Chapter 2

Functioning of the Cardiovascular System of Women in Different Phases of the Ovarian-Menstrual Cycle

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Additional information is available at the end of the chapter

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Abstract

Seventy seven women with 17–19 years of age examined central hemodynamics and its wave structure at rest, with orthopedic and psychoemotional load in different phases of the ovarian cycle (OC). It was established that in the luteal phase of the OC in the lying position, the blood pressure was higher than in other phases. In orthoprost in the luteal phase, in comparison with other phases, the growth of cardiac rhythm wave strength in the range of 0.04–0.15 Hz is observed, their concentration and connection with oscillations of the shock volume of blood, and the leveling of differences in blood pressure levels. The involvement of spontaneous baro-reflex sensitivity of the studied states and reactions is discussed.

Keywords: central hemodynamics, variability of the cardiac rhythm, women, ovarian-menstrual cycle

1. Introduction

The basis of modern human physiology is the systematic approach, the synthesis of the theory of functional systems and the theory of adaptation, which allows us to obtain meaningful information about the functional state of the organism during ontogenesis and use the obtained data for practical actions [1–3].

Heart rate variability (HRV) is a fundamental physiological property of the human body, which reflects the state of regulatory mechanisms of homeostasis, in particular, the tone of the autonomic nervous system [4]. Therefore, the study of HRV has become important for qualitative diagnosis, prediction, and prevention of various diseases [5, 6].

At the beginning of the twenty-first century, the attention of researchers is drawn to the study of the variability of the duration of the interval R-R [7–10], blood pressure [11–13], shock volume [14], respiratory arrhythmia [15–17], and the relationship of wave changes in various hemodynamic parameters. This is due to the wide introduction of information technology to the theory and practice of medicine and physiology, high diagnostic value of parameters of regulatory rhythms of hemodynamics.

Of all the physiological systems of humans, the most important and little studied is reproductive [18–22]. In particular, insufficient research on the chronostructure of physiological systems in women suggests that the productivity and stability of body systems, in addition to the annual seasonal changes in various physiological functions and the seasonal exacerbation of some diseases, significantly affect the ovarian-menstrual cycle [23, 24].

An analysis of the above-mentioned developments of scientists and practitioners shows that the preservation and strengthening of health significantly depends on the further study of adaptive reactions of the female body, taking into account the ovarian-menstrual cycle, the individual annual, and the seasonal period of physiological functions.

On the adaptive trophic role of the sympathetic department of the VNS, including the reproduction, one of the first pointed academician Orbeli [15]. However, to date, the question of the state of the autonomic nervous system, including the activity of the cardiac rhythm, in women during the menstrual cycle is inadequate. A series of review papers [25–27] provides data on age and gender changes in some HRV indicators. However, these data relate, preferably, to short (2–5 min.) Records of R-R intervals are performed on contingents of persons with different pathologies [28–30]. At the same time, the characteristics of the wave structure of the vibrations of hemodynamic indices in healthy women in different physiological conditions and loads in the process of ontogenesis are insufficiently analyzed.

It should be emphasized the existence of certain contradictions in the results of various studies of the variability of the cardiac rhythm in women in different phases of the ovarian-menstrual cycle and the treatment of their mechanisms.

There remains an inadequate study of the problem associated with the influence of the ovarian-menstrual cycle on the indicators of central hemodynamics and cardiac rhythm variability under different physiological conditions. In particular, studies of changes in the oscillations of the shock volume of blood, spontaneous baro-reflex sensitivity in women under different stresses.

In Ketel et al. conducted in randomized tubes for 149 men and 137 middle-aged women, revealed that HRV levels were inversely related to age and heart rate in both sexes. The level of LF in men is significantly higher than in women and is negatively related to the level of triglycerides, insulin. The power of the R-R interval for women is higher than that of men.

The widespread introduction of the ECG holter monitoring method into clinical practice allowed the evaluation of HRV in the course of the day and at certain intervals, and also used this method for studying the state of autonomic regulation of the heart rate. Extreme values of total spectrum power and power in the very low and low frequency range under holter monitoring of women in comparison with men were also recorded in Fluckiger et al. [31].

In this case, the power in the ranges of low and high frequencies was negatively correlated with age. The total power of the spectrum was relatively reduced between 20–29 years and 60–69 years by 30%.

The same gender and age characteristics of the wave structure of the heart rate were also confirmed in measurements of 302 men and 312 women conducted by Bai et al., for 653 persons performed by Aubert et al. [7], and on 276 persons conducted by Barrett et al. The gender differences in HRV are measured at the sixth decade of the human life cycle. Changes in the cardiac rhythm and its spectral components during orthopedic trial at this age did not have sexual differences.

