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Research Article

**ADAPTATION OF 1ST AND 4TH YEAR FEMALE STUDENTS
TO MENTAL LOAD BASED ON PULSOMETRY DATA AND
HEART RHYTHM VARIABILITY**

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Abstract:

This paper deals with the peculiarities of the physiological adaptation of the 1st and 4th year female students to mental load at the beginning and at the end of the academic week based on the functional indices of autonomous and central mechanisms of the regulation of the heart rhythm (HR). It was found that the load applied on Monday led to an increase in sympathetic activity in first-year students, and on Friday increased the tension of both parts of the autonomic nervous system that affect the HR. All female students showed a decrease in their stress index associated with an increase in subcortical and parasympathetic activity with a decrease in central control of HR regulation. The pronounced sinus arrhythmia, moderate and pronounced impairment of automatism contribute to the maladaptation of female students and determine the development of body fatigue by the end of the week in freshmen, and during the week in fifth-year students.

Keywords: *adaptation regulation mechanisms, mental load, pulsometry, heart rate variability, integrative indicators, functional status.*

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INTRODUCTION:

The rhythm of the heartbeats is subject to central and autonomous regulation systems that determine the adequate response of the myocardium and the body to any external influences of the environment and their adaptation [1, 2]. The heart rhythm (HR) reflects the final result of numerous regulatory influences on the circulatory system, being its most labile indicator [3, 4], aimed at stabilizing the functional state of homeostasis mechanisms [5].

Integral parameters of pulsometry and mathematical analysis of heart rate variability (HRV), reflecting the functional state of the central [7] and autonomous regulation circuits [6], are most suitable for studying mechanisms of adaptation to functional loads. It is known that a moderate increase in the activity of the parasympathetic nervous system (PNS) with a decreased activity of the central regulation of body functions at rest ensures a higher level of somatic health, adaptation and reserve capabilities of a person [1, 8].

MATERIALS AND METHODS:

The study voluntary involved students of the National University of BelSU, who were conditionally healthy and had no chronic diseases. The first group included 15 freshmen aged 17-18 years, the second - 17 fifth-year students aged 21-23 years.

The assessment of the adaptation of students to the mental test [4] was performed based on the parameters of pulsometry and mathematical analysis of HRV [3, 9, 10] with the use of the hardware-software complex "Interpulse interval analysis" [11]. The pulsograms of subjects obtained on Monday and Friday in the morning from 9.00 to 11.00 hours in a state of relative physiological rest before and after the mental load - multiplying two-digit numbers,

subtracting rapidly three-digit numbers from 400 - were recorded and analyzed [4].

According to the statistical analysis of the dynamic series of 100 R-R-intervals, the parameters of variation pulsometry were determined [9, 12]: mathematical expectation (M), standard squared deviation (SQD), coefficient of variation (CV), mode (Mo), mode amplitude (MoA), variation range (VR), stress index (SI) [6, 9, 10, 12].

The criteria by R.M. Baevskii were used to evaluate the state and characteristics of vegetative regulation of the HR, the total effect of regulatory influences on the heart rate, the status of the function of myocardial automatism, the degree of stability of regulatory influences, autonomic homeostasis, and the state of activity of the subcortical nerve centers [4, 7, 11]. The data obtained were processed using the descriptive statistics of the package of computer programs "Statistica 6.0". The reliability of the differences was estimated by Student t-test.

RESULTS AND DISCUSSION:

At the beginning of the academic week, the M values before and after the test corresponded to the norm, but in freshmen compared to the fifth-year students, the R-R intervals before the load were shorter and less variable. Mental test in girls of both groups increased the effect of the central regulation circuit on the modulation of the HR (Table 1).

Under the influence of the load at the end of the academic week, the fifth-year students showed an increase in their M parasympathetic influence and severity ($p < 0.05$) as compared to the freshmen, who, on the contrary, had an increase in the influence of sympathetic activity on the sinus node of the myocardium (Table 1).

