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Original Article

Features of cardiovascular system indices of women's football players as a function of their hormonal status

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Abstract:

The dependence of cardiovascular activity on the hormonal status of the female body was studied based on the evaluation of central hemodynamics parameters and cardiovascular system indices in each of the phases of the ovarian-menstrual cycle (OMC). The potential of myocardium in women's football players aged 18-20 is also highlighted. The purpose is to determine the level of the cardiovascular system and central hemodynamics functionality of 18-20-year-old women's football players in different phases of the OMC, and determine the presence and nature of the links between the studied parameters. Analysis and synthesis of library resources on the effects of hormonal changes during various phases of OMC on indices of athletes' myocardium functional state; paraclinical methods; methods of mathematical statistics were applied. The study is devoted to a more detailed investigation of the parameters of the bioelectric activity of the myocardium and the central hemodynamics parameters of women's football players in the various phases of the OMC.

Key words: women's football players, ovarian-menstrual cycle, cardiovascular system, central hemodynamics, physical capacity.

Introduction

Soccer as a sports game is inherent in dynamic work of variable intensity, uneven physical and psycho-emotional loads during the game, unpredictable change in game activities and pauses between them. The basis of modern training of athletes lies in the systematic approach - the synthesis of the theory of functional systems and the theory of adaptation, which allows obtaining significant information about the functional state of an athlete's body during the training process and using the obtained data for its correction.

For a long time soccer has remained the most popular sport. As a sports game, it requires a comprehensive training of players, because it requires dynamic work of varying intensity with uneven loads during the game. However, the persistent work of athletes and coaches sometimes is lowered by ignorance or neglect of the laws of the female body's activity, which, unlike the male, functions cyclically.

The sports training system of women's football players should be different from that of male football players - it must be built taking into account the biological characteristics of the female body, the most important of which is the hormonal reorganization during the ovarian-menstrual cycle (OMC).

However, a detailed study of the functional state of the cardiopulmonary system, the state of central hemodynamics and related indices of general physical capacity and the special readiness of women's football players in different phases of the biological cycle was not carried out sufficiently. **Analysis of recent research and publications.** Physical loads, which are an integral part of sports, cause significant changes in the body of female athletes [9,10]. Along with this, the course of metabolic processes, the activity of physiological and functional systems of athletes are constantly undergoing cyclical changes due to the phases of the ovarian-menstrual cycle [1,6,3,9]. There are quite a few studies devoted to the clarification of the peculiarities of the certain systems activity of the athlete's body in different phases during the OMC. Thus, Z. Ya. Yatsenko, T. P. Stepanova [7] studied the changes in the respiratory system, L. Ya.-G. Shakhlina - the respiratory system and central hemodynamics, O. Radzievskii [7], L .Ya.-G. Shakhlina [9,10] - changes in the physical capacity level. The medical examination was supposed to be for athletes of more traditional sports for women - gymnastics, swimming, track and field, biathlon, etc. At the same time, studies devoted to a more detailed study of the parameters of the bioelectric activity of the myocardium and the central hemodynamics parameters of women's football players in the various phases of the OMC are scarce.

The purpose and objectives of the study

To determine the level of the cardiovascular system and central hemodynamics functionality of 18-20-year-old women's football players in different phases of the OMC, and determine the presence and nature of the links between the studied parameters.

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Research methods

Analysis and synthesis of scientific and methodological literature on the effects of hormonal changes during various phases of OMC, on indices of athletes' myocardium functional state; paraclinical methods; methods of mathematical statistics were used.

The research stages. The distribution of a specific biological cycle in the phases was carried out in accordance with the criteria of N. V. Svechnikova, according to which the 28-day OMC is divided into five phases [6]. In each of the phases, the heart rate (HR), blood pressure (BP), and electrical activity of the myocardium of the athletes were determined. The examinations were carried out during 3 functional states - rest, physical activity (20 squatting per 30 seconds), and at the 5th minute restoration in sitting position.

A total of 40 women's football players aged 18-20 who studied at the Lviv State University of Physical Culture were examined.

The OMC phases were verified by radioimmunoassay of venous blood in the radioisotope laboratory of the Lviv Regional Clinical Hospital. Electrocardiographic examination was carried out on the basis of the Lviv Railway Diagnostic Center.

