



Prace oryginalne - Original papers

HEART RATE VARIABILITY AS THE ADAPTATION RESERVE INDICATOR OF CARDIOVASCULAR SYSTEM

Różnorodność rytmu serca jako wskaźnik rezerwy adaptacyjnej układu sercowo-naczyniowego

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A- przygotowanie projektu badania (study design), **B-** zbieranie danych (data collection), **C-** analiza statystyczna (statistical analysis), **D-** interpretacja danych (data interpretation), **E-** przygotowanie maszynopisu (manuscript preparation), **F-** opracowanie piśmiennictwa (literature search), **G-** pozyskanie funduszy (funds collection)

Summary

Background: The effectiveness of the vegetative regulation action might be controlled by the method of heart rate variability (HRV), which has been very popularly used over the last 10 years worldwide. The analysis of many clinical studies indicates that the severity of the disease might be controlled using the method of HRV.

Material and methods: All the experimental and controlled group participants, which consisted of healthy students with none sports experience, underwent the examination according to the 5-minute standard protocol of HRV. In addition, all the examinees performed a bicycle stress test. After the bicycle stress test, some additional tests of HRV were also carried out.

Results: It was found that some significant differences, between the group of sportsmen and the group of patients, exist. The parasympathetic activity of LF is maximum in athletes and tends to decrease in patients with cardiovascular pathologies. The decreases of the activity of the vasomotor centre was noticed in both study groups. The sympathetic system activity was the lowest in athletes.

Conclusions: At the high depression of the vegetative regulation, any significant load (physical or psycho-emotional) indicates cardiovascular instability which remains beyond the capacity of adaptation. The higher the variability, the more stable the CVS is to the external loads. A sharp decrease of the variability, such as the heart vegetative innervations, causes deteriorating quality of the regulatory mechanisms and, as a result, the risk of cardiovascular diseases increases.

Keywords: heart rate variability, deterministic and stochastic loads, cardiovascular system

Streszczenie

Wstęp: Skuteczność działania wegetatywnej regulacji może być kontrolowana przy pomocy oceny zmienności rytmu serca (HRV). Metoda ta przez ostatnie 10 lat zyskała popularność na całym świecie. Analiza licznych obserwacji klinicznych wskazuje, że nasilenie choroby można kontrolować przy użyciu HRV.

Materiał i metody: Wśród wszystkich uczestników badania zarówno z grupy eksperymentalnej, jak i kontrolnej (zdrowi studenci bez dużych obciążeń sportowych) w spoczynku przeprowadzono badanie według standardowego protokołu 5-minutowego HRV. Dodatkowo wszyscy badani wykonali próbę ergometryczną (protokół standardowy i stochastyczny). 5-10 minut po wysiłku przeprowadzono dodatkowe testy HRV.

Wyniki: Ustalono, że istnieją znaczne różnice pomiędzy grupą kontrolną a grupą pacjentów z chorobami serca. Zanotowana aktywność działania układu przywspółczulnego była maksymalna u przedstawicieli grupy kontrolnej i zmniejszyła się u pacjentów z patologią sercowo-naczyniową. Stwierdzono zmniejszenie aktywności ośrodka naczynioruchowego we wszystkich grupach badanych. Aktywność działania układu współczulnego u sportowców była najniższa.

Wnioski: Przy obniżeniu wegetatywnej regulacji każde znaczące obciążenie (fizyczne, psycho-emocjonalne) wskazuje na strefę niestabilności sercowo-naczyniowej, co jest poza możliwością adaptacji. Większa zmienność rytmu – to wskaźnik stabilnej pracy serca przy obciążeniach zewnętrznych. Gwałtowny spadek zmienności rytmu, tj. „autonomiczne unerwienie serca”, to wskaźnik pogarszającej się jakości mechanizmów regulacyjnych, w wyniku czego zwiększa się ryzyko chorób sercowo-naczyniowych.

