therefore, the relevant result of modern studies concerning the impact of sports training on the body of skilled athletes is the determination of the exact quantitative level of their functional capacity manifestation at the end of the preparation process.

The functional fitness of athletes is the result of their body's adaptation to the conditions of training loads. It is generally accepted that the regulatory changes and reorganization of systems associated with adaptation processes are strictly individual in nature (Sparrow et al., 1998). Performance of the same work by different equally trained athletes is accompanied by different shifts of functions.

Currently, a steady trend in sports pedagogy is the individualization of the training process and the design of a training program with account for the adaptive potential of athletes (Beaver et al., 2022). This approach is based on the need to obtain objective information about the physiological response of the athlete's body to this or that training impact, both within the framework of acute and long-term adaptation. In this approach, it is of paramount importance to find adequate research methods, the results of which would most accurately reflect the physiological and metabolic changes during strenuous muscular activity (Madeiros, 2009).

An effective solution to the problem of preparation individualization requires abandoning the current practice of isolated, restricted professional studies. The solution consists of the transition to an integrated organization (Bolotin & Bakaev, 2016). This is due to the fact that the phenomenon of individuality characterizes the unique integrity of the person as an individual, personality, and subject of activity. An important methodological problem is the reflexive comprehension of the very integrity of the natural and social aspects of the motor individuality of a particular body in the conditions of competitive activity.

Understanding the mechanisms of manifestation peculiarities of the key to particular activity processes is one of the most important factors for the possibility of their purposeful improvement.

The mechanism of augmentation of maximal oxygen consumption value does not represent a haphazard increase in the volume and intensity of training loads performed by athletes (Guimaraes et al., 2008). It consists of their purposeful influence on achieving the highest possible value of respiratory minute volume and the lowest possible value of absolute oxygen concentration in exhaled air at the end of physical activity.

Thus, there is a real chance to use exceptionally well-aimed training impacts on the functional manifestations of the respiratory system to enhance its capabilities by differentiated improvement of individual components through the means of interval and continuous training methods (Kolumbet et al., 2019).

A differentiated approach to the training process to improve aerobic performance in elite athletes offers additional opportunities for its objective management to achieve the maximum level of their functional capacity manifestation (Chen et al., 2016). It is necessary to achieve such modification of functional manifestations of the respiratory system, which will enable each individual athlete to achieve the highest possible individual level of fitness. The training of athletes, which is aimed exclusively at improving the value of maximum oxygen consumption with unsystematic use of a set of training impacts of different training orientations, leads to significant uncertainty in their specific choice and unpredictability of the results obtained (Morrow et al., 2003).

Based on the absolute value of the maximum oxygen consumption alone it is not quite clear at the expense of which peculiarities of aerobic performance manifestation it was eventually achieved (Barbieri et al., 2019). The coach in such a situation completely lacks a clear idea of how and at what expense it is necessary to realize its specific improvement in the future (at the expense of influence on the ventilatory component of the respiratory system or at the expense of impact on its gas-exchange component). In this case, the coach has only one choice to conduct training to improve aerobic performance. It consists in being guided by those general provisions of the theory and methodology of sports training without the possibility of taking into account the individual functional characteristics of each individual athlete (Mersier et al., 1994; Nunes et al., 2017).

There is no differentiated approach to the nature of the use of these methods of training in the theory and methodology of sports training. Instead, a systematic increase in the quantitative indices of the volume and intensity of training loads performed by athletes is carried out. At the same time, the main preference for their choice at the higher stages of sports training is currently reduced to increasing the intensity of the work performed by athletes without taking into account their individual peculiarities (Moreira et al., 2008; Tambasco et al., 2017).

The use of an individual approach to the planning of methods, means, modes, and volumes of physical loads is most possible through modeling using model characteristics of the athlete (Monteiro & Araujo, 2009). However, at present, the model characteristics of special physical and technical fitness are mainly used in the competitive activity (Nunes et al., 2016), whereas those that reflect the functional, psychological fitness and morphological peculiarities of the model of the strongest athlete are not sufficiently developed in most sports events, and especially in cycling (Wei et al., 2016). The increased intensity of training loads in cycling indicates the need for individualized modeling based on the dynamics of functional state during long-term training (Kolumbet et al., 2021; Sullivan et al., 1989).

Therefore, the need to individualize the training process is obvious. Although in sports physiology this provision is not new, but it has been insufficiently studied.

The objective of the study - studying the possibility of the practical application of the principles of the training process individualization for highly skilled road racers.