Materials and methods of research

Measurement of blood pressure (BP, mm Hg) was performed by the Korotkov method by a mechanical apparatus for measuring blood pressure of the model BP AGI-20. The definition of HR (beats/min.) was carried out with palpation on the radial artery for 15 seconds with the next recalculation to determine the number of beats per 1 minute. To study the state of central hemodynamics, the following parameters were used: BPmax (systolic blood pressure), BPmin (diastolic blood pressure), PBP (pulse blood pressure), ABP (average blood pressure), MBV (minute blood volume), SBV (systolic blood volume), PVR (peripheral vascular resistance), HI (heart index), BI (beat index).

An electrocardiographic study of the heart function was performed on the UCARD three-channel electrocardiograph "UTAS" (Russia), with automatic synchronous recording. The following amplitude and time parameters of the ECG were studied: the amplitude of the main P, R, T waves, and the duration of the intervals P-Q, QRS, Q-T, R-R. The evaluation of digital indices was performed with using of *Statistska 6.0* statistical programs.

Results and discussion

All studied parameters of myocardium electrophysiological activity of following women's football players aged 18-20 during the OMC were within the sexual and age norm. At the same time, in different phases of OMC, ECG indices had certain differences. In the first phase of the biological cycle, the physical activity did not change the duration of the P wave; the growth of the amplitude of this wave was not veritable (1.33 ± 0.48 versus 1.18 ± 0.62 mV at rest, $p > 0.05$). At the same time, during the restoration, there was a probable decrease in both the duration and the amplitude of the discussed wave in terms of the results obtained during the functional stress, as well as at rest ($p < 0.05$). Such changes in the duration and amplitude of the P wave were observed in the III phase of the biological cycle: the functional load was accompanied by a tendency to increase the discussed parameters ($p > 0.05$); during the recovery these figures decreased. In another way the atrium reacted to the II and IV phases of the OMC - in these phases, during the functional recovery there was an obvious tendency to increase the amplitude of the P wave relative to the results obtained both in load state and at rest. In the V phase of the OMC, the duration of the P wave practically did not depend on the functional state of the athletes, whereas its amplitude after loading increased and did not return to the initial level after rest ($p < 0.05$).

The analysis of the data suggests that in women's football players, in the vast majority of cases, physical activity was accompanied by an increase in the amplitude of the P wave. Its increase after physical activity and the subsequent reduction in recovery condition in the I, III and V phases of the OMC are the result of an increase in the tonus of the parasympathetic nervous system (n vagus), whereas the growth of the amplitude of the discussed wave in the state of recovery after loading in the 2nd and 4th phases is a sign of enhancement of the tone of the sympathetic nervous system. However, the strengthening of the influence of n. vagus on the heart muscle can be regarded as a sign of the economy of the heart activity while simultaneously accelerating the course of restorative processes in the myocardium during the "weak" phases of the biological cycle. It is important to note that the duration of the P wave in the V phase of the biological cycle did not depend on the functional state of the women's football players, which may also indicate the need to include additional compensatory possibilities of the myocardium in this phase. Reducing the duration of the P wave (as compared to the data obtained during the functional load), which is observed in the recovery stage in I and III phases of the OMC, may indicate miocardium tension in these phases of the biological cycle.

The duration of atrial-ventricular conduction in the myocardium of women's football players during I and III phases of the biological cycle under the influence of physical activity did not change. However, in the V phase of the biological cycle, the duration of the P-Q interval after exercise was reduced (0.14 ± 0.02 s vs. 0.15 ± 0.02 s at rest condition, $p > 0.05$) with subsequent return from recovery to initial indices (0.15 ± 0.01 s). The dynamics of changes in the duration of the interval P-Q during the II and IV phases of the OMC was different: after exercise in the second phase of the cycle, it elevated from 0.13 ± 0.02 s to 0.15 ± 0.02 s ($p < 0.05$), in the IV phase of the cycle - from 0.14 ± 0.02 s to 0.15 ± 0.02 s; ($p > 0.05$). In those phases of the cycle, the duration of atrial-ventricular conduction in the state of restoration after loading remained at the level of values achieved during physical activity. The established dependence of the duration of atrial-ventricular conduction on the functional status of women's football players indicates that in the II and IV phases of the cycle the conduction of impulse in the myocardium from the atria to the ventricles improves.

