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# TOTAL EVALUATION OF REGULATORY BLOOD CIRCULATION SYSTEMS OF ROAD CYCLISTS

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**Key words**: road cyclists, regulatory systems of the organism, type of regulation of the circulatory system.

**Annotation.** This article provides data on the total assessment of the regulatory systems of blood circulation (hemodynamic and autonomic) of 186 road cyclists with the qualification level: Candidate Master of Sports and Master of Sports. All cyclists were divided according to the type of self-regulation of the circulatory system into three groups: athletes with a vascular type of regulation (n = 149), with a mixed type (n = 22), with a cardiac type (n = 15). The aim of the study was to summarize the regulatory circulatory systems of road cyclists with different skill levels. In the CMS-MS groups, the values of the total assessment of regulatory systems were -7, which corresponds to the state of an athletic heart. When analyzing the results of cyclists with different indices of self-regulation of the circulatory system, this condition was noted only in athletes of the subgroup with the vascular type, in other subgroups there were values -6 for cardiac type and -4 for mixed type.

**Introduction**. Adaptogenesis, from the position of adaptation of functional systems of the body to long-term muscular loads, is carried out by various mechanisms at different structural and functional levels of the body. One of adaptive mechanisms is the redistribution of energy, metabolic and structural resources in favor of organs and systems, at the level of which there is a qualitative and quantitative adjustment [1, 2]. Regulation is provided by intersystem and intrasystem mechanisms, which are versatile and multifunctional. The study of the formation of adaptive mechanisms of the organism of athletes is an important problem of the sports physiology and makes it possible to assess the functional state of this category of individuals in the process of medical and pedagogical control.

On this basis, the aim of the study was an attempt to summarize regulatory circulatory systems of road cyclists with different skill levels.

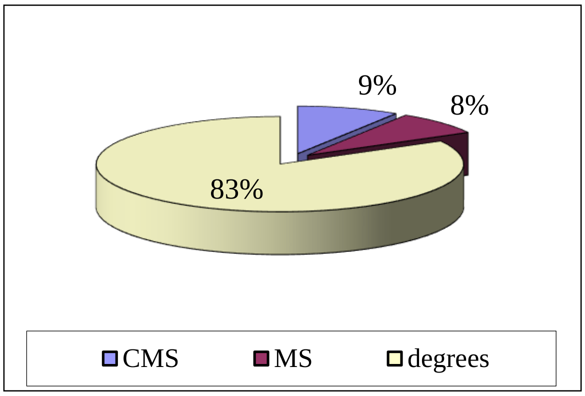
**Methods and organization**. The work is based on results of physiological and pedagogical studies carried out in laboratory conditions, during cycling training, aimed at studying the functional state of the body of road cyclists. The study was carried out at the Department of Anatomy and Sports Medicine of the Kuban State University of Physical Culture, Sports and Tourism, the Department of Physical Education of the Kuban State Agrarian University named after I.T. Trubilin, as well as on the base of the Multifunctional Sports Complex and Sports School for Cycling in Majkop. The study involved 186 male road cyclists, of whom 32 were highly qualified athletes: 17 Candidates for Master of Sports (CMS) and 15 Masters of Sports (MS) and 154 rated cyclists (1-2 degree) in the age of 19,7±2,5 years.

The index of cardiovascular regulation (ICR) was determined according to the method developed by N.I. Arinchin [3] and modified by V.N. Karlov et al. [4]. A quantitative assessment of the autonomic regulation of the cardiovascular system was carried out using spectral and statistical analysis of heart rate variability [5]. The total assessment of regulatory systems (TARS) was carried out for a comprehensive assessment of the autonomic homeostasis [6]. The vegetative tone with the identification of leading mechanisms of regulation was determined by the method of A.M. Vejn [7]. The recording and decoding of the cardiointervalogram was carried out according to the method proposed by R.M. Baevskij [7] on the "Valenta" apparatus. Statistical processing of obtained results was carried out using the Statistica 6.0 analysis package. The assessment of the reliability of various studied indicators was carried out according to the Student's t-test at a significance level of $P<0,05$. Frequency indices were compared according to the Fisher's exact test using the two-sided $\chi 2$ criterion.