There are significant differences in the reactivity of fluctuations in the interval of R-R and the peripheral pressure of men and women on physical, mental, and cold loads. So in the research of Peshakova [32] shows that women under these conditions have a greater centralization of the mechanisms of regulation of the cardiovascular system, and for men, an increase in the activity of the sympathetic link of the autonomic nervous system.

Many researchers [33–36] point out that cardiovascular analysis is more appropriate to detect minor fluctuations of the VNS activity during the menstrual cycle than the use of traditional indicators such as heart rate and arterial pressure. However, the results of studies of changes in the heart rate in different phases of the menstrual cycle are still controversial. It should be noted that significant changes in HRV in women of reproductive age, both at rest and during psychoemotional stresses, may be due to the phase of the ovarian cycle [37–42]. SDNN in young women was the highest during the follicular phase of the menstrual cycle [43]. According to Koening and co-authors [44], in women during the luteal phase compared with the follicular showed an increase in the activity of the sympathetic department of the autonomic autonomy of the autonomy according to the HRV indices. However, a group of researchers, Grossman et al. [45], insists on the absence of differences in the parameters of the wave structure of blood pressure and heart rate when performing orthopedic and stimulating carotid sinus in women in different phases of the ovarian cycle.

Japanese scientists [43] demonstrate a significant increase in sympathetic and decreased parasympathetic activity in the lutein phase compared to follicular, as evidenced by an increase in the values of LF/HF and LF, as well as a decrease in HF in the luteal phase. The facts of the increase in the level of LF/HF in the early and middle luteal phase are given in Holzen et al. [46], with the late luteal phase showing a tendency to decrease the level of LF/HF. At the same time, some researchers, Princi et al. [47] and Sato et al. [39] refute this assumption, indicating that there is no significant change.

Although some researchers point to an increase in the level of HF in the follicular phase compared with the luteal and menstrual phase, measurements were made only one [48–50] or twice a week [51] during the cycle. Since hormonal and physiological changes during the menstrual cycle are complex and complex, they can not be characterized by two measurements, which indicate the need for long-term research.

In studies [52], in 10 completely healthy women, it was found that spontaneous baroreflectory sensitivity increases during the luteal phase compared to the follicular phase. It was stated that there were certain differences in the logRSA fluctuations during the menstrual cycle, which were related to the average NSC indexes.

According to Weisman, there are significant changes in both the wave structure of the cardiac rhythm and its reactivity to the burden on women in the first 20 weeks of pregnancy. So, normally in this period, the power of OT components increases, often the synchronization of respiratory and baroreflector waves is observed. In pathological development of pregnancy, there is an inversion of such regulatory relations.

The variability of the cardiac rhythm during the physiological course of pregnancy is reduced, which indicates an increase in the activity of the sympathetic department of the autonomic nervous system [21, 53]. In women with gestosis, HRV is more pronounced. Revealed by scientists, the facts of changes in HRV with other hypertensive states in pregnant women, as well as in normal and complicated childbirth are few and controversial. The emphasis is placed on the prospect of further study of sympathetic activity in relation to changes in HRV in pregnant and childbearing, as well as on the need for widespread introduction of cardiointervalography in obstetrics.

The process of reproduction in humans regulates complex neuroendocrine mechanisms, so the normal functioning of the reproductive system is possible only with the integrated control of the nervous and humoral signals. One of the manifestations of complex changes in the body of a woman is the menstrual cycle: cyclic changes in the hypothalamus, pituitary gland, and ovaries; cyclic changes in the target organs (uterus, fallopian tubes, vagina, and mammary glands); cyclic changes in the endocrine, nervous, and other systems of the organism. The most pronounced changes occur in the ovaries (ripening of the follicles, ovulation, and development of the yellow body) and the uterus (desquamation of the endometrium is actually menstruation, regeneration and proliferation of the functional layer, secretory changes in it, and again desquamation). Due to these changes, the reproductive function of the woman is carried out: ovulation, fertilization, implantation, and development of the embryo in the uterus. If implantation does not occur, pregnancy does not occur, and the functional layer of the endometrium is exfoliated, from the genital tract, there is a spotting (menstruation). The appearance of menstrual discharge indicates the completion of cyclical changes in the body and the absence of pregnancy. The main symptom of normal functioning of the reproductive system of a woman is a normal menstrual cycle. This biorhythm is genetically determined in a healthy woman, and it is stable throughout the generative age according to its parameters.