Changes in the duration of intraventricular conduction (QRS interval) in general terms repeated the changes in the R wave. Thus, during the I and III phases of the biological cycle, the duration of the QRS complex was resistant to physical activity (correspondingly, 0.05 ± 0.01 vs. 0.05 ± 0, 02 s and 0.06 ± 0.02 s vs. 0.06 ± 0.02 s at rest; $p > 0.05$). However, during the II and IV phases of the biological cycle, physical activity resulted in a slight increase of indices at rest ($p > 0.05$). At the same time, if in the II phase of the OMC, the duration of the QRS complex after restoration was slightly higher than at rest (0.06 ± 0.02 s vs. 0.05 ± 0.02 s, $p > 0.05$), then in the IV phase of the cycle it returned to the level of initial indices (0.05 ± 0.02 s vs. 0.05 ± 0.02 s). During phase III of the OMC some physical activity did not increase the time of intraventricular conduction, whereas after restoration it was significantly higher than at rest and after loading ($p < 0.05$ in both cases). We find the obtained results as signs of the tension of the compensatory mechanisms of the myocardium during a functionally significant for the female body phase of the biological cycle.

The analysis of the R-R intervals allowed to establish that in the III and V phases of the OMC after their physical activity, their moderate decrease, which was associated with the acceleration of heart rate, and after a five-minute recovery, a moderate increase (in all cases, $p > 0.05$), which, naturally, increases the load on the cardiac muscle and the cardiovascular system as a whole. In the first phase of OMC physical activity resulted in a definite decrease at rest, duration of the cardiac cycle (0.76 ± 0.05 s vs. 0.89 ± 0.08 s, $p < 0.05$) with subsequent restoration of its parameters to the rest state level (concerning that parameter in the state of physical activity $p < 0.05$, concerning that parameter in the state of rest $p > 0.05$). The obtained data may indicate that the potential of the myocardium in the I phase of the OMC is greater than in the III and V phases of the biological cycle The dynamics of the R-R intervals duration after physical activity and recovery during the "strong" phase of the biological cycle was different. Thus, in the II phase of the OMC physical activity resulted in its moderate growth relative to the parameters at rest ($p > 0.05$); after rest, the heart cycle was not fully restored: the duration of the R-R intervals practically did not differ from the data obtained after physical activity (1.03 ± 0.17 s vs. 1.09 ± 0.22 s, $p > 0.05$). In the IV phase of OMC physical activity resulted in a probable decrease in the duration of the interval R-R (0.90 ± 0.15 s vs. 1.00 ± 0.07 s; $p < 0.05$). After recovery, the duration of the cardiac cycle continued to be at the level determined after exercises (0.91 ± 0.15 s vs. 0.90 ± 0.15 s; $p > 0.05$). Thus, in the III and IV phases of the OMC, at the fifth minute of the recovery in the myocardium, there is a tendency to increase recovery processes. The increase concerning rest parameters of the duration of the R-R interval after exercise and rest in the second phase of the OMC is regarded as a sign of the influence of n.vagus on the circulatory system after physical activity. By contrast, a modest decrease after the functional trial of the R-R interval duration observed in the IV phase of the cycle can be considered as one of the signs of adaptation of the cardiovascular system to physical activity.

The electric heart systole (Q-T interval) is normally in wide range. The duration of the electric heart systole is an objective indicator of the functional capacity of the heart muscle: its increase, caused by tachycardia, indicates a violation of the coordination of myocardial functions due to stress. Such changes were observed at players' ECG in the I phase of the OMC (0.37 ± 0.02 s with heart rate of 72 beats/min at rest and 0.36 ± 0.03 s at heart rate of 79 beats/min after physical activity). In other phases of the biological cycle, the duration of the Q-T interval corresponded to heart rate, which is a good sign.

Thus, the analysis of changes in the bioelectric activity of the cardiac muscle confirmed the distribution of the phases of the OMC to "strong" and "weak". At the same time, both of them were not homogeneous. Thus, women's football players' I and V phases of the OMC were characterized by greater potential myocardial capacity than the III one, in which there were signs of tension of the compensatory mechanisms of the atrium. However, in the first phase of the cycle, there was a violation of coordination of myocardial activity and its insufficient ability to recover after physical activity, and in the V phase, due to the reduction of reserve ventricular capacity, there was clearly a need for the inclusion of additional compensatory mechanisms. It was established that in the "strong" phases of the biological cycle, the atrial-ventricular conductivity was better than that in the "weak" ones, and the manifestations of the action of compensatory mechanisms in the myocardium was less; in the IV phase of the biological cycle, the potential of the myocardium was greater than that of the II phase.

