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Peculiarities of Heart Rate Variability of Female Students with Various Motion States

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Abstract

Objectives: The study of effect of sports loads on adaptive and regulatory capabilities of female students' bodies with various motion states is of interest from the perspective of discovery of mechanisms of long-term and individual adaptation to physical effects. **Method:** Female students, which are the members of volleyball and basketball group (53 persons) aged 18-21, served as test subjects. Female students not engaged in sports activities (save for 2 hours of physical education per week) have been examined as a control group. Electrocardiogram (ECG) recording and calculation of heart rate variability (HRV) were carried out by means of Poly-Spectrum-8/EX hardware and software complex in prone position for 5 minutes. **Findings:** Two regulation groups have been identified in each sport: with the predominance of central and autonomous type of regulation. The first group with the predominance of central type of regulation is characterized with lower values of time analysis – SDNN, RMSSD, pNN50%, CV% – and high **SI**. The predominance of slow waves of the first order (LF) and the second order (VLF) has been registered in the rate spectrum. Sports physical loads result in growth of general power of regulatory impact, which increases adaptive capabilities of female athletes' bodies. Sports activity in the course of volleyball and basketball training sharpen tension of adaptive mechanisms and significantly increase "adaptation price" for representatives of the first group; especially high tension of adaptive mechanisms was found in the first group of female basketball players. The most favorable adaptive status was shown by female athletes of group 2, which makes it possible to conclude that sports physical loads favorably affect female athletes of this group, since they had significantly higher adaptive potential as compared to the test subjects. **Application:** In general, sports activities promote normalization of regulatory mechanisms status and reduction of quantity of members of the first adaptation group (with predominance of central regulation type). Such regulation type is characteristic of the absolute minority of female athletes, while a half of the test subjects, who are not female athletes, demonstrate such regulation type.

Keywords: Adaptive and Regulatory Peculiarities, Basketball, Female Students,Cardiovascular System, Heart Rate Variability, Vegetative Nervous System, Volleyball

1. Introduction

Modern educational process in higher school is notable for progressive intensification. However, given the fact that students are not similar, offered academic and physical loads are not adequate for everyone.

Increase in motor activity is one of the key issues; in this regard, it is necessary to make a comprehensive assessment of the impact of mental, physical, psychological and emotional loads on the mechanisms, which support the process of long-term adaptation to educational activities.

Vegetative nervous system and balance of sympathetic and parasympathetic divisions play an important role in providing adaptation processes. The condition of regulatory mechanisms affects the final result of the activity of cardiovascular system and whole-body regulatory and adaptive capabilities. The heart is rather sensitive indicator of all processes taking place in the body, since cardiovascular system is a basic adaptive and regulatory system of not just homeostatic, but the adaptation layer.[1] Transition from urgent phase into stable long-term adaptation is based on formation of functional changes

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primarily in cardiovascular system and its regulatory mechanisms. In this regard, study of change of regulation quality of the cardiovascular system of students under the influence of sports load is of certain interest.

In recent years, a particular emphasis is put on the need for detailed study of the heart rate variability and hemodynamics, as disruption of adaptive and regulatory mechanisms precedes occurrence of hemodynamic, metabolic and energetic disruptions. Therefore, the study of heart rate variability is the main prognostic sign of disruption and breakdown of adaptation mechanisms.[2,3]

Sports activities, especially team sports (volleyball, basketball) are very popular among the students. However, study at a higher education institution combined with sports activities imposes high requirements on the condition of regulatory and adaptive mechanisms. Physical loads play a significant role in formation of functional reserves of the body, but it is important to remember that their volume should not exceed functional capabilities of the body. Load adequacy principle is very important, since training programs accompanied with study at a higher education institution are not always designed to account for adaptive and regulatory capabilities.[4]

Numerous literature related to study of the impact of sports trainings on the condition of blood circulatory system, including the heart's pumping function and hemodynamics, gave relatively little attention to study of the mechanisms of vegetative regulation of heart activity based on analysis of HRV. In recent years, some authors emphasized the need for more detailed study of HRV, since disruptions in the state of body regulatory systems precede occurrence of hemodynamic, metabolic and energy problems, which are the earliest prognostic signs of prenosological states.[1,4] According to the literature on the subject, girls experience emotions with higher arousal, emotional instability and anxiety, as compared to boys, they are characterized with less developed velocity and general body stamina associated with more aerobic capacities and less energy conserving manner of exercising.[5] In view of the above, study of the effect of sports loads on adaptive and regulatory capabilities of female student's bodies with various motion states is of interest from the perspective of discovery of the mechanisms of long-term and individual adaptation to physical effects.

