

The state of vegetative status and adaptive reserve to physical activity in the elderly

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Abstract:

Introduction. The use of physical activity to improve the health of the elderly requires regular medical and pedagogical control of the reserve capabilities of their body. The heart rate variability (HRV) method allows such control. However, the use of the HRV method to monitor the elderly is not well understood. **Research aim:** to assess the vegetative status, adaptive reserves and physical activity of the elderly using the method of heart rate variability. **Materials and methods.** The research project involved 88 people aged 60 years and older, who attended a physical culture and sports institution in the city of Nizhny Novgorod (Russia). According to the measurements of length and body weight, BMI was estimated, kg/m². Physical activity was assessed using the Motor Activity Questionnaire (ODA-23+). HRV analysis was performed according to electrocardiogram data in the supine position and in the orthostatic position. **Results.** In the regulation of the heart of the elderly, the power of the very low frequency of the spectrum dominates, LFnu slightly exceeds HFnu in the supine position. In the prone position, the only significant determinant of HRV was BMI, which was positively correlated with a measure of total stress. In the orthostatic test, age became an important factor influencing the autonomic response with a relative decrease in sympathetic modulation (%LF and LFnu) and an increase in VLF activity. It was found that 15.9% of the survey participants showed a very high level of physical activity, 18.2% - a high degree of it. 32.9% of respondents recorded an average level of physical activity, 20.5% - a low level, and 12.5% - a very low level. It was found that individuals with a high level of physical activity showed significant tolerance to physical activity, as a higher level of adaptive reserves of the body prevailed. **Conclusions.** The dependence of HRV scores on age, BMI and physical activity is important from a practical point of view, as it provides the key to using the heart rate variability technique for individual monitoring of health promotion effects. The use of the ODA-23+ questionnaire makes it possible to form patterns about the level of physical activity.

Key Words: physical activity, physical activity, elderly people, heart rate variability (HRV)

Introduction

An analysis of the scientific literature indicates a trend towards physical inactivity and a decrease in the energy expenditure of the body in the population of many countries (Pengpid et al., 2019; Chen et al., 2020; Dominski, & Brandt, 2020). According to WHO (World Health Organization. European Regional Office, 2016), more than a third of the world's population has a sedentary lifestyle, in which the metabolic equivalent is 1-1.5 min/week, which corresponds to a state of rest (Jordan et al., 2020). A sedentary lifestyle is considered by scientists as a factor that negatively affects human health (Chekhovska et al., 2020; Flatt et al., 2020; Setiakarnawijaya et al., 2021).

The most effective for maintaining and promoting health is moderate physical activity with an intensity of 150 minutes or more per week (WHO guidelines on physical activity and sedentary behavior, 2020). Researchers have shown that regular physical activity reduces the risk of heart disease, stroke, type 2 diabetes, cancer and other severe non-communicable diseases in humans (Zhang et al., 2019; Ushakova et al., 2017) and increases life expectancy (Rueggsegger, & Booth, 2018). This allows us to recommend a moderate intensity of physical activity for persons of mature and elderly age under strict control of the volume and intensity of physical activity.

However, some aspects remain unclear or controversial, among which is the problem of accurately dosing exercises for a particular person and monitoring results in the short term. Given the J-shaped relationship between the amount of exercise and health benefits, it seems important to choose the right intensity and volume of exercise programs (O'Keefe et al., 2018).

General approaches (for example, using the standard recommendation of 150 minutes of moderate exercise per week or calculating heart rate using workout formulas) cannot take into account an individual's response to exercise or daily changes in their state (or functional state). Research by Guzii et al (2020), Christiani et al. (2021), Bocharin et al., (2022) showed the possibility of using the method of heart rate variability (HRV) to control the intensity of physical activity. This method provides information about autonomic regulation, which is very sensitive to any external or internal physiological stimuli. This approach has been shown to be effective in controlling the functional characteristics of the body in professional athletes, amateur athletes and exercisers (Seshadri et al., 2019; Guzii et al., 2020; Christiani et al., 2021; Bocharin et al., 2022). Wearable electronic devices may be used, many of which include assessment of functional status or stress levels based on HRV analysis. The issue of extrapolating these results to a real older population, which includes people with different levels of physical activity, health status and medication, remains unclear.

