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Prace oryginalne - Original papers

# BADANIE REGULACJI RYTMU SERCA U ZDROWYCH LUDZI PRZY POMOCY STOCHASTYCZNYCH METOD TESTOWYCH

## The examination of the heart rate regulation in healthy people with the stochastic tests methods

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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)

**Streszczenie**

**Wstęp**: Problem relacji pomiędzy złożonością regulacji układu sercowo-naczyniowego i wpływem na niego sygnału testowego od standardowego obciążenia fizycznego nie jest całkowicie rozwiązany. Można spróbować rozwiązać ten problem za pomocą stochastycznych (przypadkowych) metod testowych, a nie tradycyjnego (deterministycznego) obciążenia fizycznego.
**Cel pracy:** Porównać reakcję układu sercowo-naczyniowego zdrowego człowieka przy obciążeniu fizycznym (deterministycznym i stochastycznym).
**Materiał i metody:** W badaniach przy użyciu ergometru rowerowego wykorzystano dwa rodzaje obciążenia fizycznego: tradycyjne (test ze stopniowym wzrostem mocy 50, 100 i 150 W przy czasie trwania każdego etapu 3 minuty) i stochastyczne (przy mocy w przedziale od 40 do 160 W i przy czasie trwania każdego etapu około 30 sekund).
**Wyniki:** średnie obciążenie wymagane do osiągnięcia submaksymalnego tętna było odpowiednio 509 W dla testów tradycyjnych i 445 W dla stochastycznych metod testowych. Osiągnięcie submaksymalnego tętna przy metodzie tradycyjnej odbyło się na siódmej minucie, a przy obciążeniu stochastycznym - znacznie wcześniej (na 5 minucie). Uzyskane wyniki pozwalają stwierdzić, że granica wydajności układu sercowo-naczyniowego przy wykorzystaniu metod stochastycznych obciążenia fizycznego jest osiągalna szybciej niż przy wykorzystaniu tradycyjnego (deterministycznego) obciążenia fizycznego.
**Wnioski:** Stochastyczne (przypadkowe) obciążenie fizyczne może być przydatne dla diagnostyki efektu treningowego w fazie przygotowań sportowców. Zastosowanie stochastycznych metod może być skuteczne w diagnostyce chorób układu krążenia i rehabilitacji pacjentów z chorobami sercowo-naczyniowymi. Ze względu na nieprzewidywalność i adekwatność odpowiedzi częstotliwościowej układu sercowo-naczyniowego, stochastyczne obciążenia pozwalają ok. 1,5 razy szybciej diagnozować rezerwy fizjologiczne organizmu.
**Słowa kluczowe:** deterministyczne i stochastyczne obciążenia, tętno, sportowcy.

**Summary**

**Background:** The determination of relations between the complexity of the cardiovascular system regulation and the complexity of the test signal is not a fully solved problem. The elimination of this uncertainty can be done using stochastic test signals and power value which changes are random.
**Aim of research:** To compare the reaction of cardio - vascular system during the deterministic and random loads.
**Material and methods:** In the research,h two types of physical loads were used: the traditional bicycle ergometer test with stepwise increasing load and 3 minutes steps duration and test with a stochastic pseudonormal load values distribution and 30 seconds steps duration.
**Results:** It is established that the average load required to achieve a submaximal heart rate was 509 W for the traditional and 445 W for the stochastic test, respectively. The time of obtained submaximal heart rate during stepwise-increasing load was 7 min., whereas during the stochastic load significantly less - 5min. The results show that the limit of efficiency of the cardiovascular system during stochastic load test is achieved faster than during deterministic load test.
**Conclusions:** Stress tests using random loads can be useful for the athletes training. Supposedly, the use of stochastic loads must be effective during rehabilitation of patients with cardiovascular diseases, for instance the increasing of the physical load time in each stage can be used in order to reach steady state. Also, the proposed study confirms the perspectives of non-linear and stochastic methods in the diagnosis of the cardiovascular system diseases.
**Keywords:** deterministic and stochastic loads, heart rate, sportsmen.

## Background

The determinations of physical performance occupies an important place, both in sports and in assessing the status of people of different age and sex witch are engaged in physical culture. The diagnostic systems for different body elements are the basic problem of modern sports medicine which methods are improving consistently. Obviously, the objective assessment of physical health is important for achieving high results in the modern sports. At the present time the determination the professional competence, readiness for sporting activities and other forms of physical activity, as well as the improved performance using dosage loads methods lead out of the organism to normal functioning. The equipment for dosage loads methods includes bicycle ergometer, treadmill, step ergometer, hand ergometer [1-4].