2. Methods

Research was carried out at the premises of Child Development Physiology Laboratory of the Research Institute for Complex Issues at **Adygea** State University. Electrocardiogram (ECG) recording and calculation of heart rate variability (HRV) were carried out by means of Poly-Spectrum-8/EX hardware and software complex in prone position for 5 minutes.

To better quantify the periodic processes in heart rate spectral analysis was involved, which allows evaluating the interaction of cardiac rhythm management levels. Spectral analysis consisted in measuring power of VLF-, LF-, HF-waves in the spectrum of heart rate variability which was performed in percentage of the total power of the spectrum (TP), which shows the relative contribution of each component in the total power of heart rate fluctuations.

Time method was based on statistical analysis of the changes in the duration of successive R-R intervals between typical sinus cardiac cycles with the calculation of a variety of coefficients. The statistical characteristics of a dynamic line of cardio intervals include SDNN, RMSSD, pNN50, CV, which are determined primarily by the influence of the parasympathetic part of the autonomic nervous system and is a reflection of sinus arrhythmia associated with breathing.[2]

Mathematical analysis of heart rate according to R.M. Baevsky[1] was carried out to analyze the performance of Mode (Mo) and Mode amplitude (AMo), which reflect the measure of the mobilizing impact the of sympathetic division. Besides, the **stress index (SI)** was used in the analysis, which reflects the degree of centralization of heart rhythm management.

Female students, which are the members of volleyball and basketball group (53 persons) aged 18-21, served as test subjects. Female students not engaged in sports activities (save for 2 hours of physical education per week) have been examined as a control group.

The division of the surveyed contingent into adaptive groups was performed, using the classification of states according to the degree of regulatory stress index by Bayevsky[1] and types of vegetative regulation according to N.I. Shlyk.[3]

The contingent under analysis was divided into two groups: the first group – with a predominance of the central type of regulation and the second group – with a predominance of self-contained regulation.

3. Results

Female student volleyball players of group 1 (with predominance of central regulation) amounted to 31% of

the total quantity of examined female volleyball players and demonstrated low general spectrum power (TP-1140.6 ms^2±546, p≤0.05), decreased RMSSD values (36.4 ms±17.4, p≤0.001), SDNN (32.6 ms±10.3, p≤0.001), pNN50 (22.4%±17.7, p≤0.01), which evidences tension of adaptive and regulatory mechanisms (Table 1). High values of AMo (52.3s±11.7, p≤0.001) and Mo(0.7s±0.03, p≤0.001), which reflect influence of the sympathetic link of regulation of vegetative nervous system, also evidence adverse condition of the cardiovascular system. The **stress index**, which reflects the degree of tension of regulatory systems, is also an important informative indicator of adaptive and regulatory condition of the body. In this group, **stress index (SI)** has high values (210.5±103.1, p≤0.001), which is indicative of overstrain or unsatisfactory adaptation condition. In such condition, functional capabilities of the body decrease, which can result in non-specific changes of certain organs and the entire body.[6]

Analysis of the rate spectrum revealed predominance of slow period waves (LF%-33.4±8.2, p≤0.001), which evidence apparent predominance of activity of the sympathetic system of vegetative nervous system and proves significant tension of adaptive and regulatory mechanisms in this group and can be seen as a condition of evident tension of adaptive mechanisms or fatigue (Table 1).[7]

