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A. V. Akimova, V. A. Mironov and V. V. Gagiev

Heart Rate Variability in Young Men at Rest and in Autonomic Stress Testing

A. V. Akimova[1, a)], V. A. Mironov[1, b)], and V. V. Gagiev[2, c)]

[1]*Ural State Medical University, 3 Repina St., Ekaterinburg, 620028, Russian Federation*
[2]*5 Military Clinical Hospital of National Guard Troops of the Russian Federation, 10 Soboleva St., Ekaterinburg, 620036, Russian Federation*

[a)]Corresponding author: anna_v_akimova@mail.ru
[b)]vamironov2013@yandex.ru
[c)]vasilij-gagiev@rambler.ru

Abstract. The article presents the study of 105 healthy young men aged 18 to 25. The aim of the study is to assess the state of autonomic regulation of sinus heart rhythm in young men: conscripts, students and cadets. The following methods were applied: therapeutic examination, A. M. Vein's questionnaire, asthenic scale, hospital anxiety and depression scale (HADS) and visual analogue pain scale, high-resolution rhythmocardiography at rest, and mixed autonomic stress testing. Rhythmocardiography at rest showed longer RR intervals in the group of cadets, which testifies to their greater physical fitness. Among the conscripts, significantly lower heart rate variability and amplitude of respiratory arrhythmia at rest and in the Valsalva-Bürker maneuver was observed, as well as adequate response to the load. The students showed more scores on the anxiety and depression scales, more symptoms of asthenia and autonomic dysfunction, headache, back pain, and increased sympathetic effects on HRV. The cadets had no disorders of their psycho-emotional and autonomic status; rhythmocardiography showed a high level of physical fitness and paradoxical reactions to the load, increased humoral-metabolic effects and good adaptive capacity.

INTRODUCTION

The state of health of young men is an urgent problem of modern society. In addition to the presence of chronic diseases and intoxications, which can negatively affect the state of health, an important role is played by the adaptive capabilities of the body, which are closely associated with the peculiarities of autonomic regulation. According to N. S. Krasnopolskaya (2008), a common violation of autonomic regulation among 21- to 24- year-old students is an increase in recovery time in the load test, which indicates a violation of tolerance to physical activity. Also, the reaction to deep breath in the Valsalva maneuver is increased, which suggests chronic inflammatory processes of the upper respiratory tract [1]. C. C. Grant et al. (2012) found that the exercise intervention leads to a significant increase ($p < 0.05$) in vagal influence in the supine position, during rising and standing. The sympathetic control decreased in the supine position, and it increased during rising and standing. In the initial orthostatic response to rising from the supine position, the exercise intervention leads to increased ($p < 0.05$) vagal withdrawal and an increased sympathetic control. The orthostatic response measured as the difference between the standing and supine positions indicated only an exercise-induced increase in sympathetic control [2]. R. C. Melo et al. (2005) showed that physically active young people had lower heart rates and a higher RMSSD index than young men who were sedentary, thus regular physical activity has a positive effect on the vagal activity of the heart and, therefore, reduces the effects of aging in vegetative heart rate control [3].

The aim of this study is to assess the clinical symptoms and autonomic regulation of sinus heart rhythm in young men (soldiers, students and cadets).

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MATERIALS AND METHODS

The research was conducted at the 5th Military Clinical Hospital of National Guard Troops of the Russian Federation, Ekaterinburg, in the course of 2017. We studied 147 young men aged from 18 to 25. The study was based on voluntary participation and informed written consent. We recruited male aged 18 to 25, without acute diseases and exacerbation of chronic diseases at the time of the study and with the absence of physical and psycho-emotional overload for at least 3 days before the study. A total of 147 young men with a median (25%÷75%) age of 22 (20÷23) were enrolled in this study. All students and cadets met the inclusion criteria. Of the 83 conscripts surveyed, only 41 met the inclusion criteria. The remaining 42 were excluded from the study. All participants underwent standard anthropometry and examination by a therapist. We used the Hospital Anxiety and Depression Scale (HADS), visual analog scale (VAS) of pain, Vein's questionnaire of autonomic state, and asthenic scale. We calculated the smoking index and the number of connective tissue dysplasia (CTD) signs.