2. Methods

Seventy seven women aged 18–19 were tested under the conditioned close to the state of basal metabolism in the prone position, at tilt test, and during the test of psychic-emotional stress (Makarenko) [54]. As a mental load, we used a 10-minute test to determine the performance of the brain in the feedback mode by the method of prof. M.V. Makarenko using the Diagnostic-1 system. Each woman was tested three times: in follicular phase (I), ovulation (II), and luteal phase (III) of ovarian-menstrual cycle. Cycle phases were determined according

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to anamnesis, taking basal body temperature, and using a set of inkjet ovulation tests "Solo" (IND Diagnostic, Inc., Canada).

The main method for determining the phases of the CMC was the collection of anamnesis. Using the test-microscope "Arbor" in the studied group of students examined the presence of ovulation by the nature of the crystallization of saliva. The method is based on the fact that during ovulation, when the concentration of estrogen in the blood of a woman becomes maximal, in saliva, the concentration of salts increases, which is manifested in the maximum crystallization of saliva. Thus, a graphic image on a glass under a microscope was called a "leaf of ferns" (**Figure 1**).

Confirmation of reliability of phase change of the cycle (selectively) was carried out by means of ultrasound diagnostics, the apparatus, HDI 1500, as well as the set of jet tests SoloTM (company "Pharmaco", the registration certificate of the Ministry of Health of Ukraine NO 1856/2003 of 16.05.2008, the international certificate of quality ISO 9001/ISO 13485, and Manufacturer of IND Canada) to determine the ovulation.

The confirmation of the MC phase was also carried out using the technique of basal body temperature measurement Krupko-Bolshova (1986). During the ripening of the egg in the follicular phase of the cycle, against the background of increased estrogen BBT is low (36–37°C), after ovulation, in the lutein phase, begins the temperature increase (37.2–38°C), which is due to the low estrogen levels in the background of increased progesterone in the blood of women.

BBT was measured every morning, at the same time, from 600 to 800 hours (depending on the time of year), not getting out of bed for 5 minutes, mercury thermometer in the rectum at a depth of about 5 cm. Rozultaty entered into the table: date, day of the cycle, BT, and special circumstances.

The difference between the mean values of the second and first phase of the CTD can be 0.5–0.8°C, but it should not be less than 0.4–0.50°C. This is evidence of the normal course of CMC. If during the whole cycle the temperature on the graph is kept, for example, on the same level, or the graph looks like "tyna" (when the low temperature constantly changes high), rather than biphasic, this is due to the fact that ovulation was not (**Figure 2**).

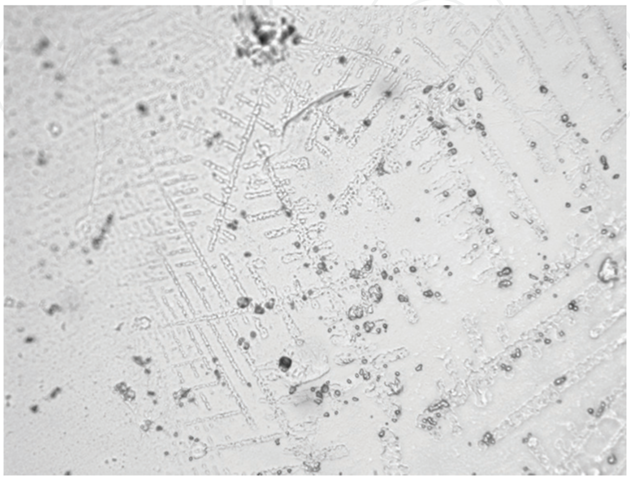

Figure 1. Photo of smear of saliva of student L. (during ovulation).