Table 1: The total effect of regulation of heart rhythm (R-R intervals) in female students

Indicators, rel.un.	Group I			Group II		
	M±m	Max	Min	M±m	Max	Min
At the beginning of the academic week before mental load						
M, s	0.79±0.040	1.11	0.52	0.83±0.033	1.06	0.61
SD, ms	5.16±0.521	9.01	2.62	5.51±0.560	9.1	1.21
CV, %	6.41±0.442	10.28	3.89	7.36±0.671	14.44	3.44
At the beginning of the academic week after mental load						
M, s	0.71±0.037	0.97	0.48	0.82±0.037*	1.09	0.55
SD, ms	5.47±0.760	9.62	1.11	5.64±0.622	9.70	1.00
CV, %	9.36±0.872	16.65	4.36	8.23±0.693	15.19	3.83
At the end of the academic week before mental load						
M, s	0.81±0.038	1.10	0.64	0.85±0.029	1.11	0.57
SD, ms	5.99±0.621	9.92	2.40	6.21±0.474	9.70	2.90
CV, %	7.15±0.525	3.72	1.11	7.13±0.440	11.11	4.02
At the end of the academic week after mental load						
M, s	0.79±0.031	1.09	0.64	0.88±0.033*	1.12	0.56
SD, ms	5.60±0.760	9.70	1.12	5.68±0.693	9.70	1.00
CV, %	8.87±0.835+	15.60	4.49	9.20±0.661++	13.65	4.73

Note: *M* - mathematical expectation, *SD* - standard deviation, *CV* - coefficient of variation; changes in indicators before and after the load between groups of students: * - ($p < 0.1$), changes in the indicators within the group: + - ($p < 0.1$), ++ - ($p < 0.05$)

The values of CV increased in freshmen after having experienced load at the beginning ($p < 0.01$) and at the end ($p < 0.1$) of the week, in fifth-year female students - only at the end of the week ($p < 0.05$), indicating an increase in the influence of vagal activity on the sinus rhythm of the myocardium. The increase in SD values at the end of the week before the load indicated an increase in vagal effects on the sinus rhythm of the myocardium, indicating the stress of the heart muscle and a decrease in functional capacity in a state of relative rest (see Table 1). Reduction of SD in both groups of students at the end of the week after load compared to the initial values was accompanied by an increase in the influence of sympathetic activity on the modulation of the HR.

At the beginning of the week, in freshmen, the CV before the load indicated a balanced activity of the vegetative sections. The change in the CV after the load in the students of both groups corresponded to the negative chronotropic effect associated with functional stress and fatigue (see Table 1). The shortening of the R-R-intervals in freshmen at the beginning of the week after the load indicated an increase in the activity of the sympathetic department and an increase in the influence of the central contour of regulation on the formation of CP in the performance of the mental test [1, 2]. At the beginning of the school week, according to the average Mo values, the first-year students had a moderate tachycardia ($p < 0.1$), and the five-year students had normocardia (Table 2). The test strengthened the effect of moderate tachycardia in the freshmen.

Table 2: Indicators of the degree of centralization of HRV control in female students

Indicators, rel.un.	Group I			Group II		
	M±m	Max	Min	M±m	Max	Min
	At the beginning of the academic week before mental load					
Mo, c	0.76±0.043	1.15	0.50	0.80±0.036*	1.05	0.60
MoA, %	40.8±3.41	76.0	24.0	38.6±2.75	61.0	24.0
ΔX, c	0.25±0.030	0.56	0.12	0.35±0.048+	0.86	0.11
SI, rel.un.	152.6±29.44	400.0	24.8	113.0±27.46	462.1	20.5
	At the beginning of the academic week after mental load					
Mo, c	0.69±0.037	0.95	0.45	0.81±0.040*	1.10	0.50
MoA, %	36.13±4.46++	82.0	20.0	33.88±2.66	64.0	24.0
ΔX, c	0.36±0.034	0.59	0.16	0.37±0.040	0.69	0.11
SI, rel.un.	106.0±24.82	325.4	21.1	93.6±25.20	447.6	18.3
	At the end of the academic week before mental load					
Mo, c	0.79±0.037	1.10	0.60	0.84±0.032	1.10	0.55
MoA, %	39.3±3.82	69.0	18.0	34.9±2.77	60.0	20.0
ΔX, c	0.26±0.031	0.53	0.07	0.31±0.033	0.71	0.15
SI, rel.un.	122.2±31.20	479.2	2.7	95.3±21.23	285.7	18.8
	At the end of the academic week after mental load					
Mo, c	0.80±0.044	1.20	0.60	0.77±0.041	1.15	0.55
MoA, %	29.4±2.84	44.0	18.0	32.5±3.15	70.0	19.0
ΔX, c	0.35±0.043	0.75	0.19	0.36±0.031	0.68	0.17
SI, rel.un.	78.3±13.95	179.8	12.6	79.0±21.48	374.3	3.6

Note: Mo – mode MoA – mode amplitude ΔX – variation range SI – stress index; * – ($p < 0.1$).