Based on the anamneses and medical histories, the number of acute respiratory diseases (ARD) over the past year was determined, as well as the number of infectious and inflammatory foci, such as caries, chronic rhinitis, sinusitis, tonsillitis, bronchitis, esophagitis, gastritis, gastric ulcer and/or duodenal ulcer, cholecystitis, pancreatitis, colitis, cystitis, pyelonephritis, and dermatitis.

The survey included questionnaires and scales. Vine's questionnaire was used to identify autonomic disorders [5]. In identifying, 0-14 points were recorded in the absence of autonomic disorders, 15-29 points meant moderate autonomic disorders, and more than 30 points implied expressed autonomic infringements. For rapid diagnosis of asthenic manifestations, a survey was conducted on the asthenic state scale (L. D. Maikova, T. G. Chertova). This scale consists of 30 points-statements reflecting the characteristics of the asthenic state. In identifying, 30-50 points were recorded in the absence of asthenia, 51-75 points meant "weak asthenia", 76-100 points implied "moderate fatigue", and 101-120 points corresponded to "severe fatigue". The severity of pain syndromes was assessed using a visual analog scale (VAS) of pain. The following localization of pain was taken into account: headache, heart pain, back pain, joint pain, chest pain, abdominal pain. The patients independently noted the severity of pain of a certain localization on the scale from 0 (no pain) to 10 points (maximum, unbearable pain). Screening-diagnostics of anxiety and depression was performed using the hospital anxiety and depression scale (HADS) [6]. The scale is composed of 14 statements serving 2 subscales: "anxiety" (odd points 1-13) and "depression" (even points 2-14). Each statement corresponds to 4 variants of the answer, reflecting the gradation of the severity of the symptom and encoded by an increase in the severity of the symptom from 0 (absence) to 3 (maximum severity). When interpreting the results, the total index for each sub-stump is taken into account, with 3 areas of its values: 0-7 – "normal" (the absence of reliably expressed symptoms of anxiety and depression); 8-10 – "subclinically expressed anxiety/depression"; 11 and above – "clinically expressed anxiety/depression".

We studied heart rate variability (HRV) by rhythmocardiography (RCG). The examination was carried out on a CAP-RC-01-Micor computer diagnostic complex (registration certificate No. FS 02262005/2447). HRV indicates statistical analysis: median (25%÷75%) of the duration of the RR interval in seconds, standard deviation of all the waves from the mean RR (SDNN), standard deviation of each fluctuation: humoral-metabolic (σl), sympathetic (σm), parasympathetic (σs) effects, divisions of the autonomic system, and the average amplitude of respiratory arrhythmia (ARA). The ratio of the factors of regulation in the sinus node after the expansion wave structure of the HRV frequency components 3 in the Micor program presents the percentages of influence on the pacemaker: humoral-metabolic effects – at a very low frequency (VLF%), sympathetic – at a low frequency (LF%), and parasympathetic – at a high frequency (HF%) in the frequency ranges relative to the total spectrum, taken as 100%. Recording was performed during supine rest, modified Valsalva maneuver (Vm), Ashner-Dagnini test (Pa), active orthostatic test (Aop); loading test is a modified PWC120 test (power working capacity) [4].

The participants (n=105) were divided into the following 3 groups: group 1 consisted of conscripts (n=41), group 2 were medical university students (n=33), and group 3 was represented by cadets (n=31). A comparative study of the groups was conducted. Normal distribution of the trait in the groups was not observed. To assess the statistical significance of differences on a quantitative basis between the groups, the nonparametric Mann-Whitney U-test was used. The differences were considered to be significant at $p < 0.05$.

RESULTS AND INTERPRETATION

The median age (25%÷75%) of the subjects was 22 (20÷23).