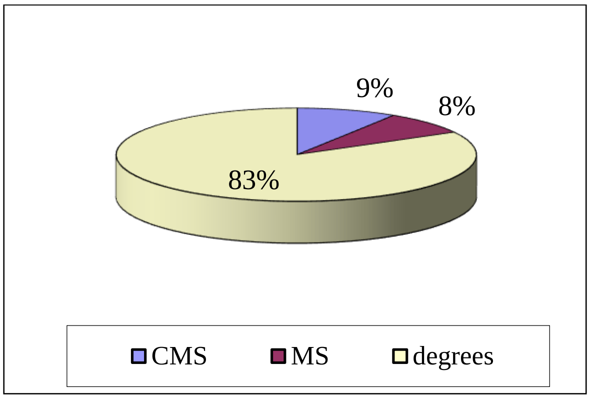
When examining athletes, all bioethical requirements were met according to the 1964 Declaration of Helsinki. Examinations were carried out at the end of the pre-competition stage of the one-year training cycle. All test subjects were subject to the same requirements regarding the testing procedure.

**Results and discussion.** All cyclists were divided according to the type of self-regulation of the circulatory system (ICR) (Fig. 1): athletes with a vascular type of regulation (n=149), with a mixed type (n=22) and with a cardiac type (n = 15).

In order to identify comprehensively the functional state of the organism of road cyclists, we conducted a total assessment of regulatory systems (TARS) [6]. According to the method, proposed by the aforementioned author, the TARS is presented as a comprehensive assessment, including the integration of the main blocks: the total effect of regulation (TER); function of automatism (FA); vegetative homeostasis (VH); activity of subcortical nerve centers (ASNC); spectral structure of rhythm (SSR); assessment of the values of the indicator of the total power of the spectrum (TP) (Table 1).




A




B

Fig. 1. Distribution of the sample of road cyclists, taking into account qualifications (A) and the type of self-regulation of the circulatory system (B)

Table 1

Assessment of regulatory mechanisms according to TARS values

| Points | +2 | +1 | 0 | -1 | -2 |
|---|---|---|---|---|---|
| Total effect of regulation | Severe tachycardia | Moderate tachycardia | Normocardia | Moderate bradycardia | Severe bradycardia |
| Automaticity function | Constant rhythm | Severe sinus arrhythmia | Moderate sinus arrhythmia | Moderate violation of automatism | Severe violation of automatism |
| Vegetative homeostasis | Predominance of sympathetic regulation | Moderate predominance of SNA | Vegetative homeostasis | Moderate predominance of the parasympathetic nervous system | Severe predominance of the parasympathetic nervous system |
| Activity of subcortical nerve centers | CI>8 | CI 5-8 | CI 2-5 | CI 1-2 | CI<1 |
| Spectral structure of the rhythm | VLF or ULF predominance | Predominance of LF | Balance sheet | The predominance HF at HF from 30 to 50% | The predominance of HF at HF from more than 50% |
| TP, $мс^2$ | < 1000 | 1000-2248 | 2248-3366 | 3366-4484 | > 4484 |

Note: SNA – sympathetic nervous system; CI – centralization index; VLF – very low frequency; ULF – ultra low frequency; HF – high frequency; TP – total power of the spectrum

The data presented in this work were subjected to statistical processing. A comparative analysis was carried out in the groups: CMS-MS; Total sample (TS) –

MS; TS – CMS; TS – cardiac type (CT); TS – mixed type (MT), TS – vascular type (VT).

The total effect of regulation is normalized in terms of heart rate, in the case of bradycardia and tachycardia, moderate and pronounced degrees are identified. According to this assessment, overall values of the sample of cyclists' heart rate are interpreted as a state of moderate bradycardia. The values of CMS, MS and cyclists with VT are included into the same range. The indicator of the total effect of regulation of cyclists of the MT group can be attributed to the state of normocardia, the group of CT cyclists – to the state of moderate tachycardia (82,0±5,1 beats/min) (Fig. 2, 3).

| | | | | | | |
|---|---|---|---|---|---|---|
| +2 | | | | | | |
| +1 | | | | | | |
| 0 | * | | | | | |
| -1 | | * | * | | * | |
| -2 | | | | * | | * |
| | CER | AF | VH | TP | ASNC | SSR |