At the end of the week, *Mo* decreased in the students of both groups after the mental load under the influence of vagal activity. The stabilizing effect of the centralization of the HR control was revealed in the students of both groups by the values of *MoA* at the beginning of the week (Table 2), and a decrease in their *MoA* after the load, especially at the end of the week, indicated a decrease in the degree of centralization of the HR regulation.

The freshmen showed equilibrium of the activity of the autonomous nervous system (AMS) by ΔX at the beginning and at the end of the week before the load, and the fifth-year students had a moderate predominance of parasympathotonia. Mental load caused an increase in the moderate prevalence of parasympatonia in freshmen (see Table 2).

SI in both groups of students before and after the mental test at the beginning and at the end of the week corresponded to the equilibrium of the vegetative sections, but at the end of the week after the test there was an increase in vagal activity.

An analysis of the indication of the total effect of all regulatory influences on the HR modulation by individual values showed that at the beginning and at the end of the academic week before and after the tests, the majority of female students in both groups had normotonia.

The state of the function of the automaticity of the conductive system of the myocardium in students of both age groups is shown in Figure 1.

At the beginning of the week, most of the freshmen (57%) had sinus arrhythmia, and after the test - only 34% of female students had it; moderate and severe impairment of automatism - in 25% and 33% of female students, respectively. Severe sinus arrhythmia was detected at the end of the week before the load in 47% of freshmen, and after it - in 60%. The remaining students have a moderate and pronounced impairment of the automation function.