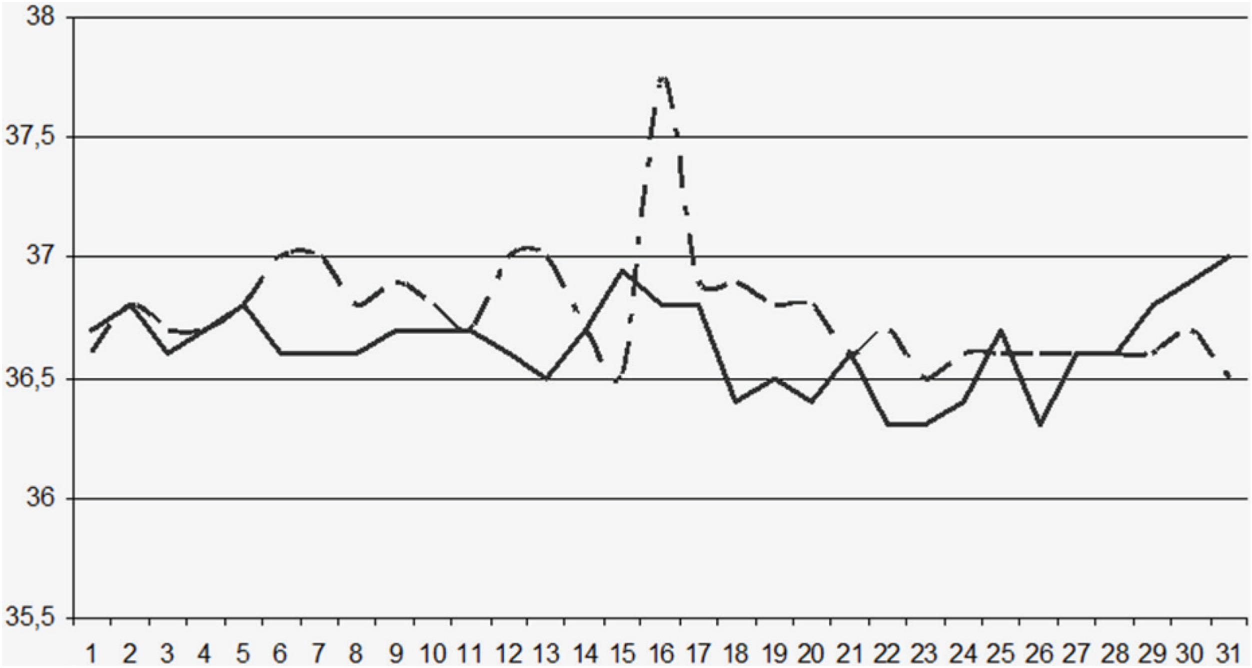

Figure 2. In the middle of the chart changes in basal body temperature in a normal ovarian-menstrual cycle (dashed line) and an anulatory (solid line).

3. Analytical methods

Systolic and diastolic AP (APs and APd, respectively) were measured with Korotkov auscultation method by mercury tonometer ("Riester", Germany). Mean arterial pressure (APm) was calculated with Hickam formula; blood struck volume (BSV) with Kubichek formula [55] by the signals of differentiated impedance rheogram by all the realizations (beat-to-beat) during 5 minutes.

With the help of a rheographer and pneumograph, only cardiointervalograms and pnevmograms were recorded. Cardiointervalograms were recorded using Caspico [56] in MS DOS mode. For this, a cardiac sensor T31 (Polar Electro OU, Finland) was applied to the thoracic cell, which formed 8 ms pulses at the top of the QRS complex. These impulses were telemetrically perceived by the pulse meter A1 and, together with the pnevmogram signal, were transmitted to a 5 kV galvanic switch comparator, which closed the contacts on the LPT port of the computer. The program scanned the device with a frequency of 1000 times per second. The power of R-R and BSV oscillations spectrum was calculated in standard frequency ranges of very low frequencies of 0–0.04 Hz (VLF), low frequencies of 0.04–0.15 Hz (LF), high frequencies of 0.15–0.4 Hz (HF), general oscillation power of 0–0.4 Hz (TP), and normalized power in the range of 0.15–0.4 Hz (HFnorm). Besides, spectral and cross-spectral density and the frequency of the highest amplitude oscillation peak of t-R-R and BSV in the LF range were estimated in the prone position at rest for 5 minute records, at tilt test from the 2nd till the 5th minute and in psycho-emotional test from the 3rd till 7th minute [10].

The method of impedance reopeltysmography was used to calculate cardiac output [57], associated with it indicators of relative blood flow to the body of the chest.

Signals of differentiated ECG and rheograms were fixed with the aid of a biopower RA-5-01 (Kyiv Research Institute of Radio-measuring Equipment). The spring electrodes of rheograms were standardized [10]. The frequency of the reagent's probe signal was 70 kHz.

The pnevmogram signal was obtained from a piezoelectric sensor placed directly in front of the subject (nostrils of the nose).

All these signals were "digitized" through an analog-to-digital converter ADC-1280 (Holit Data Systems, Kiev) with a sampling rate of 860 times per second. The digital signals were stored on the hard disk of the computer for further processing. To analyze signals, identify critical points on them, and export them to spreadsheets, Bioscan [10] was used.

4. Statistical methods

Due to the abnormality of the value distribution of oscillation power of haemodynamic indicators, their medians, the limits of 25 and 75 percentile were found; the average values and their errors for AP indicators distributed normally were determined. The reliability of differences between values in different OMC phases was estimated by means of Wilcoxon paired comparison and Student's t-test. The relationship between indicators was calculated by the nonparametric Spearman correlation coefficient.