The tasks were set, on the one hand, to determine the energy criteria - indices of changes in the energy supply character, and, on the other hand, to identify these criteria according to pulse. In addition, we wanted to find out to what extent our identification of energy supply criteria by pulse corresponds to the differentiation of the load level according to pulse regimes used in cycling. These pulse regimes, or “pulse zones”, characterize loads of different training directions. An important practical task was also to determine the correspondence of these “pulse zones” to the energy criteria of the energy supply character of skilled road racers. We considered it especially important to determine the degree of individual differences in pulse values, which characterize the preferential participation of different energy factors.

Material and methods

Participants

The object of the study was 26 road racers, skill level: international master of sports, age: 19-26 years.

Organization of study

The examination was performed during the competitive period of the annual training cycle (2021 year). A complex technique to determine the level of functional fitness was used (Kolumbet et al., 2021; Kolumbet et al., 2022). It included registration of the main parameters of gas exchange, external respiration, blood, and the cardiovascular system under different loads. The following types of loads were used:

- maximum one-minute load (athletes performed the maximum amount of work in 60 seconds with a load of 5.0-5.6 kg);
- stepwise load (work was started at a power of 1200 kgm.min⁻¹ and was increased every 2 min by 150 kgm.min⁻¹; such load was continued until the athlete was unable to maintain the set frequency of pedaling within 5% (100 rpm⁻¹);
- standard load (work (15 min.) at a constant work power of 3 watts per kilogram of body weight);
- work at a critical power level (work “to failure”; critical power was defined as the lowest work power at which maximum oxygen consumption (MOC) is achieved).

In the process of testing athletes, the changes in indices of ventilatory and gas exchange components of reactions of functional manifestations of the respiratory and circulatory systems in response to the given testing loads were investigated.

The following instrumental research methods were used to determine the athletes' body response to their impact; *chronometry, ergometry, spirometry, gas analysis, pulsometry, methods of mathematical statistics*.

The “Oxycon Pro” stationary gas analyzer, bicycle ergometer “Monark” (Sweden), and telemetric heart rate analyzer T31 “Polar” (Finland) were used to investigate the athletes.

The interrelated parameters of gas exchange, external respiration - frequency, depth, minute respiratory volume, alveolar ventilation, O₂ and CO₂ content in exhaled and alveolar air, main pulmonary volumes; indices of diffusion conductivity - respiratory and circulatory components; blood circulation - minute blood volume according to Defar V.S. Mishchenko modified, systolic volume, pulse, arterial pressure, the proportion of venous blood admixture; respiratory function of the blood – blood oxygen capacity, hemoglobin content, O₂ and CO₂ tension in blood, O₂ tension in arterialized blood according to Astrup, arterial blood oxygen saturation by oxyhemometry using special calibration method; body temperature of an athlete; indices of arterial blood acid-base balance, blood lactic acid, and glucose content were determined.

The study of the oxygen-transport system of the athletes' bodies during physical load envisaged the analysis of oxygen and carbon dioxide parameters in parallel with the analysis of the activity of the main functional systems that determine them. Quantitative and qualitative evaluation of the correlation between the indices of work capacity and O₂ consumption - CO₂ excretion, other oxygen and carbon dioxide parameters and functional indices were investigated.

Lactic acid in the blood was determined using a laboratory analyzer “Biosen S.-Line lab+” (according to Barker-Sammerson and Strom modified) at the 3rd and 5th minutes of the recovery period.

Statistical analysis

The findings were subjected to mathematical processing. The following statistical parameters of the sample were calculated: arithmetic mean ($\bar{X}$); standard deviation (S); coefficient of variation (V%); $\Delta\bar{X}$ - the confidence interval corresponded to 95%. The Student's t-test was used to compare two normal distributions. To test statistical hypotheses the critical level of significance was $p < 0.05$. Correlation analysis of the results was performed using Pearson's linear correlation coefficient. The experimental material was processed using integrated statistical and graphical packages MS Excel-7, Statistica-10. The study was conducted in compliance with the ethical principles of the European Convention and the Helsinki Declaration (ethics principles regarding human experimentation). It was confirmed by the Bioethics Commission of the University. Examined provided written approvals for analysis and subsequent disclosure.

Results and discussion

The results of our studies showed that in skilled athletes (at the same high level of functional fitness structure) the specific weight of individual factors can vary significantly. A number of individual peculiarities of response to the load are distinguished (Table 1).