Table 1. HRV values (M±m) of female student volleyball players at rest

HRV Values	Group 1	Group 2
TP, ms^2	1140.6±546	8294.3±4513.2
VLF, ms^2	399.4±229.8	1808.5±1307.1*
LF, ms^2	383.4±221.1	2575±2112*
HF, ms^2	358.3±215	5183±3677*
VLF%	38.2±14.9	18.9±6*
LF%	33.4±8.2	25.9±4.8*
HF%	27.8±9.8	55.2±6*
RRNN, ms	737.6±29.3	897.4±168.7*
SDNN, ms	32.6±10.3	127±47.1*
RMSSD, ms	36.4±17.4	134.9±45.3*
pNN50, %	22.4±17.7	43.6±23.4*
CV, %	4.2±1.3	14.2±4.6*
Mo, c	0.7±0.03	0.9±0.1*
AMo, %	52.3±11.7	36±16.2*
SI, c.u.	210.5±103.1	18.3±13.3*

Notations: to the left – significance of differences (p≤0.001) among different groups

The second group of female student volleyball players with predominance of autonomous type of regulation amounted to 69% of the total quantity of examined female volleyball players and demonstrated high statistical values of HRV (SDNN-127 ms±47.1, p≤0.001; RMSSD-134.9 ms^2±45.3, p≤0.001; pNN50%- 43.6±23.4, p≤0.01) (Table 1).Increase of such values registered in this group gives evidence of shift of the vegetative balance towards predominance of parasympathetic regulation link of the vegetative nervous system.[2,5]

Spectrum analysis of background components of the HRV showed low values of VLF% (18.9±6, p≤0.001) and LF waves (25.9±4.8%, p≤0.01). At the same time, fast waves (HF- 55.2%±6, p≤0.001), which evidence hypersthenia of parasympathetic nervous system, make the biggest contribution into rate spectrum (Table 1).

The first group of female student basketball players with the predominance of central type of regulation amounted to 27% of female basketball players and demonstrated low TP values (1375.5±289.3, ms^2 p≤0.05); however, these values were higher than similar ones shown by female volleyball players, i.e. in the course of volleyball training the overstrain condition is developed to a greater extent as compared to basketball, which, in our opinion, can evidence smaller time dedicated to overall physical conditioning during volleyball training (Table 2). The rate spectrum of this group demonstrated predominance of low frequency (LF%-29.75±10.5, p≤0.001) and very low frequency waves (VLF%-48.5±17.8, p≤0.001) provided that high frequency waves made insignificant contribution to the rate spectrum (HF% - 21.75±7.3). The above data, together with high values of **stress index** (**SI** 244.7±83.3), evidence the condition of increased functional tension of the adaptation mechanisms, i.e. adaptation of the body to the conditions of sports training within this group of test subjects is achieved through significantly higher tension of regulatory systems as compared to the group of female volleyball players, which results in increased consumption of the functional reserves of the body.[1] It also creates the danger of the adaptation breakdown and disruption of the intersystem and intrasystem functional links in the body and, as a result, occurrence of pathological processes.

The second group of female students, who are members of the basketball group (73% of female basketball players), demonstrated high values of the total spectrum power (TP – 7386.3±3188.6, p≤0.001), which reflect the extent of activation of periodic components of the heart rate (Table 2). The time analysis of this group has sig-

nificantly (p≤0.001) high values of SDNN (88.5±21.3), RMSSD (105.75±25.5), pNN50 % (64.8±9.4), CV % (9.01±2.4), which evidence significant predominance of the parasympathetic regulation link over the sympathetic link. Thus, predominance of the parasympathetic tone of the vegetative nervous system and high activity of autonomous control structures at rest evidence that the regulation systems of female student basketball players of this group are in optimal condition and reflect high energy and reserve capabilities of bodies.[8]

The spectrum analysis of this group has explicit inclusion of high frequency waves (HF). Normally, vagal activity is the main constituent of a high-frequency component, which is reflected by the value of the total power of respiratory waves of the heart rate in absolute numbers (HF-4073.75±2406.1 ms^2, p≤0.001) and as a relative value (HF%-55.2±6, p≤0.001) – therefore, HF-waves values are indicative of the condition of vegetative nervous system. The **stress index** within the second group of female student basketball players has significantly (p≤0.001) lower values (29.8±17.4) than the first group of this section (Table 2).