For a more detailed examination of the cardiovascular system, we determined the state of central hemodynamics

The definitions of heart rate and blood pressure were investigated at a rest state. The study results concerning the central hemodynamics indices range during different phases of the biological cycle are presented in Table. 1

Table 1. Indices of central hemodynamics of the women's football players aged 18-20 during different phases of OMC, n = 40

Indices	**OMC phases**				
	I X±m	II X±m	III X±m	IV X±m	V X±m
HR (beats/min)	а) 69.10±5.59	65.90±6.38	63.90±4.83*	70.37±6.50#•	74.33±7.34*#*
	б) 75.50±5.28	73.35±5.98	70.10±5,04	75.55±6.33•	77.25±8.15•
BPmax (mm Hg)	а) 114.67±6.81	114.33±6.79	107.33±8.07*#	113.17±7.01•	109.33±7.34*#
	б) 103.75±9.58	103.75±9.58	98.75±10.37	103.75±9.16	102.75±9.39
BPmin (mm Hg)	а) 65.83±5.10	65.33±5.07	63.67±5.56	67.33±4.10•	60.67±3.88#•
	б) 61.75±4.94	61.75±4.94	59.50±6.05	58.25±4.94*#	61,25±5.82.
PBP	а) 48.83±6.25	49.00±6.87	43.67±7.06*#	45.67±6.91	48.67±6.9•
(mm Hg)	б) 42.00±8.18	42.00±8.18	39.25±9.36	45.50±7.59•	41.25±9.01
BPaverage (mm Hg)	а) 85.79±5.34	86.59±4.87	82.44±5.78*#	86.97±4.45	81.53±4.80*#
	б) 79.81±6.08	78.81±7.31	76.38±6.76	77.82±5.99	78.99±6.01
SBV (ml)	а) 73.40±5.07	73.90±5.09	72.15±5.53	70.91±4.82*#	76.35±4.38*#•
	б) 72.28±4.87	72.28±4.87	72.26±6.23	75.98±4.94*#•	72.21±6.34*
MBV (ml/min)	а)5100.74±535.53	4843.01±609.91	4609.14±4777.19*	4922.16±612.95	5683.68±709.96*
	б)5452.92±474.83	5293.38±454.49	5061.84±551.60*	5735.88±559.32#•	5650.75±671.44#•
PVR dyne/sec/cm -5	а)1389.77±181.43	1451.57±195.87	1445.66±184.10	1408.65±156.98	1166.10±166.63*
	б)1179.37±139.34	1215.10±145.87	1220.42±170.77	1095.53±140.56#•	1138.97±186.54
HI (ml/min/м²)	3221,85±379.885	3083.91±355.19	2958.36±345.84*	3166.26±375.48•	3633.63±492.61**
	3221.85±379.885	3324.70±360.77	3195.06±386.15	3585.85±434.44#•	3500.38±450.88•
BI	а) 46.42±4.53	46.59±4.30	46.87±6.16	45.44±4.60	48.18±4.18
(ml/м²)	б) 45.17±4.61	45.43±4.59	45.66±5.13	47.51±4.70	44.86±5.09

otes: 1 a) women's football players general group (GG); b) women's football players control group (CG)

As the study showed, the background parameters of players' heart rate during the entire biological cycle were within the age and sex. At the same time, the phase range of the investigated parameter was determined: the highest heart rate indices were observed in the V phase of the cycle (74.33 ± 7.34 beats/min). From the 1st to the 3rd phase of the cycle, there was a progressive decrease in the parameters of the heart rate: 69.10 ± 5.59 beats/min in the first phase, 65.90 ± 6.38 beats/minute in the second phase, 63.90 ± 4.83 beats/min in the third phase, herewith the difference between the parameters of the I and III phases was statistically significant ($p < 0.05$). From the IV phase of the cycle, the intensive growth of the heart rate began: the parameters of the heart rate of the IV phase were significantly higher than in the III and II phases (in both cases, $p < 0.05$), while the V phase parameters were greater than IV phase ones (74.33 ± 7.34 beats/min vs. 70.37 ± 6.50 beats/min; $p < 0.05$).

The BPmax indices in the examined women's football players were the highest in I, II and IV phases (114.67 ± 6.81; 114.33 ± 6.79 and 113.17 ± 7.01 mm Hg respectively), the lowest in the V and III phases (109.33 ± 7.74 and 107.33 ± 8.07 mm Hg respectively, $p < 0.05$). The phase distribution of the BPmin definition results was slightly different: the highest indices were observed in the IV phase (67.33 ± 4.10 mm Hg), the lowest ones were in the V phase (60.67 ± 3.88 mm Hg).

During the I and II phases of the OMC, its parameters were practically at the same level and slightly decreased in the III phase of the cycle. The increase in the numerical values of the discussed parameter in the IV phase of the cycle considering its value in the III phase was probable ($p < 0.05$). In the V phase of the cycle, the numerical values of systolic pressure compared with the IV phase were smaller (60.67 ± 3.88 versus 67.33 ± 4.10 mm Hg).