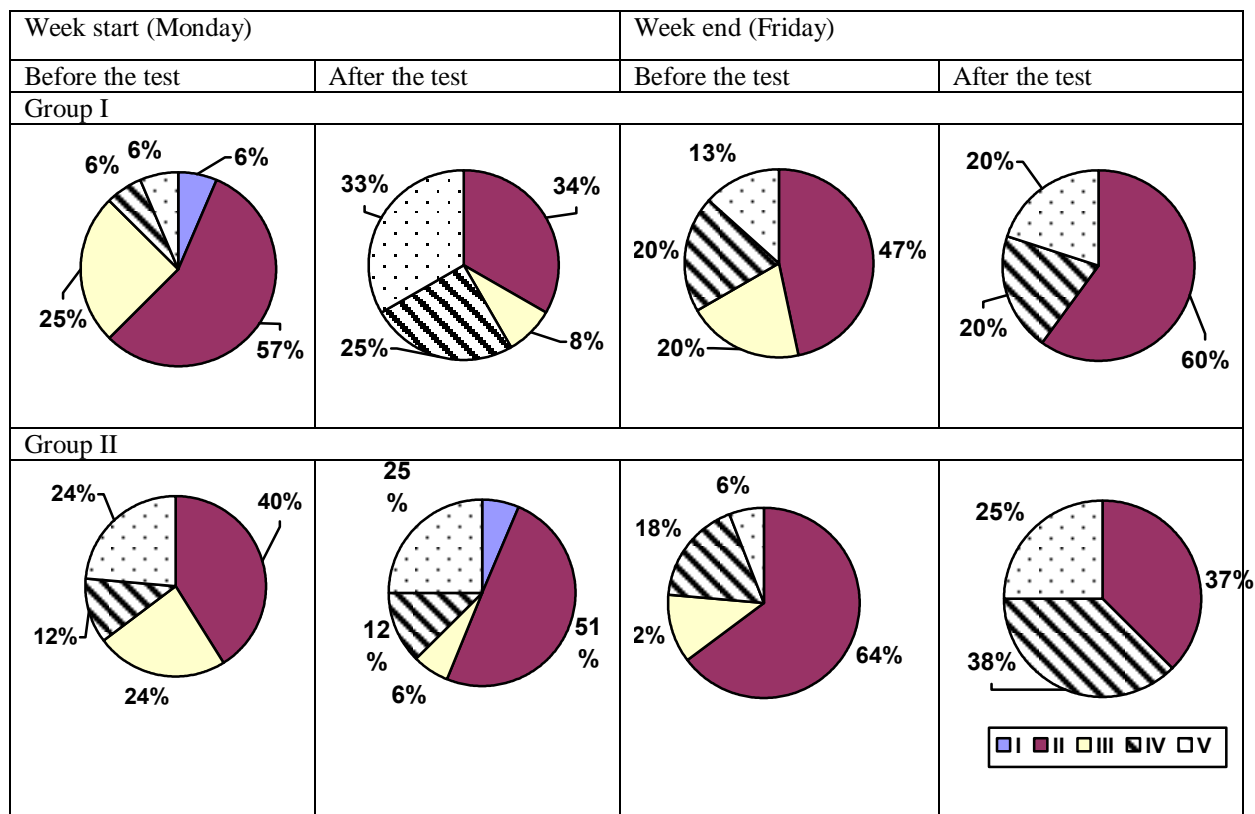


Figure 1. Dynamics of the severity of the function of automatism of students before and after the mental test: I – steady rhythm, II – pronounced sinus arrhythmia, III – moderate sinus arrhythmia, IV – moderately impaired automatism, V – severely impaired automatism.

At the beginning and at the end of the academic week, respectively, 40% and 64% of fifth-year students had a pronounced sinus arrhythmia (see Figure 1). At the beginning of the week after the load, the percentage of students with severe sinus arrhythmia increased up to 50%. By the end of the week, the percentage of fifth-year students with the manifestation of arrhythmia decreased up to 37%, while others had a pronounced impairment of automatism and moderate sinus arrhythmia (see Figure 1).

The result of evaluation of vegetative homeostasis in female students of both groups is presented in Figure 3. At the beginning of the academic week, 67% of the freshmen had a moderate, and 20% had a pronounced predominance of sympathetic regulatory activity. After the load, the percentage of students with pronounced sympatonia increased (36%) and those with moderate (14%) and severe (14%) parasympatonia appeared (Figure 2).