Among conscripts who were examined at the hospital for various symptoms and before entering the contract military service, a large percentage of persons (50.6%) with acute and exacerbation of chronic diseases, as well as autonomic dysfunction syndrome (ADS), were identified. In a previous study of conscripts (n=46), we found 60.1% of ADS against the background of chronic pathology [9]. Among healthy young men, the number of ARD per year and the number of foci of infection in the groups did not differ.

The clinical characteristics of the study groups are presented in Table 1.

TABLE 1. Clinical characteristics of young men – conscripts, students and cadets, Me (25%÷75%)

Parameters	Conscripts (n=41)	p 1,2	Students (n=33)	p 2,3	Cadets (n=31)	p 1,3
BMI, kg/m^2	22.4 (20.95÷24.3)	0.89	22.4 (20÷ 244.6)	0.57	22.8 (21.6÷24.2)	0.59
Smoking index	0.067 (0÷0.6)	**0.05**	0 (0÷0)	0.38	0.003 (0÷0.3)	0.16
CTD signs	6 (2.5÷7.5)	0.71	6 (3-7)	0.71	6 (3÷8)	0.28
ARD over the past year	2 (1÷3)	0.35	1(1÷2)	0.83	1(1÷2)	0.4
The number of infectious and inflammatory foci	1 (1÷2)	0.68	1(1÷3)	0.91	1 (0÷3)	0.77
HADS depression, score	3 (1÷5)	0.48	4 (2÷5)	**0.006**	2 (1÷3)	**0.04**
HADS anxiety, score	2 (0÷4)	**0.000**	6 (3÷8)	**0.000**	1(1÷4)	0.8
Vein score	3 (0÷12.5)	**0.000**	18 (12÷29)	**0.000**	4 (0÷8)	0.93
Asthenic scale, score	37 (33÷48)	**0.000**	50 (42÷55)	**0.000**	36 (33÷40)	0.40
Back ache, VAS	0 (0÷3)	0.14	2 (0÷3)	**0.007**	0 (0÷1)	0.34
Head ache, VAS	0 (0÷2)	**0.006**	2 (1÷3)	**0.004**	1 (0÷2)	0.96

There were significant differences in the psycho-emotional statuses of the studied groups. The students showed more points on the scale of depression HADS compared to the cadets (p=0.006). The conscripts also differed from the cadets by higher scores of depression (p=0.04). However, the indicators corresponded to normal values. The students significantly differed from the conscripts (p=0.000) and the cadets (p=0.000) showed higher alarm points on the anxiety scale, which also did not indicate a clinically expressed alarm. This may be due to the peculiarities of higher medical education, which is characterized by high requirements for students, regular and strict control of knowledge. However, higher levels of anxiety in students may be associated with autonomic disorders. The students, compared with the conscripts (p=0.000) and the cadets (p=0.000), demonstrated significantly higher scores on Vein's questionnaire, corresponding to a mild degree of autonomic disorders. They also had higher scores on the asthenic state scale, which corresponded to a mild degree of asthenia, compared with the conscripts (p=0.000) and the cadets (p=0.000). When assessing the severity of pain syndromes on the visual scale of pain, the students noted more pronounced headaches compared to the conscripts (p=0.006) and the cadets (p=0.004) and back pain compared to the cadets (p=0.007). The severity of pain was low and the median was 2 points out of 10. Headaches are probably associated with autonomic dysfunction in this group, and back pain must be attributed to a sedentary lifestyle.

The revealed differences in the studied groups may be related to the initial medical selection for military service, and especially the entrance tests to the law Institute of the Ministry of Internal Affairs, which involve a sufficiently high level of physical and mental health, and living conditions. Unfavorable factors for the medical students can be considered a sedentary lifestyle, often disturbed work and rest associated with night shifts and part-time work, irregular meals, high psychoemotional and mental stress. Among healthy conscripts and cadets, psychoemotional and autonomic disorders have not been identified.