5. Results

It was established that in the state of rest in women significant differences between the indices of central hemodynamics, which were analyzed depending on the phases of the CMC, were mostly not observed. However, differences were available at the levels of ATs, ATSer, and ZPO. Changes in these indices were observed in the III phase of the OC ($p < 0.05$) in comparison with the I and II phases (**Table 1**), which is consistent with the results of many authors' studies.

With regulated breathing 6 times/min, we observe the natural increase of practically all indicators in the III phase ($p < 0.05$) in comparison with the I and II phases, except for clinical symptoms, heart rate, CI, and R-R.

When moving to a vertical position in all conditions, there is a natural decrease ($p < 0.001$) of t-R-R, SI, SOC, and increase in LPA (**Table 2**).

Reactivity of blood pressure indicators depended on the OC phase. Thus, in the 1st and 2nd phases, there was a probable increase in ATs, ATD, ATSer, and in III, changes were not statistically significant. This led to the fact that the differences in the levels of ATs and ATSer between the phases of the OC are at rest lying leveling, and there were differences for t-RR between III and I and II phases (676 ± 17, 641 ± 16, 634 ± 11 ms, $p < 0.05$, respectively).

Indicator	Phases of the cycle		
	I	II	III
APs, mm Hg. Art.	98.1 3 ± 1.43	99.22 ± 1.54	101.41 ± 1.87*
APd, mm Hg. Art.	64.38 ± 1.14	65.31 ± 1.05	66.88 ± 1.47
APm, mm Hg. Art.	75.63 ± 1.17	76.61 ± 1.02	78.39 ± 1.48*
т-R-R, ms	801 ± 15.6	784 ± 17.3	803 ± 17.9
SOK, ml	54.96 ± 2.12	58.15 ± 2.93	54.50 ± 2.29
CI, ms	3260 ± 106	3109 ± 87	3304 ± 128
ZPO, din* cm^{-1} *p-5	1569 ± 91	1418 ± 72	1638 ± 82#

*–$p < 0.05$ in comparison with indicators in phase I.
#–$p < 0.05$ in between the indices in the 2nd and 3rd phases.

Table 1. Indicators of central hemodynamics are at rest lying in different phases of the biological cycle of women.

Indicator	Phases of the cycle		
	I	II	III
APs, mm Hg. Art.	98.28 ± 1.46	97.81 ± 1.50	99.37 ± 1.82#
APd, mm Hg. Art.	63.59 ± 0.9	63.90 ± 0.86	66.87 ± 1.34#
APm, mm Hg. Art.	75.15 ± 0.9	75.20 ± 0.95	77.70 ± 1.34#
BS	22.75 ± 0.85	22.29 ± 0.85	22.57 ± 0.85
ZPO, din* cm^{-1} *p-5	1558 ± 71	1458 ± 90*	1591 ± 62#
MVB, ml/min	4051 ± 157	4304 ± 202*	4042 ± 149#
Heart rate ubs/min	75.13 ± 1,29	77.42 ± 1,65*	76.33 ± 1.52
CI, ml	2542 ± 99	2699 ± 127*	2533 ± 92
R-R, ms	805 ± 13	785 ± 16*	796 ± 16

*–$p < 0.05$ in comparison with indicators in phase I.
#–$p < 0.05$ in between the indices in the 2nd and 3rd phases.

Table 2. Indicators of central hemodynamics at regulated respiration (6 times/min) in different phases of the biological cycle.

The reactivity of all indicators in regulated breathing significantly changed in the III phase compared with the 1st and 2nd phases. No changes occurred in the significance of ATs in all phases, but SI significantly changed in the 3rd phase.

Thus, the major changes in the state of central hemodynamics in the rest of the lying were observed in the luteal phase of the OMC, which disappeared in various loads on the body (respiration 6 times/min, orthopedic, and psychoemotional load).

The cardiovascular system of the human body is one of the most important physiological systems, in the functioning of which involved rhythmic processes that interact with each other. The most important of these is the main cardiac rhythm and breathing.

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When analyzing the parameters of the wave structure of the heart rate at rest, it was found that significant differences between their levels, depending on the phase of the OC, were largely absent. The exception is higher values of HFnorm in the III phase of the OC compared with II (65.4 [54.8, 75.0] and 55.4 [42.6, 68.9]%, respectively) and less aLF (11,533 [5449, 23,958] and 17,224 [9769, 26,508] ms^2*Hz-1, respectively), indicating a higher level of activation of the parasympathetic branch of the autonomic nervous system (VNS) in the follicular and luteal phases.