Table 1. Individual differences in functional fitness structure of highly skilled road racers

№ №	Factors and parameters of evaluation	Measurement units	Subjects			
			A.K-v	N.P-v	M.S-v	V.K-o
<i>Power</i>						
1	Power of work critical level	kgm.min.kg ⁻¹	27.2	28.7	28.7	33.0
2	Maximum oxygen consumption	ml.min.kg ⁻¹	70.3	66.8	68.1	71.7
3	Maximum minute output	l.min. ⁻¹	34.3	33.8	36.4	38.5
4	Maximum oxygen pulse	ml.bt. ⁻¹	26.3	26.0	25.7	28.1
5	Pulse functional range (HR _{max} – HR ₀₀)	bt.min. ⁻¹	143.0	140.0	137.0	155.0
6	Lactate power	kgm.kg ⁻¹	5.0	5.3	4.8	4.3
7	Maximum lactate concentration	mMol	12.2	10.9	7.5	9.9
8	Oxygen debt during 10-min rest	l	10.6	9.0	9.1	8.5
9	Index of acid-base balance (pH)	c.u	7.21	7.29	7.31	7.25
<i>Stability</i>						
1	Time of maintaining work critical power	s	540.0	480.0	660.0	780.0
2	Coefficient of pulse functional stability	c.u	3.8	8.3	4.6	5.0
3	Stability coefficient of oxygen utilization in the lungs	c.u	5.2	7.5	8.0	4.5

A high level of functional fitness is achieved by different combinations of the presented factors of its structure (Byrne & Hills, 2002). High absolute values peculiar to one individual (for instance, power parameters: oxygen consumption, oxygen pulse, minute blood volume) are combined with a lower specific weight (according to the total sum of factors) of economy or stability parameters (Table 2).

Table 2. Individual differences in functional fitness structure of highly skilled road racers

№ №	Factors and parameters of evaluation	Measure-ment units	Subjects			
			A.K-v	O.M-v	M.S-v	V.K-o
Mobility						
1	The ratio of O ₂ consumption in the first 30 s to baseline at maximum one-minute load	%	136.3	96.5	129.0	113.8
2	Time of pulse recovery to 120 bt.min ⁻¹	s	120.0	240.0	180.0	180.0
3	The constant of pulse response development time	s	25.0	35.0	30.0	18.5
Economy						
1	Anaerobic metabolic threshold work power	kgm.min.kg ⁻¹	23.3	24.5	21.1	26.3
2	Watt pulse of standard load	kgm.bt. ⁻¹	8.5	8.9	10.0	9.6
3	Mechanical work efficiency	%	31.0	32.8	31.5	32.5
4	Ratio of oxygen consumption and pulse increase at different levels of load	l.cu.kg ⁻¹	0.07	0.05	0.04	0.05
Respiratory system realization						
1	The ratio of the mean pulse of critical power load to HR _{max}	%	91.2	92.7	83.6	91.6
2	The ratio of the average respiratory rate at critical power load to the maximum respiratory rate	%	92.0	93.4	90.2	92.6
3	The ratio of oxygen consumption at a maximum one-minute load to critical power load	%	96.8	92.3	93.5	92.7

Individual differences are associated with the peculiarities of the cyclist's body and the difference in the structure of the athlete's previous long-term preparation (Figure 1).