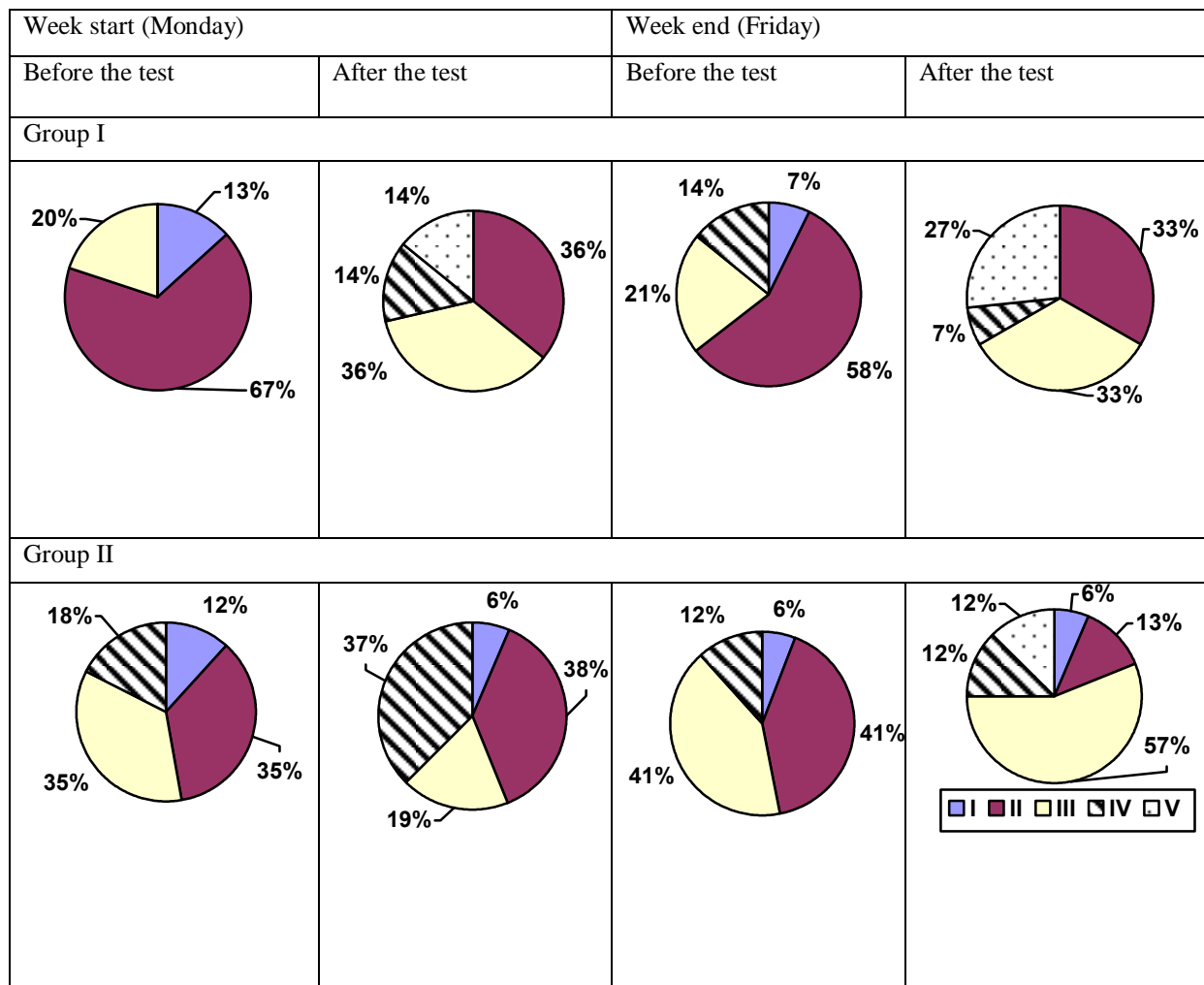


Fig. 2. Dynamics of autonomous balance in female students before and after mental load: I – significant predominance of SNS, II – moderate prevalence of SNS, III – vegetative homeostasis preserved, IV – moderate predominance of the PNS, V – expressed predominance of the PNS.

At the beginning of the week, most of the fifth-year students equally showed a moderate prevalence of sympathy and normal homeostasis; after the load, their percentage with moderate parasympatonia increased, while the one with normotonia decreased (Figure 3). By the end of the week after the mental test, the percentage of fifth-year students with autonomic homeostasis increased.

At the beginning of the week, the freshmen in the state of relative rest showed domination of the normal and moderately intensified activity of the CNC. After the load, the percentage of students with a pronounced activity of CNC increased (Figure 3).