During orthogonal testing, there were significant changes in the wave structure of the cardiac rhythm that had certain features in different phases of the CMC. Thus, the level of VLF did not change, LF probably ($p < 0.05$) decreased from 670 [273, 974] to 459 [276, 689] ms^2 only in the 2nd phase. Significantly ($p < 0.001$) in all phases, HF, HFnorm, and TP decreased. Similar changes are the characteristic for this type of load and consist in increasing the tone of the sympathetic link of the CNS [17, 58, 59].

Under conditions of regulated breathing, minor changes in heart rhythm values were observed. Thus, the value of VLF changed in the second phase, and LF in the third phase is devastating with the I and II phases. The value of a LF showed significant changes in all phases (**Table 3**).

At a psychoemotional load, VLF did not change, LF was likely to decrease from 2.0 [1.1, 4.3] to 3.4 [1.8, 5.7] ms^2 only in the 2nd phase ($p < 0.05$). Significantly ($p < 0.001$) in all phases, HF and aLF increased.

The analysis of the cardiac rhythm reactivity in orthostatic conditions (**Table 4**) showed that in the luteal phase, an increase in the power of low frequency waves of heart rate was observed, which was significantly higher than the amplitude of their decrease in the ovulatory phase. Also, in the 3rd phase, there was a significant increase in the maximum peak in the frequency range of 0.04–0.15 Hz (60.8%).

In regulated breathing, the changes in all phases were in VLF, aLF, and TPover. Insignificant in HF and HFnorm (**Table 5**).

It is noteworthy that the greatest deviation of the values of reactivity to the load is typical for indicators that characterize the frequency range of oscillations R-R from 0.04 to 0.15 Hz.

Indicator	Phases of the cycle		
	I	II	III
VLF, мs^2	9.33 [6.44; 12.49]	6.65 [3.48; 13.56]*	6.84 [3.47; 11.19]
LF, мs^2	33.11 [13.48; 43.05]	38.36 [18.76; 57.03]*	42.09 [20.9; 59.79]#
HF, мс^2	18.9 [10.9; 35.32]	20.9 [13.83; 33.71]*	21.98 [14.36; 33.05]
aLF, мs^2/Гц	23.61 [8.53; 57.74]	39.19 [17.80; 63.68]*	32.28 [15.23; 83.52]#
HFnorm, %	40.82 [28.74; 52.61]	36.68 [26.36; 49.77]*	36.01 [23.04; 47.87]
TPover, мs^2	62.87 [48.09; 98.42]	62.98 [46.90; 103.43]	70.24 [48.9; 103.33]#

*−p < 0.05 in comparison with indicators in phase I.

#−p < 0.05 in between the indices in the 2nd and 3rd phases.

Table 3. Indices of the variability of the heart rate at regulated respiration (6 times/min) in different phases of the biological cycle.

Indicator	Phases of the cycle		
	I	II	III
VLF	−15.8 [−49.5; 43.5]	−20.4 [−57.5; 25.8]	−8.9 [−46.3; 64.8]
LF	−1.4 [−35.6; 60.8]	−21.7 [−59.2; 29.7]	27.6# [−35; 71.8]
HF	−73.4 [−88.7; −3.5]	−70.8 [−85.5; −1.3]	−73.3 [−83.4; −5.2]
aLF	14.1 [−21.5; 127]	24 [−38.4; 88.3]	60.8# [−2.2; 228.6]
fLF	−8.5 [−45.8; 20.3]	−5.8 [−27.5; 14.7]	−19.6 [−38.4; 19.6]
HFnorm	−56.5 [−65.9; −39.2]	−50.8 [−60.6; −34.3]	−49.3 [−64.3; −40.9]
TP	−38.7 [−59.5; 0]	−41.3 [−71.2; 7.3]	−35.7 [−52.6; 32.5]

*−$p < 0.05$ in comparison with indicators in phase I.
#−$p < 0.05$ in between the indices in the 2nd and 3rd phases.

Table 4. Reactivity (%) of heart rate variability parameters at orthopedic examination in different phases of the biological cycle of women (median, borders 25, 75 percentiles).

Indicator	Phases of cycle		
	I	II	III
VLF, мs^2	74.4 [2.38; 147.47]	2.68 [−46.24; 98.00]*	−29.13 [−51.01; 29.53]#
LF, мs^2	33.1 [13.48; 43.05]	38.36 [18.76; 57.03]	42.09 [20.9; 59.59]#
HF, мs^2	19.0 [10.96; 35.32]	20.90 [13.83; 33.71]	21.98 [14.36; 33.03]
aLF, мs^2/Hz	1850 [905; 2949]	1966 [545; 3034]*	2195 [1070; 4148]#
HFnorm, %	−56.2 [−64.07; −28.71]	−52.44 [−67.53; −33.49]	−52.38 [−71.19; -40.89]
TPover, мs^2	77.6 [8.24; 220.25]	62.10 [6.06; 172.36]*	90.79 [46.71; 171.50]#

*−$p < 0.05$ in comparison with indicators in phase I.
#−$p < 0.05$ in between the indices in the 2nd and 3rd phases.