Within the framework of a state grant, our group began a longitudinal study aimed at developing an expert system for monitoring the functional state and promoting the health of older people. This paper presents data on the initial characteristics and dependencies of autonomic regulation, estimated by HRV indicators in a sample of elderly people attending a regional health promotion center who will perform moderate physical activity.

Research aim. To assess the vegetative status, adaptive reserves and physical activity of the elderly using the method of heart rate variability (HRV)

Material & methods

The research project involved 88 persons, with an average age of 67 ± 1.4 years, who performed different modes of physical activity in a sports institution in the city of Nizhny Novgorod (Russia). All participants signed informed consent before beginning any study procedures. The study protocol was approved by the local ethics committee and all procedures were in accordance with the 2003 Declaration of Helsinki. The study group included 85 women and 3 men who were excluded from diseases associated with cardiac arrhythmias (atrial fibrillation, atrial flutter, ectopic rhythms), frequent extrasystoles, implanted pacemakers and acute infections. During the screening procedure, all participants filled out a form with information about their daily activities and health status. Basic anthropometry was performed with the calculation of body mass index (BMI). Motor activity was determined using the Motor Activity Questionnaire (ODA-23+), which included questions about physical activity regimes, the frequency of using adaptive physical culture loads during the week, preferred types of adaptive physical culture, and healthy lifestyle features (Krasnitskiy et al., 2021). Using the software product, we created, we calculated the results of the survey, in which each of the 23 questions was evaluated in points, then the integral value of the physical activity indicator was calculated. The adaptive parameters of the organism of the examined persons were evaluated according to the results of the analysis of heart rate variability. To do this, the patients' electrocardiograms were recorded in a quiet room from 10:00 to 14:00 using a cardiograph based on the PC "Poly-Spectrum-8/E" with the software "Poly-Spectrum. Net/Rhythm" (Russia). We performed a time-domain analysis by calculating mean interval between normal beats (RRNN, ms), standard deviation of intervals between beats (SDNN, ms), root mean square of successive RR interval differences (RMSSD, ms), and power spectrum analysis (using Fast Fourier). We calculated total power in the range of 0.003-0.4 Hz (TP, ms^2), powers at very low frequency (0.003-0.04 Hz, ms^2), low frequency (0.04-0.15 Hz, ms^2) and high frequency (0.15-0.4 Hz, ms^2), ranges. We expressed the powers of LF and HF in normalized units to reflect the sympathetic-parasympathetic balance, as well as the powers of VLF, LF and HP as a percentage of TP (%VLF, %LF, %HF). The autonomic equilibrium index (LF/HF) was calculated; the integral parameter of the presence or absence of a stress state (SI) was evaluated. To study the level of adaptive reserves, a classical six-minute walk test was used (Enwright, 2003). In this case, the cardiointervalogram was recorded immediately after the end of the stress test. The obtained data were processed using Statistica 12 software (Statsoft Inc, USA). All continuous variables were reported as medians and interquartile ranges (Me [25%-75%]). Nonparametric statistics were used to assess differences between groups (Mann-Whitney U test) and parameter correlations (Spearman R rank). The results were considered statistically significant at $p < 0.05$.

Results

Analysis of the calculation results of the Quetelet II index (BMI) showed that in 17 (20.7%) participants the value of the body mass index was within the normal range ($\text{BMI} \leq 24.9 \text{ kg/m}^2$). Thirty (36.7%) sample participants were overweight ($\text{BMI} = 25.0\text{--}29.9 \text{ kg/m}^2$) and obese in 35 (42.6%) cases, $\text{BMI} \geq 30 \text{ kg/m}^2$, median = $28.7 (25.4\text{--}31.6) \text{ kg/m}^2$. The study of the level of adaptive reserves of the project participants in terms of heart rate variability in lying and standing body positions is shown in Table 1.