Słowa kluczowe: zmienność rytmu serca, deterministyczne i stochastyczne obciążenia, system sercowo-naczyniowy

Background

The main function of the cardiovascular system (CVS) is to transport oxygen to the tissues in continually changing external environment (psycho-emotional and physical activity). CVS, in turn, is an example of a perfect management system, built on many hierarchical principles, where each lower level in normal conditions operates autonomously. At various load changes or the development of a pathological process, the upper levels of management are involved. Constantly interacting inhibitory and accelerating processes support homeostasis. It provides the function of stabilizing the level of blood pressure by variation series of control parameters. Variable heart rate, cardiac output and vascular tone are optimized by oscillations of blood pressure at „perturbations” of the environment. Thus, property of variability, in our opinion, defines adaptive resources of the organism and can serve as an adequate criterion for the effectiveness of treatment of many pathological conditions [1].

The effectiveness of the action contours vegetative regulation and is controlled by the method of heart rate variability (HRV), the clinic dynamics whose distribution over the last 10 years expressed a geometric progression. The analysis of many studies using the method of HRV suggests that the disease severity appears regularly in HRV parameters [2,3]. As a rule, the initial phase of the disease is the deterioration of the vegetative regulation and dominates the sympathetic regulation department. Next, on the background of general decline variability, dominant parasympathetic division can be manifested. At high severity pathology, depression of heart rate appears, which means limiting depletion of reserves adaptation [4,5]. Nowadays the method of HRV has acquired weighty importance than other non-invasive methods for studying CVS, and has been approved as an international standard [6-8].

HRV allows us to estimate the contributions of the sympathetic and parasympathetic components of the vegetative regulation, the ratio between the activity of the central nervous and autonomic regulation.

The aim of this study was to analyze the possibilities of the method of HRV as a criterion for the stability of the cardiovascular system when exposed to constantly changing environmental factors.

Material and methods

We examined 204 people, among them: a group of athletes (athletics) - 52 people; and a group of the practically healthy - 56 people, with angina pectoris (functional class 1-2 on Canadian classification) - 51 people and with a history of myocardial infarct (PHMI) - 45 people. The average age of the athletes was - 25 3 years, in the other groups the average age was 51 5 years, reliable age statistical differences between groups were not observed.

All participants underwent a study on the 5-minute standard protocol HRV at rest. In addition, the examinees performed the bicycle stress test (BST).

Two types of load studies were used: the traditional bicycle stress test with stepwise increasing load (50, 100, 150 W) and the duration of each step of 3 minutes and stochastic test with pseudo-normal distribution law in the range of 40-160W and duration of each stage of 30 seconds (figure 1).

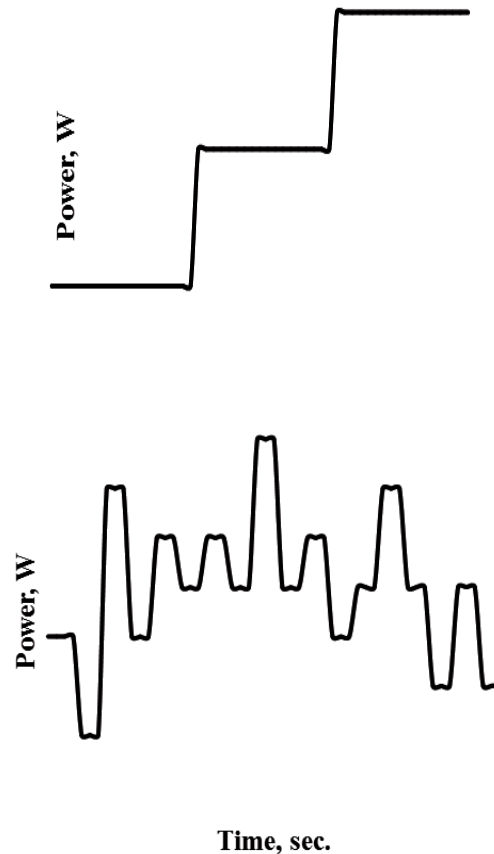


Figure 1. Stepwise increasing and stochastic load power change protocols (W)

Both loads were equivalent to the work performed (28 kJ), average power (50 watts) and test time (9 min) [9-11]. The data of BST in sportsmen are not compared with other groups because they performed the protocol up to 200 W and at the time of the sample to 15 min.