Table 5. Reactivity (%) of parameters of heart rate variability during regulated breathing (6 times/min) in different phases of the biological cycle of women (median, borders of 25 and 75 percentiles).

In this regard, a detailed analysis of the distribution of waves of the cardiac rhythm in it was performed on a normalized median spectrogram.

6. Discussion

As for the phases of the menstrual cycle, Princi from the sing did not find changes in the heart rate in three phases [47]. However, in our study, analyzing the heart rate reactivity, we found that in the luteal phase, an increase in the power of low frequency waves of heart rate was observed, which was significantly higher than the amplitude of their decrease in the ovulatory phase. Also, in the 3rd phase, there was a significant increase in the maximum peak in the frequency range of 0.04–0.15 Hz (60.8%).

According to Princi with singing, the total power of the spectrum and its high frequency part increased in the folliculin phase and decreased during the luteal phase.

Leicht et al. noted a high heart rate in the ovulation phase at a constant level of all endogenous hormones, and even the variability of the heart rate was the same in different phases of the cycle. However, they identified the correlation between the level of estrogen and the absolute expression of HRV in ovulation. The correlations found between the peak of estrogen and HRV are attributed to the cardioprotective effect of hormones in healthy women.

Tanaka et al. (2003) believe that the cardiovascular reflex may be damaged depending on the level of estradiol Guasti (1999) studying autonomic function in the normal ovulatory cycle and evaluating HRV sensitivity of baroreceptors in healthy women. They found increased sympathetic activity in the second phase of the cycle. This gave reason to speak of different baro-reflex sensitivity in different phases of the cycle.

Investigating the state of hemodynamics and HRV in the studied group of women in different conditions, it was found that the nature of the distribution of spectral power in different phases of the CMC is significantly different. At rest, the phase I is characterized by one peak at a frequency of 0.1 Hz, and for II and III phases, there are two peaks that can have different mechanisms of origin [47]. Moreover, in the third phase, the wave at frequency 0.08 Hz, which according to the experimental data characterize the functioning of the baroreflex [22], is most pronounced. These results largely coincide with the conclusions of many authors that HRV is a genetically determined characteristic of a human body [9].

Princi [47] indicate that cardiointerval analysis is more appropriate to determine the slight variations in the VNS activity during the menstrual cycle than the use of traditional indicators such as heart rate and arterial pressure. It should be noted that the phase of the ovarian cycle can significantly affect the HRV in women of reproductive age, both at rest and in psycho-emotional stress (features of the cardiovascular system in different phases of the menstrual cycle) [28]. In our study, we found that during the neurodynamic load, significant adaptive changes in vegetative regulation in the follicular phase were observed, while the lowest reactivity and inhibition of the functional state of the organism were characteristic of the luteal phase of the CMC. In this case, in the conditions of a 10-minute neurodynamic test in the feedback mode using the method MV Makarenko, the number of processed signals was significantly higher in phase I (1533 [1309, 1642] signal) compared with II and III ([1438 [1219, 1573] signal) phases ($p < 0.05$). We believe that such changes in mental performance are due to changes in the hormonal status in the body of women. We also found that in the first phase, the difference between the ratio of correct answers of the right (52 [50, 54]%) and the left (48 [46, 50]%) hands was highly reliable ($p < 0.01$), while in II and III phases was leveled ($p < 0.501$ and 0.223, respectively). Such a pattern indicates the possibility of changes in the degree of domination of the cerebral hemispheres during the menstrual cycle.

However, the study by Grossman et al. [45] found no differences in the parameters of the wave structure of arterial pressure and heart rate when performing orthopedic and stimulating carotid sinus in women in different phases of the CMC.

In a study by Lawrence et al., studies, for 10 completely healthy women, it was found that spontaneous baroreflectory sensitivity increases during the luteal phase compared to the follicular phase.

By analyzing the distribution of cardiac heart rate wavelengths by normalized median spectrogram, we found that normalized spectral power in the range of low heart rate rhythms at orthodontic tests in men and women significantly differed at frequencies of 0.08 and 0.1 Hz. The latter can testify to the sexual characteristics of spontaneous baro-reflex sensitivity, a certain difference in the genesis of these waves.

