The Features of the Functional State of the Cardiorespiratory System of Students attending Specialized Sports Clubs (Football, Basketball)

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Abstract

The article discusses the issues of the students’ cardiorespiratory system adaptation to the athletic load. The aim of the study was to investigate the effect of playing football and basketball on the regulatory-adaptive and functional abilities of the cardiovascular and respiratory systems of the students attending sports clubs. The contingent of the tested persons included 60 people aged 18–21 years; the control group included 35 students not engaged in sports activities. With the help of the “Poli-Spektr” and “Spiro-Spektr” hardware and software systems produced by the NeuroSoft Company (Ivanovo, Russia), the study revealed three types of adaptation: a high degree of adaptation (47.0% of football players, 58.0% of basketball players); stress of the regulatory mechanisms (20.0% of football and basketball players); and unsatisfactory adaptation (33.0% of football players and 22.0% of basketball players). In the conditions of an active orthostatic test, the majority of the football and basketball players demonstrated the autonomously central version of regulation. The students with a high degree of adaptation had the highest values of the respiratory function indicators. The contingent featuring an unsatisfactory adaptation of the cardiovascular system is characterized by the decline in the indicators of the lung ventilation economy and efficiency with respect to the contingent having a high degree of adaptation.

Keywords: Adaptation, Basketball, Cardiovascular System, Football, Mass Sports, Regulatory-Adaptive Status, Reserve Forces, Respiratory System, Students

1. Introduction

A significant place in the life of a particular part of students belongs to the sports, which is to some extent an anti-stress factor. The training loads play an important role in the formation of the body’s functional reserves (Boineau; Almansbaa and Franchinib). The body becomes resistant to stress factors due to the athletic training. In the conditions of physical loads, the body’s transition to a higher level of regulation naturally leads to the increase in the power of energy containing structures and to the formation of the structural changes that increase the functional abilities of the systems responsible for adaptation. A so-called structural trace is formed, which is the basis of the adaptation transition from urgent to long-term (Saboul and Balduccii). At the same time, the training and competitive activity in parallel with the academic load in college step up the demands to the adaptive abilities of the body, which is especially true for game sports, combat sports and track and field athletics. Any discrepancy in the volume and intensity of physical loads with the adaptive abilities of the body can cause a number of changes in the functional systems of the homeostatic level and change the regulatory-adaptive status of the organism.

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predetermining the current and future adaptation course (Joyner and Coyle; Rocha).

The transition from an urgent stage to sustainable long-term adaptation under the influence of athletic loads is based on the functional changes formation, primarily in the cardiovascular system and its regulatory mechanisms (Shakhanova and Kuz'min; Abade et al.). An analysis of the revealed physiological parameter shifts on the physical load effect does not provide a complete description of the adaptive abilities of the organism, unless the key indicator of its functional state is determined, which is the quality of reserves management. Meanwhile, the cardiac rhythm caused by the two main mechanisms of the control system - the central and the autonomous ones-is considered a fairly objective indicator of the quality of management of the entire body's reserve forces (Zhang; Uusitalo).

Oxygen supply to the body is an essential condition for high-level physical performance. The most effective mechanism in this case is considered an increase in the cardiac output. However, the experimental data clearly indicate that as a result of the systematic physical training, the mechanisms ensuring the ability to deliver more oxygen to the tissues at the lower value of the cardiac output develop in the body.

In terms of the previously mentioned and from the perspective of the modern concepts, the Cardiovascular System (CVS) is the main but not the only indicator of the adaptive reactions of the entire body. The functional abilities of the respiratory system, which is the functional system of not only the homeostatic level, but also of the adaptive one, is widely used as the assessment of the adequacy of loads and adaptive properties of the organism in sports medicine (Lovering). A sufficient functional state of the external respiration system reflects the ability of the body for prolonged intense muscular work. In the conditions of athletic training, the external respiration is imposed with stepped-up requirements, since the efficiency of the whole body depends exactly on this kind of respiration, which is a prerequisite for athletic training (Shakhanova and Kuz'min).

A number of researchers refer the external respiration to the factors limiting the ability to achieve high sport results. The muscular activity requires a significant increase in ventilation, as the requirements to its optimization become much more stringent. This determines the consistent nature of reorganization of the respiratory cycle parameters aimed at the implementation of the possibly more energy-efficient implementation of the "working hyperpnea" depending on the load's nature and power, in particular, the sequential use of the reserve volumes of inspiration and expiration.