The criteria for terminating of the load were generally accepted [6,12]. The condition surveyed was monitored by electrocardiogram (ECG) with the registration of heart rate (HR) every 10 seconds. Also, blood pressure (BP) was taken in each examinee every 3 min. After BST an additional test of HRV was carried out.

The study used a 12-channel digital electrocardiograph, software system „Breeze-M” and programmable bicycle ergo meter. The apparatus fully automates load survey in accordance to the international standards. The analysis of the results were made using the statistical component of the program Microsoft Excel. The difference was considered as statistically reliable, when p was 0.05 (95 CI).

Results

Table 1 shows the study of heart rate variability at rest in all test groups.

Table 1. Averaged parameters of heart rate variability in sportsmen, healthy persons, patients with angina pectoris and persons with a history of myocardial infarction

Index	Sportsmen (athletics) (n=52)	Healthy people (n=56)	Person with angina pectoris(n=51)	Persons with a history of myocardial infarction (n=45)
HR, beats/min	56,6 ± 1,7*	74,2 ± 3,1	72,3 ± 4,3	67,4 ± 3,5
MxdMn, ms	398,4 ± 23,2*	237,3 ± 21,3	184,0 ± 25,2*	172,4 ± 21,2*
SDNN, ms	77,7 ± 4,4*	43,7 ± 4,1	33,6 ± 5,1*	33,5 ± 4,3*
pAMo, %	26,8 ± 1,4*	12,1 ± 1,3	22,1 ± 10,9*	18,7 ± 3,4*
Si, relative units	39,3 ± 5,2*	131,4 ± 24,4	243,2 ± 64,6*	288,1 ± 109,1*
HF, %	45,1 ± 1,3*	34,7 ± 2,6	35,8 ± 2,5	39,8 ± 3,0*
LF, %	28,4 ± 1,6	29,8 ± 1,9	25,1 ± 1,7*	22,8 ± 1,7*
VLF, %	27,6 ± 1,5*	35,3 ± 1,8	39,1 ± 2,5	37,4 ± 2,1

* p < 0,05

It should be noted that there are significant differences in respect to the groups of patients as well as in relation to the group of sportsmen. Figure 2 shows basic dynamics of HRV. So, the main index standard deviation (SDNN) in the transition from sportsmen to patients with ischemic heart disease decreases exponentially.

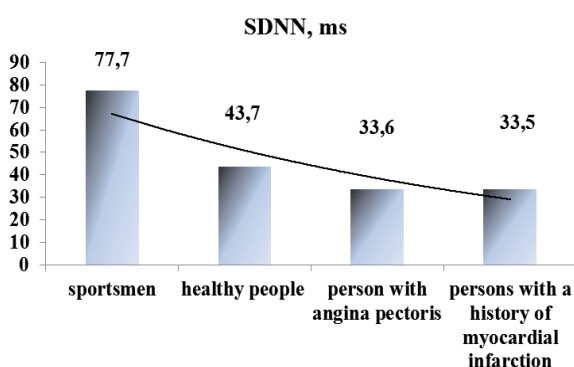


Figure 2. Indicators of standard deviation (SDNN) in the study groups

A similar dependence was found for the indicator-variation range MxdMn and stress -index- Si (figure 3).

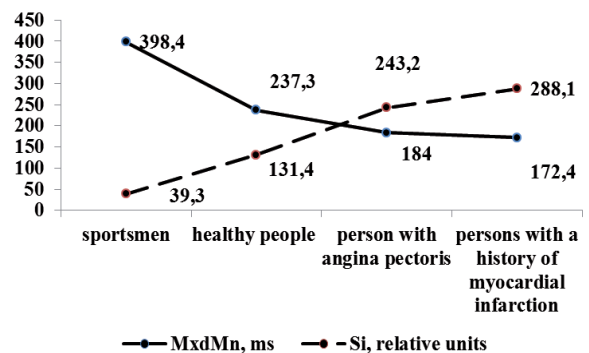


Figure 3. Indicators variation range MxdMn and stress index Si in the study groups

Spectral indicators in the study groups are presented in figure 4.