The presence of two peaks can indicate two impacts on the heart rate spectrograph. Yes, there are two theories of wave formation in the low frequency region. The first is the effect of the functioning of the baroreflector mechanism of regulation of arterial pressure [60], and the second is the influence of the endogenous rhythm generator. In studies by Cooley et al. [27] evaluated the spectra of fluctuations in blood pressure and RR intervals in patients with implanted artificial left ventricle. After a short time after implantation (1 and 15 months), there were no slow waves in the arterial pressure spectra, and in the spectra of RR-intervals of their own heart, slow fluctuations "became apparent and dominant." The endogenous oscillator is likely to capture the rhythm of waves caused by the activity of the baro-reflex mechanism, which is a manifestation of the fundamental natural synchronization phenomenon [61], and in this case, the frequency of both the baroreflex and the oscillator is the same or slightly different.

A probable increase in the level of blood pressure in the 3rd phase compared with the 2nd and even the greater is the phase I, indicating an increase in the tone of the sympathetic department of the autonomic nervous system and is consistent with the literature data (Princi et al., 2005). Some authors [52] point out the individual peculiarities of autonomic regulation in women and predict the relative stability of the type of autonomous regulation and its genetic determinism. However, there are certain contradictions. Thus, Japanese scientists [43] observed an increase in the value of LF, which reflects the effect of both the sympathetic and parasympathetic VSS on the level of AT in both I and II phases.

But Princi and sang. (Princi et al., 2005) found opposite data, that is, the growth of LF in phase I and its decline in III. But only six women were screened and therefore, in our opinion, data for statistical processing are not enough. Lucini and sang (Lucini et al., [6]) noted an increase in blood pressure in the 2nd phase. In this case, the content of sex hormones did not change. It is also noted that the HRV indices did not change in any phase of CMC. However, a correlation between the content of estrogen and the absolute peak of HRV in the 2nd phase was identified. The found correlation is attributed to the cardiotropic effect of sex hormones. The autonomic nervous system plays a significant role in the processes of adaptation of the organism, and resulting in its functional state is very variable. Dependence of types of hemodynamics from the initial vegetative tone is considered in some diseases of the cardiovascular system. Establishing this relationship in the norm allows us to clarify algorithms for diagnosing the adaptive capacity of the organism, since they depend not only on the initial level of functioning of the system and functional reserves, which are most often used in medical-pedagogical control and preventive medicine, but also from the level of voltage regulatory systems, which is practically not taken into account.

In our study, we measured the level of vegetative tone with the HFnorm. Analysis of the distribution of this indicator in the first phase of CMC allowed to distinguish three typological

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groups: sympatotonic with a level up to 44% (19 people), norm tonics within the range of 44–60%, and vagogonics from 60% (26 people).

Probable differences in blood pressure levels between individuals of these typological groups were mainly found by diastolic blood pressure. So at rest, lying in the first phase of the CMC in BT, this indicator was higher than that of CT. At orthogonal testing of ATD in the 3rd phase of OMC in NT and VH was higher than in CT. Such shifts in values are also confirmed by the analysis of the reactivity of this indicator in the transition to orthostatic position. In BT, it is probably lower than CT in the first phase of CMC. While in the third phase of CMC in ST, there was no probable increase in comparison with the level of resting lying, and then in VT, this increase was not natural.

Thus, experimental studies have shown that an integrated approach to the study of individual-typological characteristics of central hemodynamics and its wave manifestations in women in different phases of the CMC gives an opportunity to answer a number of questions that arise in this case.

Based on the results of the study, we formulated the following conclusions:

1. Theoretical analysis of scientific and methodological literature has shown that there are certain contradictions in the results of various studies of the variability of the heart rate in women in different phases of the ovarian-menstrual cycle and the interpretation of their mechanisms, individually its changes to different loads.

2. In a state of rest in women, there are changes in the levels of systolic blood pressure and blood pressure in the central luteal phase of the OC compared with the follicular and ovulatory phases. The analysis of cardiac rhythm reactivity during ortho-trial in the luteal phase was characterized by an increase in the power of low frequency waves of heart rate, as well as a significant increase in the maximum peak in the frequency range of 0.04–0.15 Hz (60.8%).

3. Lying alone, with orthogonal and psychoemotional stress, there are basically differences in the parameters of the vibration duration of the interval R-R and UOC and their synchronization in women in ovulatory and luteinous phases compared to follicle. There is a significant link between Mayer's wave power and median and diastolic pressure, mainly in the women's follicular phase of CMC in all conditions. The maximum peak amplitude of the UOC spectrograph in the range of 0.04–0.15 Hz is most closely related to the levels of APm and APd.

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