A number of authors pointed out (Lovering) that ordinary spirographic and spirometric studies of the external respiration are insufficient to characterize the external respiration of contemporary highly skilled athletes. It is necessary to use modern diagnostic tools that allow assessing the volume and flow rate characteristics.

Absence of sufficient information on the precise nature of formation of the cardiorespiratory system's functional reserves as well as on the common factors of rearrangements in the regulatory-adaptive status of a students' body in the conditions of various forms of organization of the sports activities at a higher education institution determines the study relevance. This is the knowledge database on the impact of various athletic training loads on the quality of the Cardiovascular System regulation and on the adaptive abilities of the respiratory system. It is impossible to effectively address the optimization issues of the motor activities within the sports activities performed by students in various sports clubs in order to maintain health, carry out appropriate preventive and corrective actions on the prevention of psycho-emotional overloads and recovery of the working efficiency during the learning process at a higher education institution.

2. Methodology

The experiment was conducted in the cross-sectional mode involving students who were regularly engaged in mass sports by attending sports clubs at the ASU Department of Physical Education.

The study involved 60 students of the 2-4 years studying at the not related to sports departments who played football and basketball in the mode of the sports clubs classes: 30 football players and 30 basketball players without sports qualification, with 3–4 years of the training experience. The control group consisted of 35 practically healthy students of the 2-4 courses of training at the Department of Natural Science of the Adygeya State University with a traditional motor mode (2 hours of physical training per week).

The total number of the study subjects was 95 male students aged 18–21 years. In order to standardize the conditions, all the studies were conducted before noon (9–12 hours), in the conditions of the comfort temperature (18–20 °C), at the premises of the Physiology of Child
Development Laboratory of the Research Institute for Comprehensive Problems of the Adyghe State University, in compliance with the ethical norms of a physiological experiment and under the informed consent of the tested persons.

The study of the HRV wave structure was performed using the “Poly-Spektr-12” hardware and software system produced by the NeuroSoft Company (Ivanovo) in the prone position during 5 minutes and in the conditions of the Active Orthostatic Test (AOT) in the upright position during 6 minutes, in accordance with the international standards (Circulation...1996;93:1043-1065) for short entries. The rhythmograms obtained were manually controlled in order to avoid possible artifacts.

The time-line analysis indicators included SDNN, RMSSD and PNN50 measured in msec as well as CV and pNN50 measured in %.

- SDNN (msec) or SCD (msec) is the cumulative variability of the R–R intervals values for the entire reporting period (NN means the number of “normal to normal” intervals with the exception of extrasystoles). It indicates a change in both autonomic and central contours of regulation.

- RMSSD (msec) is the square root of the sum of squares of the difference between the values of successive pairs of the NN intervals (normal R–R intervals). It reflects the activity of the autonomic contour of regulation.

- PNN50 (%) is the NN50 percentage of the total (for the entire period of record) number of successive pairs of intervals that differ by more than 50 msec. It gives an indication of the relative dominance of the parasympathetic or sympathetic component of regulation.

- CV (%) is the coefficient of variation (SCD: CV=SCD/Mx100, where M is the mean value of the R–R intervals), which represents normalized assessment and characterizes the cumulative effect of the vegetative regulation of blood circulation.

A spectral analysis consisted in measuring the power of VLF- (within the range of 0.05–0.015 Hz (20–70 seconds)), LF- (within the range of 0.04–0.15 Hz with the period of 7–25 seconds) and HF-waves (within the range of 0.4–0.15 Hz with the period of 2.5–7 seconds) in the spectrum of heart rate variability and was implemented as a percentage of the total spectrum power (TP), which shows the relative contribution of each component to the total power of the cardiac rhythm fluctuations. Based on the HRV spectral analysis, the periodic changes in the sinus rhythm frequency were characterized.

The external respiration system indicators were studied with the help of the “Spiro-Spektr” computer-based system produced by the NeuroSoft Company, Ivanovo using the following three tests:

- The “Quiet Breathing” test - VC test.
- The “Forced Expiration” test - FVC test.
- The “Maximum Lung Ventilation” test - MVV test.

The physiological assessment of the reserve and functional capacity of the adaptation respiratory component included the following definitions: Vital Capacity (VC), Forced Vital Capacity (FVC), Maximum Voluntary Ventilation (MVV), Tidal Volume (TV), Breathing Frequency (BF), Inspiratory Reserve Volume (IRV), Expiratory Reserve Volume (ERV), Peak Expiratory Volume (FEV0.5), Forced Expiratory Volume in the first second of the FVC maneuver (FEV1), Mean Expiratory Flow (MEF25-75, MEF75-85) and Maximum Expiratory Flow (MEF25%, MEF50%, MEF75%).