Table 2. HRV values (M±m) of female student basketball players at rest

HRV Values	Group 1	Group 2
TP, ms^2	1375.5±289.3	7386.3±3188.6*
VLF, ms^2	628.5±149.6	1827.8±949.3*
LF, ms^2	432.75±240.4	1484.6±628.9*
HF, ms^2	314.5±174.6	4073.75±2406.1*
VLF%	48.5±17.8	27.1±14.3***
LF%	29.75±10.5	20.3±3*
HF%	21.75±7.3	52.6±13.1*
RRNN, ms	721±93.6	991.8±105*
SDNN, ms	32±5.9	88.5±21.3*
RMSSD, ms	23±12.9	105.75±25.5*
pNN50, %	8.62±13.6	64.8±9.4*
CV, %	4.4±0.2	9.01±2.4*
Mo, c	0.7±0.09	0.9±0.1*
AMo, %	51.4±6.9	24.9±5.7*
SI, c.u.	244.7±83.3	29.8±17.4*

Notations: to the left – significance of differences (p≤0.001) among different groups

All of the aforesaid allows concluding that the parasympathetic link of regulation of the vegetative nervous system predominates in the second group of female student basketball players at rest, which is the most favorable combination of centralization and autonomy of heart rate control associated with development of high functional reserves of regulation of physiological functions of the body.[2]

Analysis of the values demonstrated by female non-athlete students in the first group with predominance of the central type of regulation (43% of the examined female non-athletes) showed that the absolute figures in the rate spectrum have low values (LF-370.5±202.7, ms^2; HF- 223±157.1, ms^2, p≤0.001), which is lower than in other groups. Low frequency (LF%-30.07±6.1, p≤0.001) and very low frequency waves (VLF%-52.6±9.8, p≤0.001) make the most significant contribution into the rate spectrum, which evidences condition of exhaustion of regulatory systems (Table 3). The capabilities of regulatory and adaptive mechanisms on the segmental level turn out to be insufficient to achieve useful adaptive effect within this group, which results in inclusion of the central regulation circuit. Fast waves have low values (HF%- 17.2±6.5, p≤0.001). **SI** was also high within this group (233.2±122.3, p≤0.001). Obtained data evidence significant impact of the sympathetic regulation of the heart rate, which reflects decreased functional condition of the body.

The time analysis of this group (SDNN-30.5±7.9 ms, RMSSD-23.5±10.5 ms, pNN50%-6.2±8.7, p≤0.001) also shows the lowest values as compared to the first group of female students, who are members of volleyball and basketball classes. This evidences sharp increase of the sympathetic link of regulation. Increase of the sympathetic regulation during physical or emotional overloads results in decrease of adaptive capabilities of the heart rate and affects characteristics of the heart rate at theinitial state.[9,10]

The second group of female students, who are not engaged in sports activities (57% of examined female non-athletes), with predominance of the autonomous type of regulation demonstrates predominance of fast waves in the rate spectrum (HF%-51.3±7.4, p≤0.001). Values of the total spectrum power TP - 3225±1075.6 ms^2 are the lowest as compared to the second group of students, who are members of volleyball and basketball classes (Table 3). The absolute values of a spectrum constituent have significant differences

(p≤0.001) as compared to the first group of female non-athlete students, but lower values as compared to the second

group of female athlete students (VLF-794.75±291.3,ms^2, LF-734.3±260.7,ms^2, HF-1696.25±722.9, ms^2, p≤0.001). In this group, the predominance of parasympathetic link of regulation of vegetative nervous system is registered, but to a lesser extent than in case of female students, who participate in sports activities, i.e. less favorable vegetative balance of heart activity regulation is observed as compared to female students, who are engaged in sports activities within sports classes.[11-12]

Table 3. HRV values (M±m) of female students not engaged in sports activities, at rest

HRV Values	Group 1	Group 2
TP, ms^2	1210.07±568.6	3225±1075.6*
VLF, ms^2	616.5±254.2	794.75±291.3
LF, ms^2	370.5±202.7	734.3±260.7*
HF, ms^2	223±157.1	1696.25±722.9*
VLF%	52.6±9.8	25±6.6*
LF%	30.07±6.1	23.3±6.1*
HF%	17.2±6.5	51.3±7.4*
RRNN, ms	732.6±410.5	817.6±104.8*
SDNN, ms	30.5±7.9	54.5±10.5*
RMSSD, ms	23.5±10.5	56.1±19.8*
pNN50, %	6.2±8.7	33.8±23.3*
CV, %	4.1±0.8	6.6±0.8*
Mo, c	6.4±21.4	0.8±.11
AMo, %	50.9±16.2	37.4±11.4*
SI, c.u.	233.2±122.3	71±30.9*