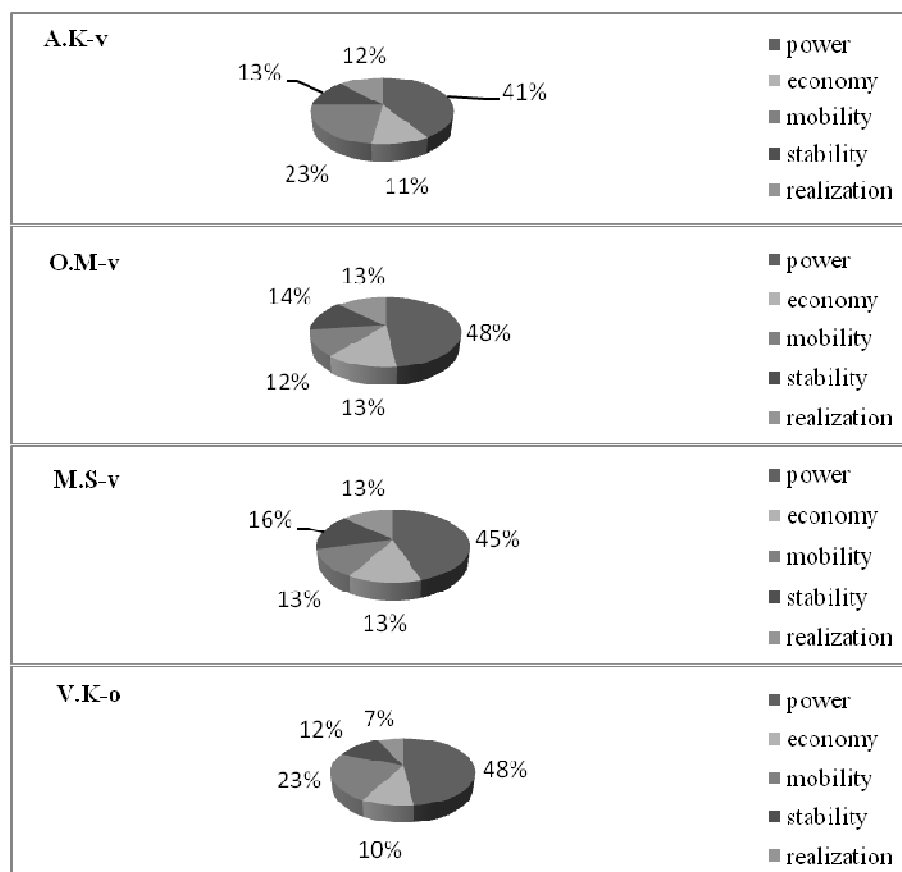


Figure 1. Differences in the specific weight of factors of functional fitness structure in some highly skilled road racers (subjects of Table 2)

The same high level of skilled cyclist's functional fitness is provided in each individual case by a different combination of functional fitness structural factors. The necessity of individualization of directed training influences is obvious. The training means and methods used in cyclist training that are standard for the entire pool of athletes have different effects on the aerobic and anaerobic relationships in the energy supply of each individual athlete's work (Grove et al., 2017). So far, there is no clearly individualized, practical way of evaluating training influences in terms of their impact on the development of the energy supply system.

In practice, any impacts on functional fitness can be monitored only by simple indicator parameters. The most acceptable for this purpose is the method of radiotelemetric pulse registration. Various ways of estimating training influences by pulse have been widespread in sports for a long time. However, until now the issue of individual differences in pulse response to the load has not been covered in the literature. Difficulties in the identification of "pulse zones", their unified interpretation, largely limit the possibility of efficient application of pulsometric criteria for sports training management (Ranisavljev et al., 2014; Weber et al., 1982).

In our studies (in terms of the possibilities of training process individual management) we proceeded from the fact that all pulsometric criteria are actually based on a clear interaction between pulse and oxygen consumption. The latter, in turn, adequately reflects the level of physical load on the body. It is known that certain levels of oxygen consumption are associated with specific changes in the character of the energy supply. Such factors as a threshold of anaerobic metabolism (TANM), aerobic-anaerobic transition, a threshold of decompensated metabolic acidosis, the beginning of reaching the maximum oxygen consumption can serve as energy indicators of the mentioned changes (Scott et al., 2015). Identification of such energy criteria by the pulse is extremely important for sports training management (McKenzie, 2012).

Based on our findings, we believe it is possible to identify five energy zones, which are fundamentally different in the nature of system functioning and the predominant participation of the energy supply factors of the work capacity. These zones also characterize differences in the training impact on the body (Table 3).

Table 3. Changes in pulse, lactate, and oxygen consumption in different zones of load intensity in highly skilled road racers

Indices	Recovery load zone		Aerobic load zone	Aerobic-anaerobic transition zone	Aerobic-anaerobic load zone	
t, min	0	5	10	15	18	20
VO ₂ , %max	10	50	60	80	97	100
HR, beats.min. ⁻¹	77	130	148	165	182	190
La, mmol.l ⁻¹	1.6	1.8	2.3	4.1	7.2	8.3
A, kgm	1200	1500	1800	2100	2300	2400

We have divided the existing in the process of sports activity pulse range as follows:

- 1) recovery or “non-training” load zone;
- 2) “aerobic load” zone;
- 3) “aerobic-anaerobic transition” zone;
- 4) “anaerobic-aerobic load” zone;
- 5) **“anaerobic load activation” zone.**

1. *The recovery or “non-training” zone.* This load promotes metabolites excretion and utilization, creates the most efficient conditions for the peripheral circulation, and in general has a favorable effect on the acceleration of the recovery process after the previous load. The energy criteria of such a load are not described in the literature.