The most popular are the uniform, step and step-increasing workloads which can be specified as deterministic [1, 5]. However, there is inadequacy of relation determination between the complexity of regulation of the cardiovascular system and the complexity of the test signal. The possible method of this uncertainty elimination is stochastic test signals which random changing power value used in test [6-8]. Usually, the stochastity is defined as follows:

1) the disturbance must correspond the level of complexity of the object, harming, do not display the object in the zone of significant non-linearity;

2) the time and frequency characteristics of the test signal must be consistent with the amplitude-frequency properties of the system under study.

The randomness corresponds to the conditions of everyday life more than determinism. Ideally, the load test for cardiovascular system is signal of "white noise" with estimated weight function of the objects [9-11], but in clinical practice is not applicable because of the technical capabilities of ergometers.

Thus, for research and practical diagnostic purposes is interesting to compare the reaction of the cardiovascular system during deterministic and random loads and this comparison was the subject of the presented research.

## Material and methods

In the present study two types of load stress: the traditional test with stepwise increasing load (50,100,150 W) and 3 minutes stage duration and test with a stochastic pseudonormal distribution in the range 40-160 W and 30 seconds stage duration (Fig. 1.) were used. Both samples were comparable in terms of work done, 54 kJ, the average power of 100 W and the duration of the study 9 minutes.

The study participated 55 students involved in sports (playing sports), including 27 males and 28 females (mean age 20.3 years) who were asked to perform two types of loads with a break to rest between test 1.5-2 hours. In reality, the load was carried out to obtain the submaximal heart rate. Submaximal heart rate corresponds to the following (200-age of the subject).

The heart state of the subjects using electrocardiogram (ECG) recording with heart rate (HR) every 10 seconds was monitored. Also the blood pressure (BP) every 3 minutes as measured during physical load.

The programmable cycle ergometer M32-B1 in investigation was used. The protocols of the changes of power load are presented in Figure 1.