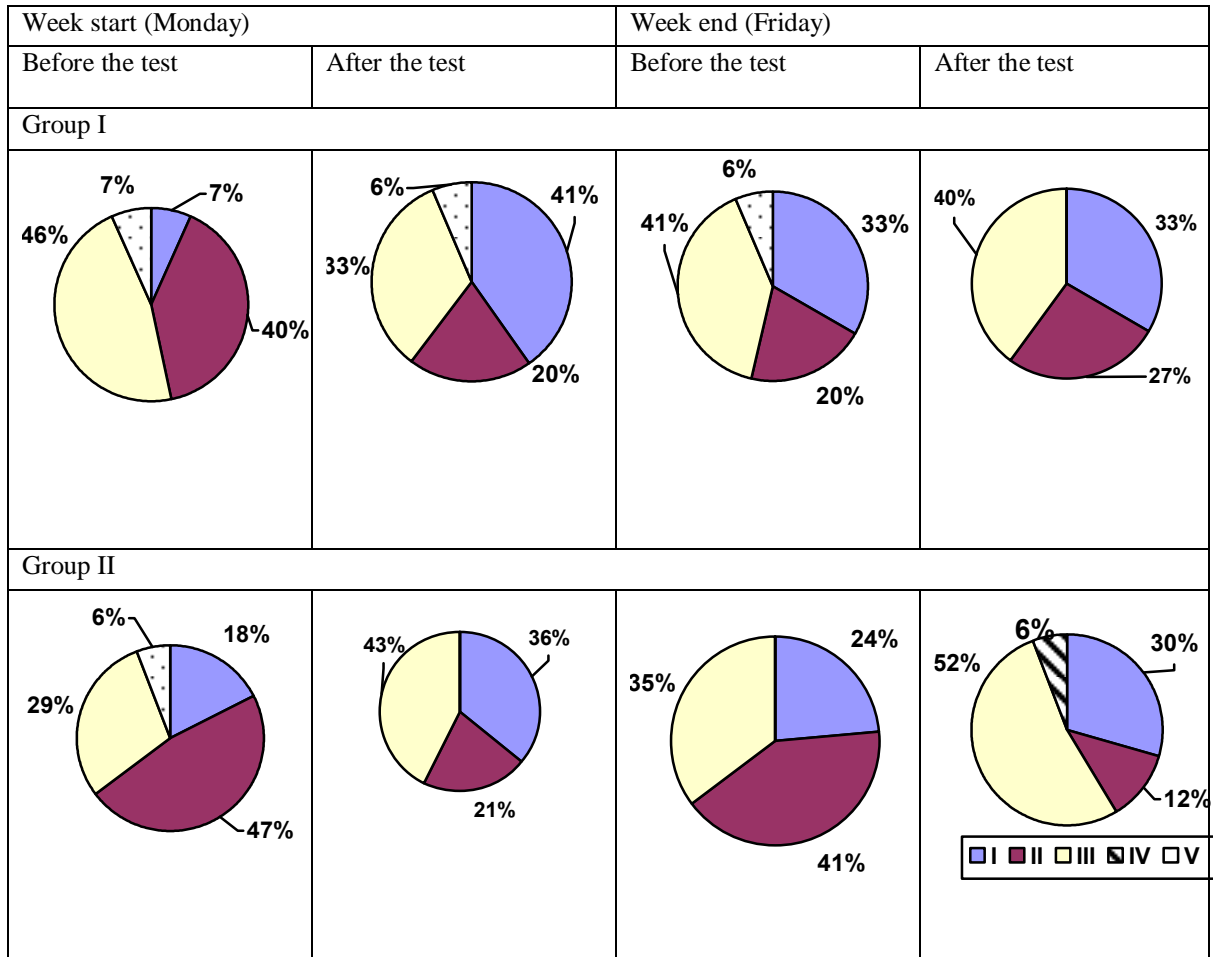


Fig. 3. Dynamics of the CNC activity in the students before and after mental tests: I – pronounced increase in activity, II – moderate strengthening of activity, III – normal activity, IV – moderate weakening of activity, V – pronounced weakening of activity.

By the end of the week the percentage of first-year students increased with the pronounced activity of the CNC. Doing the test did not cause any sharp changes in the structure of the CNC activity. At the beginning

of the week, the percentage of girls with a moderate increased and normal activity of the CNC prevailed among the fifth-year students. Mental load increased the activity of the CNC (Fig. 4).