### 3. Results

An HRV analysis showed that in 52.0% of cases, students engaged in sports clubs demonstrated the CVS function economization at rest (Table A1). The most favorable vegetative balance at rest was observed in basketball players, when the HF-waves prevailed in the spectrum of the cardiac rhythm regulation (36.2±6.2% against 32.3±7.5% at football players and 27.7±5.2% - at those not engaged in sports, р≤0.05). The HF-waves power is a marker of the vagal effects on heart (Karemaker7; Grechishkina and Silant’ev5). The increase in the parasympathetic nervous system tone was also indicated by the RMSSD index. The higher level of VLF-waves at basketball and football players than at those not engaged in sports reflects the cerebral ergotropic efforts associated with the high emotional background of a sports game.

However, 33.0% of football players, despite the fairly good spectral and time HRV indicators, demonstrated the ratio of fast (HF) and slow (LF and VLF) waves that indicated a fairly high effect of the sympathetic nervous system on the cardiac rhythm (Table 1). In these football players, likewise in 20.0% of basketball players and almost all the students not engaged in sports activities, high centralization of the cardiac rhythm control was identified, which
reduces the lability of the regulatory-adaptive systems under the influence of physical and teaching loads.

The group of basketball players in a greater degree demonstrated the prevalence of the parasympathetic component of regulation. As a consequence, the economization of the physiological functions, and reduction in the physiological “price” for the adaptive outcome achievement were observed in comparison with the students attending football clubs.

An individual analysis revealed three types of adaptation: a high degree of adaptation, regulatory mechanisms’ stress and unsatisfactory adaptation.

An HRV analysis of the football players with a high degree of adaptation (47.0%) showed a stable favorable vegetative balance at rest along with the considerable prevalence of parasympathetic (HF) effects over the sympathetic (LF, p≤0.05) ones in the setting of the inclusion of the suprasegmental regulation mechanisms (of a VLF-wave) of the cardiac rhythm (Figure 1).

The indicators of a time-line analysis also pointed to the prevalence of a parasympathetic component of regulation, which is interpreted as the most optimal combination of centralization and autonomy of the cardiac rhythm control (Grechishkina, Silant’ev and Ivantsov5).

The AOT conduction in this group of football players showed a sufficient level of maintenance of the controlling mechanisms for the neurovegetative regulation of the spectrum power. The spectral wave distribution fit into the LF>VLF>HF picture in football players, which is evidence of an adequate activation of the sympathetic division, when the adaptation was carried out due to the increase in waves of the LF-range, i.e., of the autonomously central version of regulation.

Among the students playing football and having stressed regulatory-adaptive mechanisms (20.0%), the total spectrum power (TP) was revealed to be 1.6 times lower if compared to the first group, which indicates an increase in the load imposed on the regulatory mechanisms (Figure 1). In comparison with the first group, all the time-line analysis indicators were reduced. The LF-waves enhancement points to the subcortical center activation under the high VLF-waves contribution, which suggests tension of the regulatory-adaptive mechanisms. In the AOT conditions, a relatively low activation of the sympathetic component of regulation is observed, compared to the at-rest condition against the background of a significant growth of the cerebral ergotropic effect (VLF - 40.8±4.5% against 29.3±14.6%, p≤0.05). This demonstrates the decrease in

![Figure 1. The HRV indicators at rest and in the AOT conditions at football players with a high degree of the cardiovascular system adaptation (group 1), with an adaptation mechanisms tension (group 2) and with an unsatisfactory adaptation of the cardiovascular system (group 3).](image)

Table 1. The (M±m) HRV indicators at rest within the groups of students not engaged and engaged in the sports activities in the mode of specialized sports clubs

| HRV indicators | Students playing football | Students playing basketball |
|----------------|--------------------------|---------------------------|
| HR, bpm        | 67.6±9.4                 | 63.0±8.2                  |
| SDNN, msec     | 78.5±23.7                | 96.0±22.6*                |
| RMSSD, msec    | 70.4±13.2                | 94.1±17.4*                |
| pNN50, %       | 29.9±6.3                 | 33.5±4.9*                 |
| CV, %          | 8.9±3.6                  | 10.5±3.7                  |
| TP, msec²      | 5681.7±165.3             | 6160.3±428.1*             |
| LF/HF          | 1.6±0.3                  | 1.1±0.3                   |
| VLF, %         | 33.7±8.5                 | 32.7±3.9                  |
| LF, %          | 33.9±6.9                 | 31.1±5.4                  |
| HF, %          | 32.3±7.5                 | 36.2±6.2                  |

Legend: significance of differences (p≤0.05)* between football and basketball players.
the functional reserves of the cardiac activity regulation mechanisms.