A) Cyclists – MS

| | | | | | | |
|---|---|---|---|---|---|---|
| +2 | | | | | | |
| +1 | | | | | | |
| 0 | * | | * | | | |
| -1 | | | | | * | |
| -2 | | * | | * | | * |
| | CER | AF | VH | TP | ASNC | SSR |

B) Cyclists – CMS

Fig. 2. Diagrams of activity of regulatory systems (SORS) of road cyclists with different skill levels

Note: CER – cumulative effect of regulation; AF – automatic function; VH – vegetative homeostasis; TP – total spectrum power level; ASNC – activity of subcortical nerve centers, SSR – spectral structure of rhythm

Assessment of the function of automatism [6] is based on an approach of the separation of normotropic and heterotropic disruption of the automatism of the heart rhythm, is normalized according to the range (R) indicator. If R≤0,10, it is considered as the stable rhythm, ≥0,3 – pronounced sinus arrhythmia, ≤0,3 – moderate sinus arrhythmia, ≥0,45 – moderate disruption of automatism, ≥0,6 – severe disruption of automatism.

When analyzing the indicators of cardiointervalography, it was revealed that the indicators of the stress index of adaptive systems (SI, c.u.) have the greatest variability. The mean group values of SI, as a complex criterion reflecting the activity of the humoral, sympathetic and parasympathetic channels of the HRV regulation, varied in the range of 5,0: 43,0: 576,0 (minimum: mode: maximum). There were no reliable values for this indicator in the CMS-MS groups. The CMS most often have a state of severe vagotonia (7 cyclists), moderate vagotonia – 4 athletes, eutonia – an athlete, one cyclist has moderate sympathicotonia and 2 cyclists have severe sympathicotonia. Among MS, the states of moderate and pronounced sympathicotonia were not revealed in our study. In the groups of cyclists different in the ISSR, the following distribution was obtained: in the athletes of the CT group, the state of sympathicotonia was not revealed. In athletes with a mixed and vascular type, in isolated cases, a state of moderate and pronounced sympathicotonia was observed. The data were also confirmed by the obtained values of additional indicators of VRI (vegetative rhythm index), IVR (index of range) and IARP (indicator of the adequacy of regulation processes) (Table 2).

Table 2

The main indicators of variational pulsography (cardiointervalography) of cyclists with different blood circulation self-regulation index (M±m)

| Indicators | Skill level | | |
|---|---|---|---|
| | Cardiac type (CT) (n=15) | Mixed type (MT) (n=22) | Vascular type (VT) (n=149) |
| R, s | 0,7±0,2* | 0,9±0,1 | 1,0±0,1 |
| Mo, s | 0,9±0,1 | 0,9±0,1 | 1,0±0,1 |
| AMo, % | 25,0±7,4° | 39,4±5,1* | 30,5±1,4 |
| SI, c.u. | 42,5±26,4 | 91,8±27,8 | 56,4±8,3* |
| VRI, c.u. | 2,6±0,9 | 3,1±0,4* | 2,5±0,2° |
| IR, c.u. | 71,1±4,2° | 114,2±23,6 | 86,0±9,9 |
| IARP, c.u. | 28,5±9,7° | 44,5±7,2 | 33,0±2,1*° |

Note: * – significance of differences at (P<0,05) regarding ST, MT, VT – total sample; ° – significance of differences at (P<0,05) regarding ST-MT, VT-MT; R – range; Mo – mode; AMo – mode amplitude; SI – stress index; VRI - vegetative rhythm index; IR – index of range; IARP – indicator of the adequacy of regulation processes

The data obtained during the study indicate the presence of a pronounced disruption of automatism in cyclists of the CMS and in cyclists of the CT group, a moderate violation of automatism in MS and cyclists of the SOT group, while cyclists of the SM group had moderate sinus arrhythmia (Fig. 2, 3).

The vegetative homeostasis was considered from the standpoint of the effects of sympathetic (SNS) and parasympathetic (PSNS) activity on heart rate and was assessed by two indicators: AMo and SI [6]. According to the assessment method, a pronounced predominance of SNS is observed at SI≥500 c.u. and Amo≥80%, moderate prevalence of SNS at SI≥200 c.u. and Amo≥50%, preserved vegetative homeostasis at SI≤200 c.u. and 30≤Amo≤50%, moderate prevalence of PSNS at SI≤50 c.u. and Amo≤30%, pronounced predominance at SI≤25 c.u. and AMO≤15%.