PBP in women's football players during I, II and V phase did not change; its lowest values were recorded in the III phase (43.67 ± 7.06; relative to the values of the discussed parameter in I phase $p<0.05$). From the IV phase of the cycle, the parameters of the PBP began to increase.

The BP average was characterized by the highest numerical values in the II and IV phases of the cycle (86.59 ± 4.87 and 86.97 ± 4.45 mm Hg respectively). The lowest values of this parameter are recorded in the V and III phases (81.53 ± 4.80 and 82.44 ± 5.78 mm Hg, respectively, relative to the values of the discussed parameter in II phase in both cases $p <0.05$).

The index of SBV in the group of women's football players during the first three phases was almost at the same level. However, in the IV phase, it was reduced to 70.91 ± 4.82 ml (relative to the value of the discussed parameter in the I phase $p <0.05$) with subsequent increase in numerical values to 76.35 ± 4.38 ml in the V phase of the cycle. The parameters of the MBV were also the highest in the V phase of the cycle (relative to the parameters in phase I $p <0.05$); the smallest values of these parameters were in the III phase of the cycle. It was established that during the OMC the value of the discussed indicator varied wavelike from the highest in the V phase to the lowest in the III phase. PVR indices were the lowest in the V phase of the cycle; they were the highest in the II and III phases, and, in the I and IV phases of the cycle, they were almost at the same level.

The women's football players' HI had a clear phase dynamics: the lowest of its numerical values were in the III phase (2958.40 ± 344.36 ml/min/m², relative to the values of the I phase $p <0.05$). During the I, II and IV phases, its indices fluctuated within a small range, while in the V phase of the cycle, a sharp increase (up to the maximum value) to 3633.63 ± 492.61 ml/min/m² ($p <0.05$) was observed. At the same time, the BI showed weak phase dynamics: during the first half of the cycle (I, II, and III) its parameters were practically the same, slightly decreased in the IV phase, and only increased significantly in the V phase ($p <0.05$).

Thus, we established the dependence of the studied parameters of systemic hemodynamics on the phases of the biological cycle. The most pronounced was the phase dependence of the heart rate and BPmax, and the least - indices of BI, PBP and PVR. The most pronounced was the phase dependence of the pulse and BPmax indices, the least - indices of BI, PBP and PVR. The HI indices during the OMC changed in a wave-like manner, increasing from the lowest values observed during the ovulatory phase of the cycle. The highest PVR rates were observed during the II and III phases, the lowest were during the IV-V phases. At the same time, the parameters that were subject to change, their numerical values, the nature of phase oscillations had certain peculiarities: in the III and V phases of the cycle there was a significant decrease in the BPmax and its calculated derivatives; the highest values of SBV, MBV and HI were observed in the V phase of the biological cycle. In addition, the parameters of PVR in phases II and IV were practically the same ($p <0.05$). This, undoubtedly, indicates a significant impact of playing soccer on the state of central hemodynamics.

Conclusions

Hormonal reorganization of the organism in II, III and IV phases of the OMC in women's football players aged 18-20 is accompanied by a cyclical change in the main indices. The analysis of electrocardiograms registered in different phases of OMC allowed to determine the peculiarities of the course of bioelectric processes in the cardiac muscle of 18-20-year-old players in a state of rest, after physical activity, and after recovery, and confirmed that the myocardium of women's football players disposes sufficient potential resources and adaptive possibilities.

The state of central hemodynamics of the examined 18-20 year old women's football players depends to a large extent on the hormonal status. Phase fluctuations mostly affect the parameters of heart rate and BPmax and the least on the indices of PBP, BI, PVR. The highest values of the BPmax and BP average indices in women's football players are observed in the ovulatory (III) and premenstrual (V) phases of the OMC ($p <0.05$ relative to similar parameters in phase I and II), heart rates are the highest during premenstrual (V) and menstrual (I) phase of the cycle. This indicates that in the I, III and V phases of the OMC the cardiovascular system undergoes an additional load. Consequently, the study of the state of central hemodynamics allowed the players to establish lower rates of heart rate, MBV and HI, and at the same time higher values of BPmax, BPmin, RT, AVR, SBV, PVR, indicating more economical activity of the myocardium and the best state of peripheral circulation.

Prospects for further research

Given that women's football players belongs to those types of sports that are dynamically developing, it is expedient to extend the range of inter-system correlation interactions studied, in particular, due to the indices of rheograph/rheoencephalography.

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