Basketball players having stressed regulatory mechanisms (in 20.0% of cases) are characterized by the parasympathetic nervous system's prevalence in the regulation of the cardiac rhythm control, which indicates the absence of the stress state of the regulatory mechanisms at rest, which we observed in football players of the same group (Figure B2). Whereas, the level of functioning of the autonomous contour of regulation is significantly higher than in football players of the similar group (SDNN in basketball players is 107.1±26.2msec, in football players -76.1±13.2msec, р≤0.01). The stress of the regulatory-adaptive mechanisms became apparent only during the AOT conduction and consisted in the decline of the spectrum power (ТР<13.5%), reactivity of the parasympathetic division (HF-component<by 19.0%). The LF-waves prevailed in the HRV structure (42.4±3.8% against 28.6±4.9%, compared to the background, р≤0.01). The energy spectrum power of the Very Low Frequency waves (VLF) remained virtually unchanged. We observed a less pronounced inclusion of the cerebral ergotropic mechanisms than in football players.

The students playing football with an unsatisfactory adaptation of the regulatory systems (in 33.0% of cases) were characterized by the increased centralization of the cardiac rhythm mechanisms (Figure B1). A low value of the pNN50 indicator in reference to the first and second groups is substantiated by the significant tension of the regulatory systems, when the highest levels of control are included into the process of management, which leads to the almost complete suppression of the autonomous contour activity. The total power of spectrum is 3.3 or 2.0 times lower than at the first and second types of adaptation. Some authors consider this as a sign of decrease in the protective and restorative activity of the parasympathetic component of regulation. They also demonstrated an increased tone of the sympathetic nervous system (LF-waves - 35.8±8.7%) as a universal stress implementing mechanism against the background of the low regulatory-adaptive status. Out of the HRV spectral components, the largest share accounted for the VLF-waves pointing to a significant increase in the suprasegmental mechanisms' effect on the cardiac rhythm formation and reflecting the power-hungry state of the athletes' bodies.

The AOT conducted among the football players who had unsatisfactory adaptation revealed an increase in the sympathetic component of regulation at an insufficient reactivity of the VNS parasympathetic division. A significant growth of the LF-waves was observed at a sharp decrease in the HF-waves contribution and slight decline in the VLF-waves contribution to the total power. This is due to a certain degree of depletion among the functional reserves of the regulatory-adaptive mechanisms, wherein the systems of regulation cannot provide for a favorable vegetative balance even at rest; and, where an urgent response to the non-specific load is required, an inclusion of the central contour of the cardiac activity regulation is enhanced. At the same time, the balance of the sympathetic-vagal effects on the cardiac rhythm (LF/ HF - 2.2±0.5) shifted to the side of sharp prevalence of the sympathetic nervous system effect. Based on these data, it is possible to talk on the state of the functional over-tension or over-training of the football-playing students from the group with an unsatisfactory adaptation.

In the students playing basketball who had unsatisfactory adaptation (22.0%) of the regulatory systems, the HRV indicators also showed increased centralization of the cardiac rhythm mechanisms. A growth in the percentage of the Low Frequency waves of the first (LF) and second (VLF) order (р≤0.05) was observed. A higher level of the regulatory mechanisms functioning at the basketball players of this group should be noted in contrast to the football players. The AOT results confirmed the stress of the regulatory mechanisms and depletion of the functional reserves of the mechanisms regulating the blood circulation under an unfavorable type of adaptation, but with that, the basketball players demonstrated higher orthostatic tolerance.
In the group of students not engaged in the sports activities, the following two types of adaptation were revealed: those who had stressed regulatory systems (48.0%) and those who had unsatisfactory adaptation (52.0%). At the same time, we observed no coherence between the central and autonomous contours of the cardiac rhythm regulation. This allows us to conclude that the optimization in the regulation of the cardiac rhythm of the football and basketball players who had the first and second types of adaptation is precisely the consequence of the regular athletic loads. The results obtained are consistent with the research carried out by the author on a number of athletes (Shakhanova and Kuz’min14).