Notations: to the left – significance of differences (p≤0.001) among different groups

Time analysis of a group with predominance of the autonomous type of regulation among female students, who are not engaged in sports activities, shows significantly higher values as compared to the first group of female non-athlete students: SDNN- 54.5±10.5ms, RMSSD-56.1±19.8 ms, pNN50% 33.8±23.3, CV%-6.6±0.8, p≤0.001. **SI** also has higher values as compared to the first group (71±30.9, p≤0.001), but lower values as compared to the second group of female students, engaged in basketball and volleyball; therefore, it is possible to conclude that engagement in sports activities favorably affects development of the adaptive and regulatory mechanisms of the body.[13-14]

4. Discussions

Apart from the hydrodynamic functions, cardiovascular system plays the role of a link in interrelations between the mechanisms of regulation and information and morphological structures of the body.[7] Changes of the heart rate due to activity of regulation mechanisms can be seen as a result of activity of different divisions of the vegetative nervous system, which modulate the heart function, in particular, heart rate.[15] Research carried out with respect to athletes shows that growth of fitness, regardless of sex and age of athletes, is accompanied with increase of waves, which evidence activity of the parasympathetic section of the vegetative nervous system (HF-waves), in HRV spectrum, and decrease of the share of slow waves (LF-waves), which reflect the activity of the sympathetic section of the vegetative nervous system.[5,7,16] High power of the spectrum (TP – 8294.3±4513.2,ms^2, p≤0.001) also evidences high functional reserves of the vegetative regulation of physiological functions of the body; however, the data obtained by us evidence presence of groups with different vegetative and adaptive potential within the same age group of the test subjects engaged in each sports. This fact substantiates the need for differentiated approach to design of the training process with due account for the adaptation group. Our study confirms thedata[17-19] that athletes have higher HRV values than non-trained persons.

5. Conclusion

Two regulation groups have been revealed in each group of the test subjects:

1.with predominance of the central type of regulation;

2. with predominance of the autonomous type of regulation.

The first group with predominance of the central type of regulation is characterized with lower values of time analysis – SDNN, RMSSD, pNN50%, CV% – and high **SI**. Predominance of slow waves of the first order (LF) and the second order (VLF) is registered in the rate spectrum.

Significantly higher values of time and spectrum analysis have been registered in the second group with predominance of the autonomous type of regulation. **Stress index** values were within the range of 18.3(±13.3) and 29.8(±17.4). HF-waves predominated in the rate spectrum. Thus, predominance of the parasympathetic

section of the vegetative nervous system was observed, which can be seen as the optimal condition of the adaptive and regulatory systems.

Female athletes showed significant predominance of the power of HRV as compared to female non-athletes; therefore, sports physical loads result in growth of the total power of the regulatory impact, which increases the adaptive capacities of female athletes.

Sports activity in the course of volleyball and basketball training sharpen tension of the adaptive mechanisms and significantly increase the "adaptation price" for representatives of the first adaptation group (with predominance of the central type of regulation); especially high tension of the adaptive mechanisms was found in the first group of female basketball players, which allows considering such test subjects a risk group. Increased medical supervision and correction of the training process is required for this group.

The most favorable adaptive status was shown by female athletes of adaptation group 2 (with predominance of autonomous type of regulation), which makes it possible to conclude that sports physical loads favorably affect female athletes of this group, since they had significantly higher adaptive potential as compared to the test subjects, who were female non-athletes of the same adaptation group.

In general, sports activities promote normalization of the regulatory mechanisms status and reduction in the quantity of members of the first adaptation group (with predominance of the central regulation type). Such regulation type is characteristic of the absolute minority of female athletes, while half of the test subjects, who are not female athletes, demonstrate such regulation type.

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