Assessment of HRV by high-resolution RCG showed initial differences among the participants of the study groups. The cadets differed from the conscripts and the students by longer RR intervals at rest and in all autonomic and stress tests that were conducted. This may be due to the greater training of the group members, which is consistent with the literature data [2, 3]. The resulting HRV indices at rest are presented in Table 2.

TABLE 2. Statistical analysis of HRV parameters for conscripts, students and cadets at rest, Me (25%÷75%)

Parameters	Conscripts (n=41)	p 1,2	Students (n=33)	p 2,3	Cadets (n=31)	p 1,3
SDNN	0.035 (0.024÷0.044)	**0.009**	0.047 (0.032÷0.058)	0.5	0.043 (0.033÷0.058)	**0.04**
ARA	0.053 (0.032÷0.071)	**0.003**	0.078 (0.053÷0.106)	0.19	0.061 (0.045÷0.088)	0.098
σl	0.017 (0.014÷0.023)	0.18	0.022 (0.014÷0.03)	0.65	0.024 (0.016÷0,031)	0.065
σm	0.013 (0.01÷0.024)	0.18	0.02 (0.013÷0.029)	0.74	0.019 (0.016÷0,031)	0.13
σs	0.023 (0.013÷0.031)	**0.04**	0.027 (0.022÷0.042)	0.54	0.028 (0.02÷0,039)	0.14
VLF%	31.8 (24.2÷45.9)	**0.01**	22.35 (16.7÷33.75)	0.14	29.6 (22.6÷35.6)	0.17
LF%	24.05(13.6÷28)	0.56	20 (9.05÷30.25)	0.41	24.6 (15.7÷32)	0.36
HF%	43.05 (30.4÷59.2)	0.14	53.75 (29.2÷65.4)	0.32	45.3 (27.5÷58.8)	0.64

Initially, the HRV of the conscripts was lower than that of the students (p=0.009) and the cadets (p=0.04). The conscripts had lower values of the amplitude of respiratory arrhythmia (ARA) compared to those of the students (p=0.003); this may be due to a decrease in parasympathetic tone. The median is within the normal range, but it is lower than in more trained groups. Significantly lower values of σs compared to those for the students (p=0.04) indicate a decrease in the variability of high-frequency waves. As a compensatory reaction, there should be an increase in HF%, but this is not observed. According to the integral parameters of the wave structure of the sinus rhythm in the conscripts at rest, sympathetic and parasympathetic effects would not suffice to provide the autonomic regulation of the cardiovascular system. In this group, a more pronounced humoral-metabolic effect than in the student group was registered, VLF% (p=0.01), and this indicates an increased stress of regulatory mechanisms. Similar results were obtained in a previous study of conscripts [9]. Shift work entailing lack of sleep in men causes a decrease in HRV during sleep, which indicates an imbalance in the autonomic nervous system and the risk of developing cardiovascular diseases [10].

During the Valsalva maneuver, the students and the cadets showed an almost 2 times decrease in SDNN, and it is functional. Initially, the HRV increased, but this was leveled – the reaction is paradoxical; however, the ARA indicators remain at a high level. In the conscript group, the reduction of SDNN is within the physiological range. Thus, the conscripts show healthy reactions, whereas the students and the cadets have overloading of regulatory systems and a pathological increase in parasympathetic effects (Table 3).

TABLE 3. Statistical analysis of HRV parameters for conscripts, students and cadets during the modified Valsalva maneuver (Vm), Me (25%÷75%)