The football and basketball players who had high adaptive CVS abilities demonstrated the best functional capacity of the respiratory system, when alongside with the low heart rate values, the high values of VC, FVC, IRV, ERV, MVV and TV were observed (Table 2).

The lower values of COC2575, MOC25 and MOC50 (Tables 2, 3) in football players as compared to the basketball players indicate a decrease in the total flow rate of the bronchial tree, which is obviously related to the difference in training modes.

In the group with the stressed regulatory-adaptive mechanisms, the external respiration indicators were within the limits of the standard values, but were significantly lower than those in the students with a high degree of the CVS adaptation were. The indicators of the reserve forces and the respiratory system endurance (VC, MVV) are significantly higher (\(p \leq 0.05\)) in the students playing basketball, which can be considered as an indicator of the more efficient adaptation capacity of their external respiratory system.

In the group of students who had unsatisfactory adaptation and experienced disregulatory manifestations in the mechanisms of the cardiac rhythm regulation, the significantly lower values of VC, FVC, IRV, ERV, MVV and TV were observed (Table 2).

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4. Discussion

Based on these conceptual provisions and using a system approach that provides the tools for the risks analysis and assessment with additional functionality, we have conducted a comparative physiological study of the cardiorespiratory system's functional state among the students attending sports clubs and the students who had a usual motor mode. The revealed economization of the CVS functions at rest in the majority of students (47.0% of football players and 58.0% of basketball players) occurred due to the high activity of the parasympathetic division of the vegetative nervous system (high values of HF, TP, RMSSD and SDNN) and reduction in the cerebral ergotropic effect at the low heart rate values, which,
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According to Baevskii R.M. (2001), is an indicator of the CVS's significant adaptation capacity. This is quite logical since it is known that the longstanding sports activities lead to the structural and functional transformations of the vegetative regulation (Grechishkina5). Based on the facts given, it is possible to say that the optimization within the cardiac rhythm regulation in these athletes results from the regular physical activities, since the students not engaged in sports did not demonstrate such consistency between the central and autonomous contours of regulation. A high parasympathetic tone is the result of adaptive transformation of the vegetative nervous system in response to the requirements specified for the blood circulation system by the intense athletic loads.

Table 3. The (M±m) indicators of the peak, mean, and maximum expiratory flow rate of the “flow-volume” curve of the forced expiratory at different types of adaptation within the groups of students that play basketball, play football, and those not engaged in sports activities

| Вид спорта, группа | FEV0.5, l/s | MEF25-75, l/s | MEF75-85, l/s | MEF25, l/s | MEF50, l/s | MEF75, l/s |
|-------------------|------------|---------------|---------------|-----------|-----------|-----------|
| Студенты, играющие в баскетбол | 1 группа | 6.8±1.1 | 4.0±1.1 | 8.8±1.0 | 7.2±1.1 | 9.8±1.9 | 4.8±1.1 |
| 2 группа | 6.7±1.2 | 5.1±0.8 | 7.4±2.5 | 7.1±1.7 | 8.3±0.1 | 4.7±0.8 |
| 3 группа | 6.2±0.9 | 3.8±0.4* | 7.2±2.0 | 6.9±1.2 | 7.9±0.7 | 4.5±0.3 |

| Студенты, играющие в футбол | 1 группа | *4.2±0.2 | *2.3±0.1 | *5.2±1.3 | *4.5±0.3 | 5.7±1.1 | *2.8±0.3 |
| 2 группа | 5.5±1.6 | 3.1±0.9 | 5.2±1.2 | 6.1±2.0 | 4.6±2.3 | 3.6±0.9 |
| 3 группа | 4.3±0.4 | 2.8±1.0 | 6.0±1.1* | 4.7±0.1 | 7.2±2.5* | 3.3±1.2 |

| Студенты, не играющие в спортивные виды | 2 группа | 5.7±0.6 | 3.3±1.3 | 5.1±1.3 | 5.7±1.7 | 3.6±1.3* | 3.2±0.7 |
| 3 группа | *3.9±0.5 | 2.3±1.0 | 5.4±1.3* | 4.2±0.1 | 3.2±1.3* | 3.4±1.0 |

Legend: (to the right) - significance of differences (p≤0.05)* between the athletes in groups with various adaptive abilities within one kind of sports; (to the left) - significance of differences (p≤0.05)* between the athletes in groups with various adaptive abilities of different kinds of sports.

We have revealed the differences in the quantitative and qualitative indicators of the regulatory-adaptive status between the representatives of different types of adaptation, which have shown that there are some peculiar features in the regulation of the blood circulation system.