Table 1. Summary descriptive statistics of HRV time and frequency domain parameters

Parameter	Supine (n=79)	Orthostatic (n=79)
RRNN (ms)	902.5 (814.0–993.0)	805.0 (714.0–868.0)
SDNN (ms)	28.0 (20.0–36.0)	25.0 (19.0–34.0)
RMSSD (ms)	19.0 (14.0–26.0)	12.0 (9.0–17.0)
pNN50	1.1 (0.0–4.7)	0.0 (0.0–0.6)
SI (a.u.)	235.0 (129.4–443.4)	335.5 (207.2–517.2)
TP (ms ²)	688.0 (397.0–1250.0)	593.0 (343.0–1138.0)
HF (ms ²)	104.0 (61.0–210.0)	39.0 (20.0–88.0)
LF (ms ²)	145.5 (84.0–297.0)	112.0 (60.0–244.0)
VLF (ms ²)	392.5 (178.0–676.0)	353.0 (243.0–753.0)
HFnu	44.5 (32.7–54.7)	25.5 (17.6–37.6)
LFnu	55.5 (45.3–67.3)	74.5 (62.4–82.4)
HF%	15.5 (9.3–24.2)	7.4 (4.3–11.1)
LF%	20.9 (16.2–30.0)	20.5 (13.8–26.8)
VLF%	60.3 (46.6–70.5)	70.6 (61.2–79.3)
K 30/15		1.17 (1.12–1.24)

In the supine position and in the orthostatic position, the regulation of heart rate is dominated by the component of the very low power frequency spectrum, presumably reflecting slow subcortical, thermoregulatory, and hormonal modulations of cardiac activity. This frequency band accounts for about 2/3 of the total power, which characterizes the relative psycho-emotional stress in the subjects. The power of LFnu slightly exceeds HFnu in the supine position, which reflects the tendency for the sympathetic nervous system to predominate in regulation. Overall, 54 participants (65.9% [95% CI: 54.6–76.0%]) had higher LFnu than HFnu. The SI value (even the lower quartile limit) in the supine and standing position was higher than the normal stress level value. Statistically significant results of the correlation analysis of HRV parameters with age, body composition (BMI) and physical performance are presented in Table 2.

In the prone position, the only significant determinant of HRV was BMI: it was positively correlated with global stress and negatively correlated with parameters reflecting global rhythm variability and slow modulations. In the orthostatic test, age became an important factor influencing the autonomic response with a relative decrease in sympathetic modulation (LF and LFnu), an increase in VLF activity, and a decrease in parasympathetic reactivity (K 30/15) in old age. In addition, LF was associated with the 6 MW distance, with higher LF in participants covering longer distances in 6 minutes.

Table 2. Spearman correlations for HRV time- and frequency domain parameters

Pair of variables	Valid N	Spearman R	p-value
Supine			
SDNN & BMI	79	-0.25	0.025
SI & BMI	79	0.242	0.032
TP & BMI	79	-0.26	0.021
LF & BMI	79	-0.25	0.023
VLF & BMI	79	-0.25	0.023
Orthostatic			
HF & BMI	78	-0.23	0.039
LF & Age	78	-0.35	0.002
HFnu & Age	78	0.28	0.013
LFnu & Age	78	-0.28	0.013
%LF & Age	78	-0.38	0.0005
%LF & 6MW	73	0.26	0.028
%VLF & Age	78	0.24	0.036
%VLF & BMI	78	0.23	0.046
K 30/15 & Age	78	-0.25	0.030

An important section of the research project was to determine the level of motor activity of the elderly, table 3.

Table 3. Assessment of the level of physical activity according to the ODA-23+ questionnaire

Motor activity	Points
Very high Очень высокая	85–108
High Высокая	62–84
Moderate Умеренная	39–61
Low Низкая	≤38
Very low Очень низкая	85–108

The distribution of the number of project participants by the level of physical activity is shown in Figure 1.

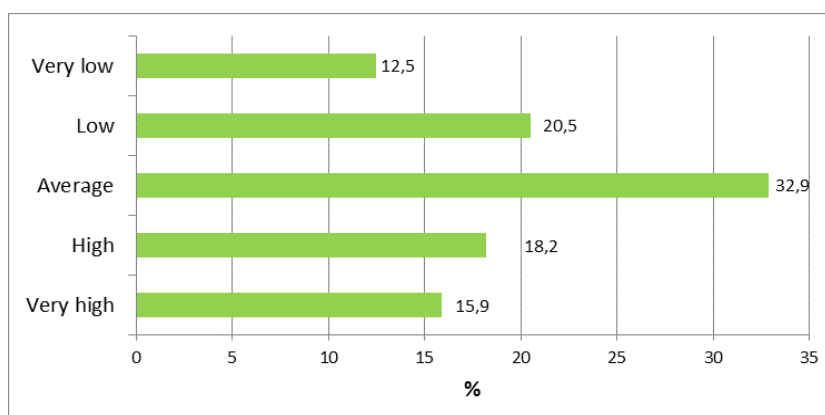


Fig. 1. The level of motor activity of the studied persons, according to the ODA-23 questionnaire+