Parameters	Conscripts (n=41)	p 1,2	Students (n=33)	p 2,3	Cadets (n=31)	p 1,3
SDNN	0.033 (0.024÷0.039)	**0.011**	0.04 (0.031÷0.052)	0.57	0.04 (0.028÷0.057)	0.06
ARA	0.048 (0.031÷0.066)	**0.011**	0.067 (0.048÷0.095)	0.21	0.054 (0.031÷0.091)	0.29
σl	0.017 (0.013÷0.021)	0.24	0.019 (0.014÷0.028)	0.72	0.021 (0.015÷0.03)	0.12
σm	0.016 (0.012÷0.025)	**0.022**	0.026 (0.015÷0.037)	0.16	0.019 (0.015÷0.025)	0.2
σs	0.019 (0.012÷0.027)	0.058	0.023 (0.018÷0.033)	0.49	0.022 (0.013÷0.04)	0.39
VLF%	25.2 (21.4÷43.4)	0.157	23.3 (16.9÷34.15)	0.29	34.7 (15.5÷46.6)	0.95
LF%	26 (16.7÷ 32.7)	0.097	32.7 (22.3÷48.25)	0.4	30 (16.9÷45.4)	0.43
HF%	39.45 (23.7÷54.5)	0.65	33.05 (26.6÷56.05)	0.61	37.3 (19÷53.8)	0.41

The Aschner-Dagnini test did not find differences in the indicators of HRV in the studied groups. This indirectly indicates the absence of significant disturbances, detected by the stimulation of the humoral-metabolic component of the complex, regulating the heart rate, among healthy young men.

In the active orthostatic test (AOP), which stimulates the shutdown of the parasympathetic link of autonomous regulation and the strengthening of the sympathetic effect on the automatic cells of the sinus node, the expected decrease in RR is about 30%. In the study groups, the decrease was 24-28%. The greatest increase of σm in orthostasis is recorded for conscripts; therefore, a sufficient amount of noradrenaline is supplied, and functional reserves are preserved. The cadets had a significantly higher degree of heart rate change than the conscripts

(p=0.007) and the students (p=0.033). The absolute time required to reach the maximum response to the stimulus was the shortest in the student group, and it was the longest in the group of cadets. The recovery time in the group of cadets was shorter, and this characterizes the features of trained young people (Table 4).

TABLE 4. Statistical analysis of HRV parameters for conscripts, students and cadets in the active orthostatic test (Aop), Me (25%÷75%)

Parameters	Conscripts (n=41)	p 1,2	Students (n=33)	p 2,3	Cadets (n=31)	p 1,3
RR	0.628 (0.558÷0.708)	**0.006**	0.725 (0.619÷0.764)	0.41	0.699 (0.622÷0.738)	0.075
SDNN	0.028 (0.02÷0.045)	0.07	0.037 (0.028÷0.045)	0.1	0.031 (0.024÷0.04)	0.59
ARA	0.032 (0.023÷0.046)	0.17	0.04 (0.031÷0.052)	0.21	0.032 (0.03÷0.047)	0.83
σl	0.0165 (0.01÷0.022)	0.07	0.02 (0.016÷0.028)	0.16	0.016 (0.013÷0.025)	0.82
σm	0.021 (0.014÷0.036)	0.15	0.025 (0.021÷0.035)	0.24	0.024 (0.017÷0.027)	0.68
σs	0.011 (0.008÷0.015)	0.9	0.011 (0.008÷0.014)	0.1	0.008 (0.007÷0.012)	0.061
VLF%	31.35 (19÷48.5)	0.59	35.9 (17.7÷45.5)	0.64	31.3 (19.9÷41.9)	0.83
LF%	54.6 (35.3÷66.6)	0.74	48.3 (41.9÷67.4)	0.32	61.2 (44.1÷67.1)	0.27
HF%	12.15 (6.5÷21.9)	0.07	7.9 (5.9÷15,7)	0.45	7.6 (4.4÷16.2)	**0.017**
ΔNN%	-29.7 (-37.1÷-23.8)	0.84	-30.9 (-37.6÷-24.7)	**0.03**	-37.5 (-43.2÷-28.3)	**0.007**
ΔNN, s	0.239 (0.17÷0.338)	0.22	0.267 (0.19÷0.32)	0.06	0.35 (0.224÷0.442)	**0.005**
tAB, int	26 (23÷31)	0.11	24 (19÷28)	**0.04**	27 (23÷34)	0.69
tAB, s	15.9 (14.14÷18.06)	0.05	14.96 (11.63÷16.44)	**0.00**	17.84 (15.29÷21.43)	**0.011**
tr, int	13 (10÷17)	0.9	12 (10÷18)	0.64	11 (10÷17)	0.7
tr, s	8.19 (5.89÷12.37)	0.21	8.42 (7.69÷13.04)	0.48	7.59 (6.58÷11.68)	0.55

During the exercise test (PWC120) conducted for the analysis of the autonomic support of physical activity, SDNN normalized in all the groups. The reduced reaction to physical activity among young men was revealed. HR 120 within 25-30 RR intervals is not achieved, despite the efforts of the subjects. The median of the tAB index is more than 30 intervals in all the three groups.