One of the most complicated issues is to determine the level of oxygen consumption at which the intensity involves a training mechanism to increase the aerobic capacity of the body (Wilson, 2017). We assumed that the level of oxygen consumption at which the load can last so long that the “endurance time” limit will no longer be related to the lack of the body aerobic capacity, but mainly the expenditure of energy resources and other factors can be considered the energy criterion for such a load.

One of the criteria for identifying this zone by pulse can be the data on the calculation of the endurance work limit time depending on the ratio of the pulse of a given work time and the maximum pulse possible for a given individual. By adopting the maximum existing in cycling time range (about seven hours) of training and competitive load and slightly modifying this method of calculation, we were able to approximately determine the minimum pulse for each individual at which such a work duration is possible. Work of such intensity is a recovery load, which has little effect on the body aerobic capacity.

2. *The “aerobic load” zone.* The concept of “aerobic threshold”, which is characterized by the appearance of the above initial level of blood lactate, a non-linear increase of pulmonary ventilation, respiratory coefficient, carbon dioxide excretion can serve as one of the criteria for this zone identification. The lactate concentration in this case is usually about 2 mmol.l⁻¹ and coincides with the highest value of oxygen consumption percentage from the exhaled air.

The load used in this zone is the basis for the formation of the body aerobic base. In cycling, this load has a high specific weight.

3. *The “aerobic-anaerobic transition” zone.* It is characterized by the presence of an unstable balance of lactate clearance in blood and its utilization. According to a number of authors (Akalan et al., 2008; Lounana et al., 2007; Nunea et al., 2009), it is within the range of lactate changes about 2-4 mmol.l⁻¹. The upper limit of the zone practically corresponds to the threshold of anaerobic metabolism. Identification of the threshold of anaerobic metabolism by the pulse is carried out on the basis of specific changes in a number of gas exchange parameters. Thus, the zone of aerobic-anaerobic transition is distinguished as a pulse range, which is limited by the aerobic threshold pulse and that of threshold of anaerobic metabolism. The load applied in this zone most intensely affects the development of predominantly aerobic sources of energy supply.

4. *The “anaerobic-aerobic load” zone.* Isolation of this zone is due to the fact that when the maximum level of oxygen consumption is reached, the work may continue for a certain time. In this case the maximum oxygen consumption does not increase; sometimes it may even decrease slightly whereas the pulse continues to increase until the end of the work. This phenomenon of inadequate oxygen consumption and pulse at a high level of load necessitated singling out this zone. The onset of reaching the maximum oxygen consumption is well identified by the pulse. Thus, the zone of the anaerobic-aerobic load is within the pulse of the threshold of anaerobic metabolism and that of the onset of reaching the maximum oxygen consumption.

5. *The “anaerobic load activation” zone.* This zone is characterized by a significant activation of anaerobic processes on the background of a close to the maximal level of aerobic manifestations. After reaching the maximum oxygen consumption, the pulse increases until the end of work. Under the condition of significant load, the pulse reaches its maximum value. The pulse limits of this zone can be the pulse of reaching the maximum oxygen consumption and the maximum possible pulse of the given athlete.

Table 4. Variants of pulse zones at different load intensities

Division of pulse range	Pulse zones				
	I	II	III	IV	V
Used in cycling training practices	<130	131-150	151-170	171-190	>190
Our data	<130.5	130.6-148.1	148.2-166.3	166.4-185.6	185.7-192.1
Individual differences	123-141	123-141	136-160	156-170	171-200
		136-160	156-170	176-200	201-215

The average limits of the pulse zones obtained in this way are largely consistent with the empirically established practice of high-level cyclists' preparation. However (Table 4), individual differences in pulse, which correspond to different energy criteria, are very big in highly skilled cyclists. Applying averaged pulse values to evaluate training impacts in practice can cause significant errors.

Conclusion

1. Significant individual differences in functional fitness structure and variable possibilities of achieving the maximum effect in the development of the system of work capacity energy supply have been established.
2. The findings allow specifying the possibilities of training load differentiation by zones of intensity, whereas ways of their measurement by pulse indicator criteria.
3. The results of the study permit to develop a method of individualization for the practical application of the specified zones of load intensity by widely available parameters of radiotelemetric pulse measurement.
4. The findings open up space for improving the effectiveness of the training process at the expense of training impact individualization.

Conflict of interest

The authors declare that there is no conflict of interests.

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