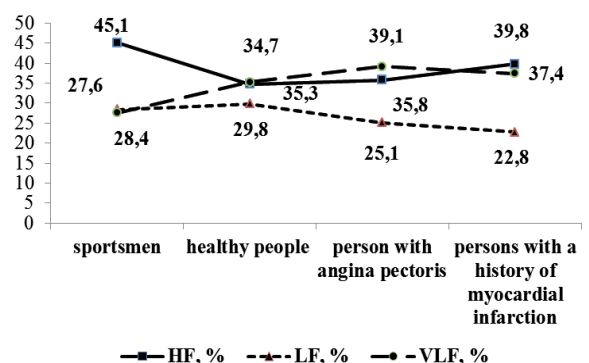


Figure 4. Spectral indicators in the study groups

The parasympathetic activity LF is maximum in sportsmen and tends to decrease in pathology which has been noted by many researchers. There was also a decrease in activity of the vasomotor centre according to the HF parameters. The activity of the sympathetic department was the lowest in the athletes. In the transition from healthy individuals to patients with angina pectoris it increases. Furthermore, in persons

with the history of myocardial infarction it drops. That is, in the transition from normal to severe pathology the so-called "autonomic denervation" [5,7,13] occurs.

We have also studied the intensity of vegetative regulation of CVS caused by exercise using the data of HRV. The last load used standard and stochastic protocols. Table 2 shows the increase of HRV parameters as a percentage relative to the initial value.

Table 2. Reaction system regulation of heart rate to exercise in healthy subjects, patients with angina pectoris and persons with a history of myocardial infarction in % relativist ate of rest

Index	Type of load	Healthy people	Person with angina pectoris	Persons with a history of myocardial infarction
Δ MxdMn, %	traditional bicycle stress test	-15,3	-10,3	-2,3
	stochastic	-19,4	-20,1	-19,9
Δ SDNN, %	traditional bicycle stress test	-17,9	-9,5	-7,8
	stochastic	-23,5	-23,1	-21,9
Δ Si, %	traditional bicycle stress test	+68,6	+29,8	+1,1
	stochastic	+49,7	+31,4	+42,2
Δ HF, %	traditional bicycle stress test	-2,6	-2,0	-3,0
	stochastic	+1,8	-3,3	-8,0
Δ LF, %	traditional bicycle stress test	-9,8	-5,2	0
	stochastic	-2,5	+2,9	-1,8

Discussion

The analysis of the data obtained shows the following. Firstly, under the standard load transition from normal to abnormal, a linear decrease of indicators MxdMn, SDNN and Si is observed. Secondly, the variation of parasympathetic activities HF does not occur during the change of vasomotor activity LF and it linearly decreases. From this it follows that in healthy individuals vegetative regulation according to the dynamics of HRV parameters is highly sensitive to physical activity, which indicates good reserve possibilities of CVS. In the process of the growth of the severity of a disease, the CVS reaction of vegetative nervous system to the load appears invariable. Thus, persons with a history of myocardial infarction noted the increase of HRV parameters much lower than patients with angina pectoris. In turn, the increase in the data of HRV parameters is lower than in healthy persons.

At the same time, the sensitivity of vegetative nervous system to the stochastic load was much higher than during the standard load. For this load during the transition from normal to abnormal, the tendency

to reduce the sensitivity is not found. Probably, in the case of unpredictable loads the central nervous regulation mechanisms activate additionally.

Conclusions

With the progression of the pathology of CVS there is a tendency to reduce the sensitivity of HRV parameters to the load. This fact can be used as a quantitative measure of adaptive reserves of CVS. High depression autonomic regulation was registered in the group of persons with a history of myocardial infarction.

At high depression of vegetative regulation any significant load (physical, psycho-emotional) of CVS displays in the zone of instability, i.e., beyond the capacity of adaptation. The higher the variability, the more stable the CVS is to external loads. With sharp decrease variability, i.e. with "of vegetative denervation" the quality of regulatory mechanisms deteriorates and, as a result, the risk of cardiovascular events increases.

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