However, the group of cadets demonstrated significantly higher values ΔNN% (p=0.027) and ΔNN, s (p=0.011) compared with the conscripts, indicating the maximum response to the stimulus, expressed as a percentage of the baseline and in seconds (Table 5). The recovery time in the exercise test was higher among the students, which coincides with the literature data [1], and lower in the group of cadets.

TABLE 5. Statistical analysis of HRV parameters in conscripts, students and cadets in the loading test (a modified PWC120 test), Me (25%÷75%)

Parameters	Conscripts (n=41)	p 1,2	Students (n=33)	p 2,3	Cadets (n=31)	p 1,3
RR	0.872 (0.746÷0.958)	0.4	0.878 (0.799÷0.965)	0.05	0.969 (0.836÷1.084)	**0.005**
SDNN	0.047 (0.031÷0.056)	**0.051**	0.059 (0.035÷0.067)	0.32	0.048 (0.037÷0.061)	0.25
ARA	0.075 (0.047÷0.101)	**0.096**	0.093 (0.052÷0.125)	0.36	0.075 (0.059÷0.114)	0.26
σl	0.017 (0.013÷0.025)	0.17	0.022 (0.013÷0.033)	0.96	0.021 (0.016÷0.029)	0.11
σm	0.019 (0.011÷0.026)	**0.05**	0.024 (0.017÷0.03)	0.23	0.019 (0.014÷0.028)	0.34
σs	0.034 (0.021÷0.043)	0.63	0.037 (0.019÷0.051)	0.95	0.033 (0.024÷0.046)	0.45
VLF%	20.9 (13.6÷31.4)	0.83	20.15 (8.8÷34.05)	0.59	25 (12.9÷30.5)	0.94
LF%	15.6 (11.2÷25.3)	0.23	20.7 (11.55÷36.25)	0.86	19.6 (12.9÷30.5)	0.28
HF%	59.6 (44.2÷68.9)	0.15	51.7 (36÷65.4)	0.57	50.1 (45.6÷ 61.7)	0.38
ΔNN%	-19.8 (-32.7÷-12.8)	0.75	-23.85 (-34.9÷-5.9)	0.15	-27.7 (-33.6÷-20.2)	**0.027**
ΔNN, s	0.136 (0.079÷0.244)	0.99	0.157 (0.047÷0.306)	0.09	0.212 (0.147÷0.302)	**0.011**
tAB, int	42 (35÷50)	0.77	40.5 (33.5÷51)	0.38	38 (30÷44)	0.23
tAB, s	22.42 (18.26÷27.34)	0.85	21.75 (18.58÷29.38)	0.69	22.23 (16.83÷26.44)	0.61
tr, int	122 (99÷151)	0.81	125 (101÷162.5)	0.17	107 (93÷138)	0.26
tr, s	93.3 (÷72.11÷115.9)	0.37	103.9 (77.69÷120.8)	0.18	88.6 (70.95÷104.27)	0.87

CONCLUSION

Thus, the analysis of HRV of young men at rest and multidirectional autonomic stress tests has shown significant differences in all the groups. According to the integral indicators of the groups, which initially differed, the differences were smoothed in the exercise test, but through different adaptive mechanisms. The conscripts do not have a high HRV, but they adequately respond to a load. The men who train much, give paradoxical reactions. The students are the easiest to restore homeostasis at rest, the cadets are more difficult, since they have excessive loads, and the conscripts are not sufficiently adapted to the loads.

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