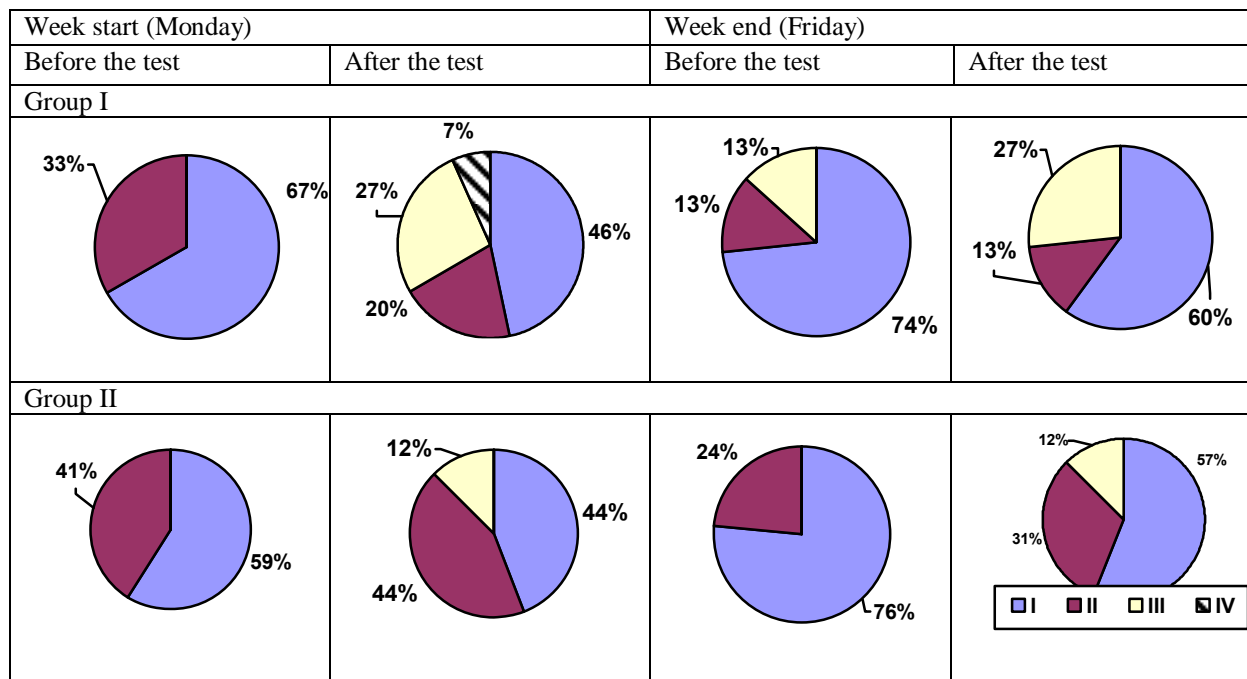


Fig. 4. Dynamics of the functional state of female students before and after the mental test: I – minimal stress, II – functional stress, III – functional overstress, IV – asthenia.

By the end of the school week after the mental load, the percentage of students with a moderate increase in CNC activity decreased, but at the same time the percentage of students with normal and pronounced activity of the CNC increased. After the load, the percentage of fifth-year students with normal and pronounced CNC activity increased (see Figure 4).

Most of the female students in both groups were found to have minimal activity in regulatory systems. The others had a functional stress (see Figure 4).

Mental test increased the percentage of freshmen with asthenia, the number of freshmen and fifth-year students with functional overstress. By the end of the week after the load, the percentage of first-year students with functional overstress increased (see Figure 4).

SUMMARY:

The study of the adaptation of female students of different age groups to mental load and the mechanisms of its regulation showed as follows:

1. The mechanisms of vegetative regulation of the HR in fifth-year female students are more perfect due to the formation of parasympathetic regulation. In relative rest and under the influence of mental loads, the balance of activity of the VNS departments normotonia was revealed in the majority of female students of both groups. Mental load increased the

effect of both VNS departments on the formation of the HR in students of both groups, noting their functional fatigue of the cardiovascular system and the body in general. Decrease in SI within the norm in both groups of female students indicated a shift in the vegetative balance towards the activation of parasympathetic subcortical activity and a decrease in the degree of centralization of the regulation of the SR at rest and under the influence of mental loads.

2. Both groups are characterized at rest by the stability of regulatory influences on the HR. At the beginning of the academic week, the mental load reduces it along the path of development of the transition process and dysregulation with a predominance of vagal activity, and at the end of the week - manifestations of the transient process. Freshmen are characterized by a moderate manifestation of sympathotonia, while the fifth-year students - by equally normal homeostasis and a moderate predominance of sympatotonia. Mental load causes a shift in the vegetative homeostasis along the path of strengthening the moderate and pronounced predominance of vagal activity.

3. At rest, both groups have a pronounced sinus arrhythmia. Mental test reduced its severity and increased the percentage of students with a moderate and severe impairment of their automatism. Both groups showed the optimum level of activity of their subcortical centers at rest, and a moderate and pronounced increase in their activity after the mental

test. The intensification of the vagotonic and the decrease in sympathetic influences on the HR with an increase in the activity of the subcortical nerve centers indicate a decrease in the functional activity of the circulatory system and a manifestation of physical fatigue in the freshmen by the end of the academic week, and in five-year students during the week.

4. Most students of both groups are characterized by the minimum tension of adaptive processes at relative rest, but under the influence of functional loads the percentage of students increases, mostly among freshmen, with their functional stress and overstress.

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