The results of a survey of 88 respondents show that 34.1% of those surveyed have a high and very high level of physical activity. 32.9% of respondents have an average level of physical activity. 33.0% of project participants have low and very low levels of physical activity. With the study group, a functional test was conducted in the form of a 6-minute walk. After the test, the urgent adaptation of the body to physical activity was studied based on the indicators of statistical and spectral analysis, which took place with the registration of an interval cardiogram after performing physical exercise (Figure 2). According to the survey, the elderly was divided into subgroups according to their level of physical activity. SDNN, SI, TP and VLF (%) were studied.

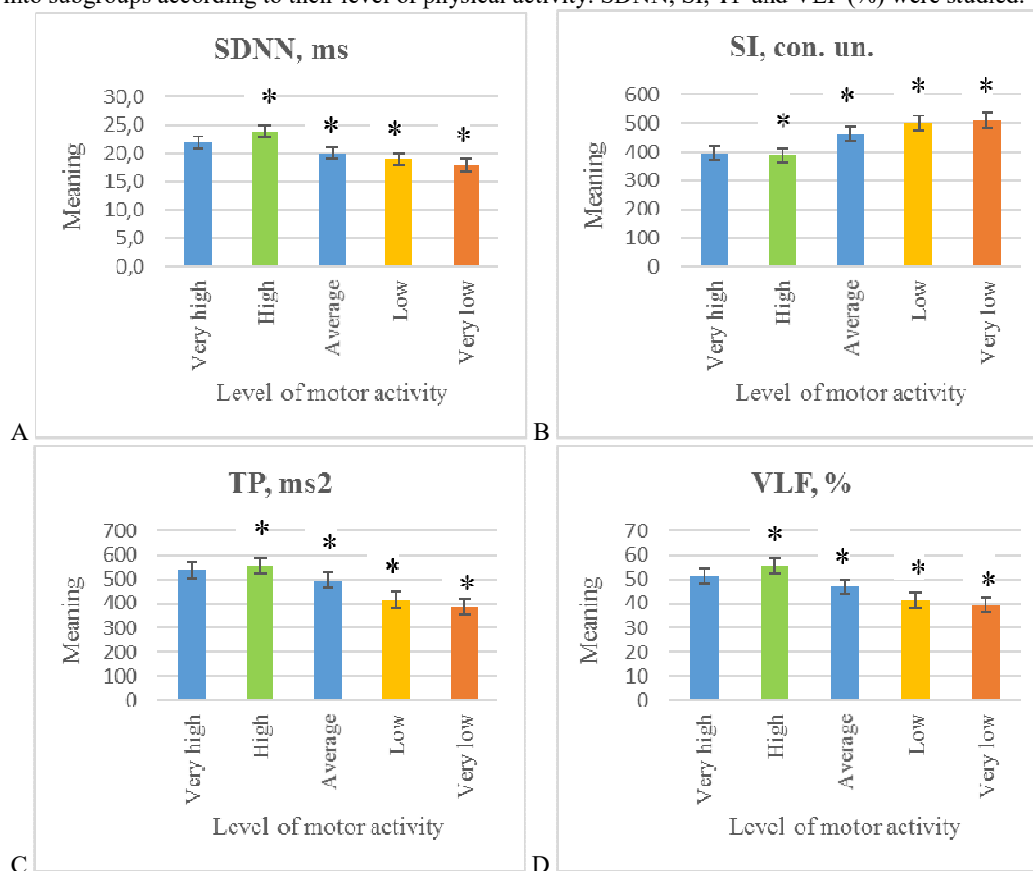


Fig. 2. The state of vegetative tone of elderly people after a load test taking into account motor activity («*» - intergroup differences are statistically significant, $p < 0.05$)

The results of the analysis showed that persons with high motor activity have more significant adaptive reserves. This is indicated by higher values of SDNN, VLF, and total spectrum power. In people with low and very low physical activity, there is an increase in the centralization of the heart rate, a decrease in adaptation reserves, tension in regulatory systems, and an increased level of stress index.