Comparative analysis showed that the optimal autonomic homeostasis was observed in CMS cyclists and the MT group. Masters of Sports, groups of cyclists with CT and VT, had a state of moderate bradycardia (Fig. 2, 3).

The highest activity (P<0,05) of the sympathetic nerve centers of the medulla oblongata was observed for cyclists of the CT group (3111,8±251,0 $ms^2$) (Fig. 4), the LF values, $ms^2$ of which differed from the sample mean values of this indicator.

The LF, ms² values of cyclists of the MT and VT groups were slightly lower and amounted to 2891,2±574,0 and 2724,3±272,7 ms² respectively. Comparative analysis of the VLF values, ms² of cyclists with different ICRs allowed us to reveal significantly higher indicators of the activity of the central ergotropic structures in athletes of the CT and MT groups (1466,8±176,3 and 1430,3±433,0 ms², respectively) (Fig. 4). Indicators of cyclists of the CT group (1078,7±159,8 ms²) did not have significant differences with the average sample, although they were significantly lower in relation to the VLF values, ms² of athletes in the CT and MT groups ($P<0,05$).

| | | | | | | |
|---|---|---|---|---|---|---|
| +2 | * | | | | | |
| +1 | | | | | | |
| 0 | | | | | | |
| -1 | | | * | | * | |
| -2 | | * | | * | | * |
| | CER | AF | VH | TP | ASNC | SSR |

A) Cyclists – CT

| | | | | | | |
|---|---|---|---|---|---|---|
| +2 | | | | | | |
| +1 | | | | | | |
| 0 | * | * | * | | * | |
| -1 | | | | | | |
| -2 | | | | * | | * |
| | CER | AF | VH | TP | ASNC | SSR |

B) Cyclists – MT

| | | | | | | |
|---|---|---|---|---|---|---|
| +2 | | | | | | |
| +1 | | | | | | |
| 0 | | | | | | |
| -1 | | * | * | | * | |
| -2 | * | | | * | | * |
| | CER | AF | VH | TP | ASNC | SSR |

C) Cyclists – VT

Fig. 3. Diagrams of activity of regulatory systems (TARS) of road cyclists with different types of the cardiovascular regulation

Note: CER – cumulative effect of regulation; AF – automatic function; VH – vegetative homeostasis; TP – total spectrum power level; ASNC – activity of subcortical nerve centers, SSR – spectral structure of rhythm

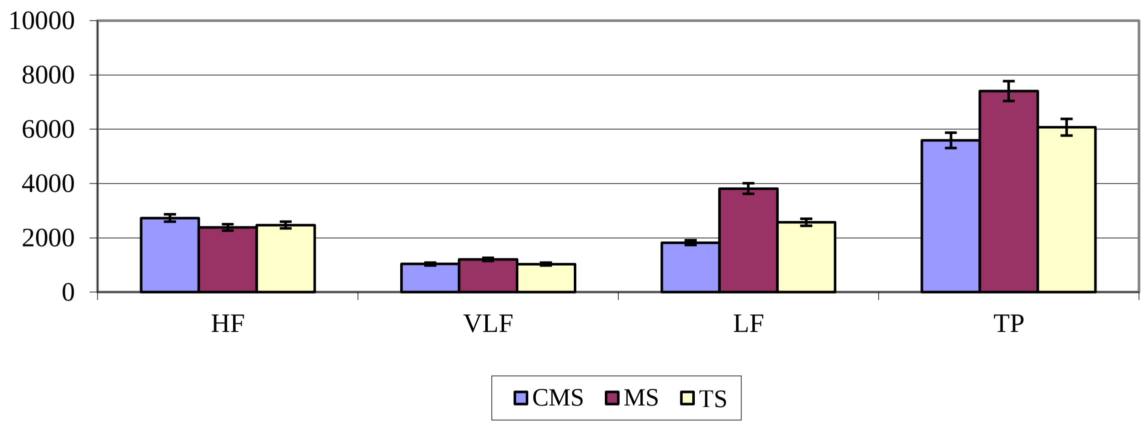



Fig 4. Main indicators of spectral analysis of road cyclists with different skill levels (ms²)

Note: HF – high frequency; VLF – very low frequency; LF – low frequency; TP – total power of the spectrum; CMS– Candidate Master of Sports; MS – Master of Sports; TS – total sample

When analyzing the TP indicator, $ms^2$ of cyclists from different ICRs, the following was revealed: the values of the total spectrum power in the CT and MT groups were significantly higher in relation to the average sample and amounted to 7786,09±1564,2 $ms^2$ and 7192,2±985,6 $ms^2$ respectively. The indicator of the total power of the spectrum, which characterizes the total activity of all regulation channels in controlling the heart rate in all groups, regardless of the level of qualification and the type of self-regulation of the circulatory system, was assessed in the same way (-2 points).