The first group of athletes, in which basketball players had a higher degree of CVS adaptation, in comparison with the football players, has reliably higher values of SDNN, RMSSD and HF (p≤0.05). Reduced heart rate occurs due to the neurohumoral regulation that progresses during the process of long-term adaptation to physical loads (Abade, et al.4), which extends the diastole and reduces the oxygen consumption in myocardial. This indicates the prevailing effect of the parasympathetic component of regulation at rest and allows stating the development of the CVS's function economization in the conditions of basketball training. The obtained findings are consistent with the studies of Shakhanova and Kuz'min14,15 which showed that under the influence of the extended motor mode, the structure of the cardiac rhythm at rest is changed, reflecting the processes of the new, more favorable interrelations: reduction of the sympathetic and strengthening.
of the parasympathetic effects on the heart. This is very important for the development of functional and adaptive abilities of an organism, since the parasympathetic division ensures the recovery of various physiological indicators, abruptly changed after intense muscular work and replenishment of the consumed energy resources. This means that in the conditions of lesser intensity, the athletic load during basketball training is more efficient than during football training. The formation of the parasympathetic component of the cardiac rhythm regulation occurs, which results are the economization of the physiological functions and the reduction of the physiological “price” for the athletic performance achievement.

According to our data, there were no persons with the high CVS's adaptive abilities among the students not engaged in sports activities. This contradicts the data provided by Alabiso, Parirsi et al. (2001), according to which LF and HF had no significant difference between the athletes and non-athletes. Besides, the data, showing that the trained persons differ from the untrained ones by the HRV time-line indicators and do not differ by the spectral indicators, were also not confirmed in our study.

The rhythm regulation at rest of basketball players who had stressed CVS mechanisms was carried out under the influence of the balanced effects of the VNS's sympathetic and parasympathetic divisions. However, the basketball players as opposed to untrained persons and football players had a tendency to increasing parasympathetic modulations and total activity of the regulatory effects. The football players and non-athletes featured the prevalence of the sympathetic effects on the cardiac rhythm. It is known that an increase in the tone of a sympathetic division is a universal stress implementing reaction of an organism in response to a variety of factors (Selye13). It is important to note that the central energy-metabolic component of regulation, which is characterized by the power of a wave spectrum in the range of the Very Low Frequencies (VLF), is closely related to the functioning of the suprasegmental vegetative structures and the endocrine system, remains intact.

The students engaged in the sports games and the non-athletic students, who were the members of the group of persons who had unsatisfactory adaptation of the CVS regulatory mechanisms and were included in the risk group, demonstrated low activity of the VNS's parasympathetic division against the background of the high activity of the VNS's sympathetic division at rest. On the part of the central structures of regulation, the pronounced activity of the power of a very low frequency component of the spectrum (a high VLF indicator) was noticed. According to some authors, this fact can serve as the first sign of over-training or exhaustion of an athlete.

The CVS state is ultimately determined by the myocardial contractility, by the availability and capacity of the compensatory mechanisms capable of maintaining a sufficient level of blood circulation as a whole. The assessment of the functional reserves of an athlete's organism is one of the prerequisites for determining the functional state of an organism and the level of its physical training. The functional reserve can be determined from the ratio of the system's functioning level and the degree of the regulatory mechanisms’ stress. The level of the body's physiological reserves can be primarily judged according to the CVS functions' indicators within the AOT conditions (Saboul and Balducci15). Therefore, a comparative analysis of the CVS reactions and mechanisms of their formation as well as the determination of its functional reserves in athletes of various sports qualification in the AOT conditions are of certain interest. AOT allows assessing the reserve forces of the regulatory system of blood circulation, which can be considered as sufficient due to the generally accepted CVS concept, as an indicator of the adaptive reactions of the entire body.

During the orthostatic test, the studied students of the adaptive groups, depending on the dynamics of the cardiac rhythm variability indicators, demonstrated three variants of the regulatory reactions of the organism systems: autonomous, autonomously central and central. The results of the conducted studies allow considering the orthostatic test as an adequate method that expands the diagnostic capabilities of assessing the functional reserves of the mechanisms regulating the blood circulation systems of athletes.