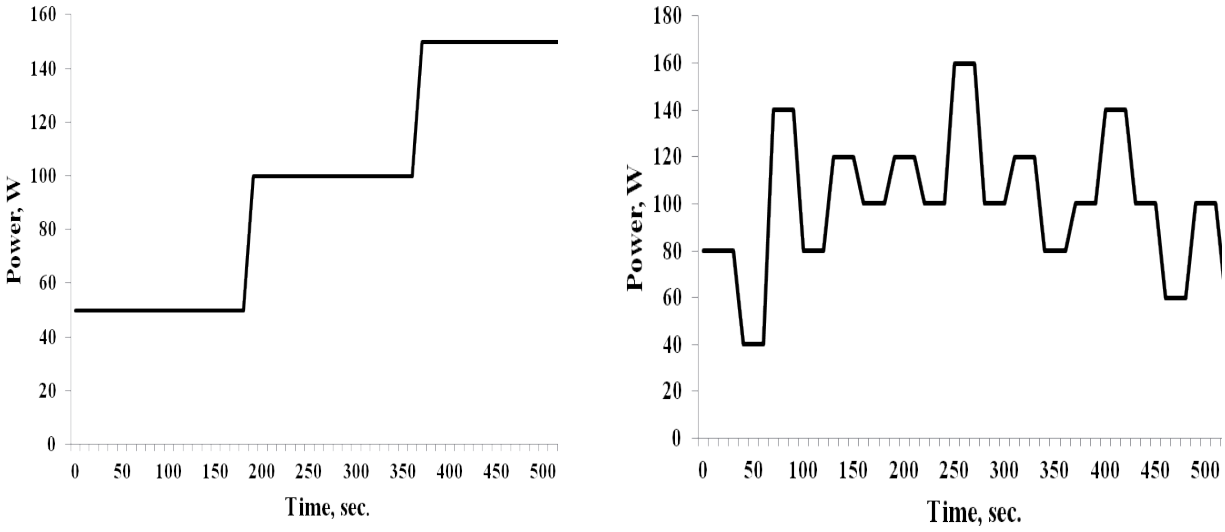


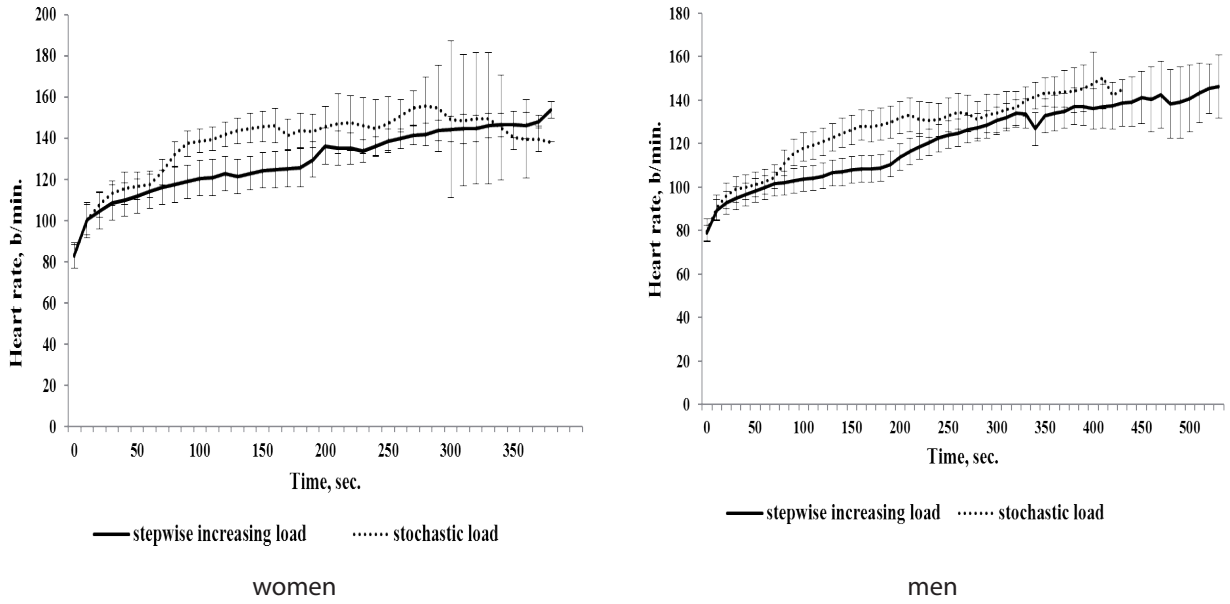

**Figure 1. Stepwise increasing and stochastic load power change protocols (W)**

Analysis of the results using the statistical component of the program Microsoft Excel was performed. The difference was considered as statistically reliable, when p was 0.05 (95 CI).

## Results

The Figure 2 shows the average statistical reaction of athletes to step-increasing and random workloads. The heart rate during test increased exponentially for both men and women. There average values are presented by solid lines and error of the mean by dotted lines.

From these data it is possible to see that both men and women reached submaximal heart rate during determined and random load. However, the significant difference between two load types was found. The average power load required to achieve a submaximal heart rate was 509 W for the step-increasing and 445 W for the stochastic test, respectively. Also, submaximal heart rate achieving time of during stepwise-increasing load was 7 min., whereas this time was significantly less during stochastic load – 5 minute 3 second ($p < 0.05$).




women men

**Figure 2. Heart rate dependence on the test time**

## Discussion

The obtained results allow conclude that the load limit of efficiency of the cardiovascular system is achieved faster using stochastic load test than deterministic. This may depend on several reasons. At first, the random loads are adequate frequency properties for the system of regulation of cardiac rhythm, which in this turn is composed from many complex hierarchical systems, combined from the autonomous and central mechanisms of regulation. When a stochastic load was used in investigation more active were mechanisms of vagal and sympathetic regulation. Secondly, the element of chance and inadvertently additionally activates the central nervous system. At the same time as a reaction to physical load is the need to activation centralization of the attention the central nervous system. Third, the different levels of power swings were in use and the information utility during the stochastic test is 62% higher than during deterministic test [10].

Comparing algorithms for the implementation of deterministic and stochastic loads, it can be assumed that the increased information load requires more intensive work of all control loops. The difference between them shows the reserves of the blood circulation regulation. In our case it is discussing about the regulation of heart rate and coronary circulation.

## Conclusions

The random sequence of load power due to the unpredictability and adequacy frequency response of the organism makes it possible to roughly 1.5 times faster and more accurately establish the physiological reserves of the organism.

Concluding, let's consider the outlook of this investigation. The physical load test using random loads can be useful for the athletes training. Supposedly, the use of stochastic loads must be effective during rehabilitation of patients with cardiovascular diseases, for instance the increasing of the physical load time in

each stage can be used in order to reach steady state. Also, the proposed study confirms the perspectives of non-linear and stochastic methods in the diagnosis of the cardiovascular system diseases.

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