Dicussion

It is generally accepted that body aging is associated with changes in the activity of the autonomic nervous system, which can be detected using the analysis of heart rate variability. Compared to the pooled HRV reference data for the general population reviewed by Nunan et al. (2010) our project participants have normal RRNN, low total heart rate variability (SDNN), low sympathetic (LF power) and vagus nerve activity (high frequency power, RMS). A certain predominance of low frequency power over high frequency power, i.e., sympathetic modulations over parasympathetic ones, can be observed both in the reference data and in our group. Unfortunately, the reference data above does not contain information about the HRV parameters in the orthostatic test. Chuangchai, Pothisiri (2021) presented data on resting heart rate variability and orthostatic variability in elderly people similar to our group.

The authors noted that if the parasympathetic activity, assessed by RMSSD in the prone position, was the same with our population, then the orthostatic test showed a significant difference. In our population, RMSSD (and HFnu power, another parameter related to vagus nerve activity) decreased in orthostasis. Our data appear to be consistent with the general concept of HRV reflecting stress responses, i.e. posture change from lying to standing is a physiological stress that requires activation of the sympathetic nervous system and deactivation of the vagus nerve to maintain proper hemodynamics. We believe that the apparently opposite answer in the cited article may be related to the technical problems of HRV analysis, since RMSSD, like other HRV parameters, are subject to artifacts and arrhythmias. In our study, we excluded 9 records (about 10%) from analysis due to problems with sinus rhythm. This observation highlights the importance of proper manual review and data cleansing before performing any HRV analysis in the time or frequency domain, especially in populations at high risk of sinus node dysfunction or arrhythmia.

There were quite a few overweight or obese people in the study sample. For example, Antelmi et al. (2004) found no significant relationship between HRV and BMI. In a study of apparently healthy people of different ages (Kim et al., 2005), the authors found a significant correlation between obesity measures (including BMI) and HRV parameters at rest, while changes from rest to standing did not differ in groups with normal weight and obesity. The HRV method is widely used to control exercise dosing with overload leading to a decrease in HRV (da Silva et al., 2019).

Taken together, these facts may open up new prospects for the use of HRV in long-term health promotion programs. Also of interest are the results of the questionnaire, characterizing the level of motor activity of older people. In the future, it is interesting to analyze whether there are any effects of the initial level of physical activity, according to the questionnaire, on the level of adaptive reserves, according to HRV. from the level of motor activity. Moreover, an excellent result would be the determination of correlation relationships between the types and modes of physical activity and the vegetative status of the studied individuals. This will be done as part of the continuation of the study.

Our study is of practical interest. The study of the level of physical performance with the help of a questionnaire allows assessing the level of motor activity, and the medical and biological block of research in the field of physiology of adaptation to physical culture and sports activities is of great importance for planning the level of motor activity of people of different ages and conducting mass screening in the field of studying autonomic tone.

Conclusions

The results of our research project highlight the importance of using a proper HRV protocol (prone and orthostatic tests) and thorough cleaning of electrocardiogram recordings before analysis. The dependence of HRV indicators on age, BMI, and physical activity that we have identified is of great practical importance. Dependency provides the key to using HRV to monitor health promotion effects on an individual basis.

The use of the ODA-23+ questionnaire makes it possible to form patterns about the level of motor activity of the studied individuals. It was established that persons performing a high level of motor activity showed a significantly significant tolerance to physical activity due to a higher level of adaptive reserves of their body. Given the high efficiency of the heart rate variability method for determining the adaptive reserve capabilities of the body, this technique can be recommended for medical and pedagogical control of mature and elderly people who lead a healthy lifestyle and perform physical activity of various capacities.

In further studies, it is advisable to determine the relationship between the types and modes of physical activity and the vegetative status of the studied groups of elderly people for the distribution of subjects by functional classes of heart rate variability.

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Conflicts of interest

The authors declared no have conflict of interest concerning this work, authorship, and/or publications of this paper.

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