In our study, to assess the degree of centralization in heart rate control, according to the theory developed R.M. Baevskij, the index of centralization (IC, c.u.) was studied [8]. Normal indicators of individuals, who do not engage in sports, according to the aforementioned authors, vary in the range of 3,9±0,21 c.u. The integral indicator of the activity of subcortical nerve centers was assessed by the index of centralization, and was interpreted as follows: +2 points for IC more than 8, +1 point for IC from 5 to 8, 0 points for IC from 2 to 5, -1 point for IC from 1 to 2, -2 points for IC less than 1.

It was revealed that the average sample values of IC in road cyclists are 1,9±0,1 c.u., while in the CMS they are 1,8±0,2 c.u., 2,1±0,2 c.u., which indicates the absence of significant differences between the centralization index of the CMS and MS from the average sample values of this indicator and between the groups. For cyclists of the CT group, this indicator was 1,3±0,2 c.u. and significantly differed from the values of that indicator of the general sample ($P<0,05$), being the lowest relative to the IC indicators in cyclists of the MT and VT groups.

The index of activation of subcortical centers (IASC, c.u.), as an integral indicator reflecting the activity of the cardiovascular subcortical center in relation to higher levels of control [8], is 1,47±0,4 c.u. in young people, who do not engage in sports. Average sample data of road cyclists fluctuate in the range of 2,3±1,2 c.u. It was revealed that the CMS has the highest values of this indicator (4,0±2,4 c.u.), which significantly ($P<0,05$) differ from the TS indicators and from the MT values (0,6±0,1 c.u.), which indicates a higher activity of the vasoconstrictor and vascular centers of the medulla oblongata in this group of athletes. Among cyclists with different ICR, the highest values ($P<0,05$) of the IASC were found in the group of VT athletes (2,5±1,3 c.u.), which were significantly higher not only in relation to the values of the IASC of cyclists of other groups, but also to the values of this indicator of the general sample ($P<0,05$).

The average sampling indicators of the spectral analysis of HRV of road cyclists were distributed in the ratio LF>VLF<HF, which, according to the classification developed by A.M. Vejn [6], corresponds to an unstressed vegetative

balance. The CMS has a state of relative vagotonia – LF<HF>VLF, Masters of Sports have a state of an unstressed vegetative balance – LF>VLF<HF.

In the groups of cyclists with different ICR, the proportion of distribution looked as follows: in the group with CET, a state of relative vagotonia was observed – LF<HF>VLF, in the groups MT and VT – LF>VLF<HF, which was considered as an unstressed vegetative balance.

**Conclusion.** The main typological features that make it possible to comprehensively assess the functional state of the organism of road cyclists are: the level of qualifications and the type of self-regulation of the circulatory system. Out of the entire sample (n=186), the distribution of the contingent by the type of cardiovascular regulation occurred in this study in an increasing position: cardiac type (n=15) → mixed type (n=22) → vascular type (n=149). An effective criterion for the long-term adaptation of the organism to long-term stresses on endurance in road cyclists is the formation of a vascular type of self-regulation of the circulatory system, which is characterized by low heart rate values, balanced influence of the sympathetic and parasympathetic parts of the autonomic nervous system, as well as moderate activity of the cardiac stimulating and vasoconstrictor centers of the medulla oblongata. For athletes with a cardiac type, hyperkinetic phenomena in terms of the cardiac index, centralization in the control of the heart rate are characteristic.

The TARS indicator can serve as a criterion for assessing the functional state of the athlete's circulatory system. In CMS-MS groups, the TARS values are within -7 points, which corresponds to the state of a sports heart. When analyzing the results of cyclists with different indices of self-regulation of the circulatory system, this condition was noted only in athletes of the group with the vascular type, in other groups there were values -6 points for CT and -4 points for MT.

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