We have established that in some cases, the reaction of students to the orthostatic test is of the autonomously central type. This gives grounds to consider the non-specific nature of the orientation of the cardiac rhythm response to the orthostasis. The central variant of the reaction indicates that the blood circulation regulatory mechanisms are orthostatically intolerant. According to Yamamoto17, the entire diversity of the orthostatic reactions, which are not accompanied by the clinical signs of the blood flow disturbances, should be considered as a functional standard. However, even with such a low level of effect on the CVS, of which the orthostatic test is a kind, a mismatch of the regulatory mechanisms can manifest itself in the form
of a vegetative instability. At the same time, the specific nature of the cardiac rhythm regulatory mechanisms’ response to the orthostasis finds its expression through the increased activity of the sympathetic division of the vegetative nervous system and the central regulatory mechanism (Shakhanova and Kuz’min14).

Depending on the type of adaptation, the qualitative and quantitative differences of the response pronunciation of the athletes’ body were revealed. At orthostasis, the dependence between the functional reserve and the degree of the regulatory mechanisms activity in athletes can be clearly seen depending on the type of the CVS adaptation. The largest functional reserves of the mechanisms regulating the blood circulation system, regardless of the kind of sports, belonged to the athletes with a high degree of the CVS adaptation (the autonomic and autonomously central variants of regulation). If the regulatory mechanisms do not possess the necessary functional reserve or if there is a hidden insufficiency of the blood circulation system, then the orthostatic load manifests itself in the body as a disorder of the regulatory systems. The non-specific responses at the orthostatic effects reflect the dynamics of reduction in the functional reserves of the regulatory mechanism, which is substantiated by a decrease in the energetic and metabolic reserves (Shakhanova and Kuz’min14). The decrease in the organism’s reserve forces requires a higher tension of mechanisms in order to ensure an adequate response to the orthostasis (a central variant). This was exactly what we observed in all the students from the third and partially from the second groups (football and basketball players) regardless of the sport event. According to Yamamoto17 this fact is a convincing proof of that the regulation of the adaptive changes of an organism is carried out due to the constant interaction between the physiological systems.

While assessing the nature of the lungs ventilation function at rest among the students as a whole who attended sports clubs, we can talk on the respiratory function economization and on the enhancement of the gas exchange efficiency, which are the results of a new level of the functional interactions in the lungs, being established during the process of long-term adaptation to the physical loads at training.

The students playing basketball and possessing no sports categories demonstrate that their patency of airways and respiratory muscle capacity are higher than those of students playing football are (p≤0.05). The specified increase in the bronchial permeability leads to the conclusion on the increase in the functioning surface area of the alveolar-capillary membranes on the enhancement of the blood flow volume in the capillary bed of lungs and on the use of the large amounts of oxygen in the ventilated air, which can significantly increase the degree of the aerobic performance of the athletes’ organism. Apparently, this occurs due to the relaxation of the trachea and bronchi smooth muscle and inclusion into the breathing process of the previously not functioning alveoli. The football players that had no sports categories demonstrated lower values of indicators characterizing the patency of bronchi.

For the athletes engaged in the game sports, endurance is of great importance, which requires the development of the aerobic capacity that can be ensured by a high level of bronchial permeability in the medium and small bronchi. The data obtained by us extend the idea that the pronounced manifestation of the economy of lung ventilation, the growth of the reserve forces due to the increase in the bronchial permeability and in the force of the respiratory muscles contraction and the enhancement of the functional abilities of the respiratory system are typical of the representatives of the game sports. Despite the reliable differences in values between the football and basketball players that characterize the bronchial permeability, all the students engaged in the game sports showed high values of indicators (p≤0.05). However, the values of basketball players were significantly higher. The relatively high functional abilities of the breathing system are an essential prerequisite for the achievement of high sports results and efficiency of the sports activity in basketball due to the enhanced motor skills necessary during the game and requirements to the state of the respiratory system because of the specificity of this kind of sports (the demand for the abrupt mobilization of the external respiratory functions caused by the constant need for committing “jerks” to short and medium distances during the game process). The paradoxically lower indicators of the lung ventilation of football players, unlike the basketball players, evidence the body’s over-stress in the conditions of a training regime inconsistent with the functional abilities. The performance achievement on the playing ground is gained due to the higher “price” for adaptation against the high level of tension of the regulatory-adaptive mechanisms. All the more so, the studies carried out on the same contingent by T.G. Petrova et al.8 demonstrated the high values of physical performance and overall endurance of the football playing students’ body against the background.
of the high stress of the neurophysiological mechanisms of adaptation.

These data are not only of the theoretical interest, deepening the understanding of the individual characteristics of the organism adaptation process. They can also be effectively used during the sports selection, training sessions, educational and pedagogical process with the purpose of health maintenance, over-tension prevention and proper planning of the training process. Ultimately, the rational construction of the educational and training process in accordance with the dynamics of indicators of the functional state of the organism’s main systems will improve the sports performance without compromising the athlete’s health and develop the effective health and fitness technologies for college students.

5. Conclusion

- A reduction in the cerebral ergotropic effect is determined as well as the strengthening of the HF-waves contribution to the overall spectrum of the cardiac rhythm variability at rest among the students engaged in sports activities, which indicates an improvement of the regulatory-adaptive abilities, weakening of the cortic-subcortical effects on the cardiac performance and activations of the self-regulatory processes and the power saving behavior of the body. However, an individual analysis has shown that the influence of the systematic physical activities leads to the unification of such a high regulatory-adaptive status in 53.0% of football players and 42.0% of basketball players. High centralization of the cardiac rhythm regulation is observed against the reduction in the reserve functional abilities of the body.

- The quantitative and qualitative indicators of the cardiac rhythm variability and the tension degree of the regulatory mechanisms at rest have allowed us to reveal three types of adaptation within each studied group. These three types of adaptation are as follows: a high degree of adaptation is observed in 47.0% of football players and 58.0% of basketball players; stressed regulatory mechanisms are typical of 20.0% of football and basketball players; unsatisfactory adaptation is featured by 33.0% of football players and 22.0% of basketball players. The risk group includes the students not involved in sports. Among them, there is no contingent with a high regulatory-adaptive status. The highest percentage of people has unsatisfactory adaptation (52.0%), wherein the sympathetic component significantly predominates in the cardiac rhythm modulation, which indicates the functional failure of the inhibitory vegetative effects.

- The differences in the regulatory-adaptive status are established between the representatives of various types of the cardiovascular system adaptation. At the students with a high degree of adaptation in the HRV spectrum, the HF-waves prevail over the LF-waves. The group who have stressed adaptive mechanisms in the total power of the spectrum, especially the football players, demonstrate a decrease in the power of the HF-waves (by 30.0%) against an increase in the VLF-waves (by 27.0%), which points to the enhancement of the sympathetic component of regulation and reduction of the functional reserves of the cardiac rhythm regulating. At the same time, the regulatory mechanisms tension in the track and field athletes is revealed only in the conditions of the active orthostatic test. The group with an unsatisfactory adaptation demonstrates the significant prevalence of the sympathetic component of regulation (LF) over the parasympathetic component (HF). The SDNN and RMSSD values are 2 times reduced in comparison with the high type of adaptation, especially among the students not engaged in sports activities, which indicates the high tension of the mechanisms regulating the cardiac activity.

- In the conditions of the active orthostatic test with a high degree of adaptation at the football and basketball players, we can observe an autonomously central variant of regulation, which is accompanied by the contiguous growth of the LF- and VLF-waves. In the groups of people who had unsatisfactory adaptation, the active orthostatic test shows only the central variant of the cardiac rhythm regulation, which is an evidence of the orthostatic intolerance and a high tension of the regulatory-adaptive mechanisms.

- The students involved in sports demonstrate the highest values of the static and space-speed parameters of the external respiratory system than the non-athletic students. The improvement of the lung ventilation efficiency under the effect of the regularly sports-oriented physical activities (on average by 2 times if compared to the students not involved in sports) can be achieved due to the increase of the following indicators: Vital Capacity (VC), Maximum Voluntary Ventilation (MVV), Tidal Volume (TV), Inspiratory and Expiratory Reserve Volumes (IRV, ERV), Forced...
Vital Capacity (FVC) and the bronchial permeability in the distal divisions (MEF75–85).

- The students with a high degree of adaptation of the Cardiovascular System demonstrate the highest values of the indicators of the external respiration function: VC (5.5±0.8l - basketball players and 5.3±0.4l - football players), MVV (116.0±18.6l and 112.9±12.7l, accordingly), MEF75–85 (4.0±1.1 l/sec and 2.3±0.1 l/sec, accordingly). The contingent with an unsatisfactory adaptation of the Cardiovascular System, in contrast, is characterized by the decline in the indicators of the lung ventilation economy and efficiency with respect to the contingent with a high degree of adaptation (by 27.0% - in basketball players, by 28.0% - in football players and by 37.0% - in students not engaged in sports activities), which cannot help but have a negative impact on the formation of the aerobic provision, reduction in the functional reserves for overcoming exhaustion, especially when engaged in the mass kinds of sports.

6. References

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