Complexity Assessment of ECG RR Interval

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Abstract

Physical load is very important and necessary for human organism and for its systems functionality. During bicycle ergometry work we can evaluate the functionality of the human organism. We looked for the complexity measure, which could integrally and simple evaluate organism reaction to physical load.

We used ECG RR interval allometric relation and RR interval information dimension. We indicated, that the slope of ECG RR interval allometric relation and information dimension could be used as the RR interval complexity measures, defining all organism reaction to physical load.

The study showed that young women RR interval complexity is higher, it means that all organism adaptation to physical load is better, different organism systems better interact together. Significant differences between load and recovery periods detected different adaptation complexity levels.

1. Introduction

The further progress of medical diagnostic technologies is unthinkable without development and usage of non-linear analysis methods based on chaos and complex systems theories. Till the second part of the past century the empirical and phenomenological approaches of medical data analysis and diagnostics were predominating in medicine. These methods couldn't assess the holism and complexity of human organism, as well as synergism and fractal characteristics of interactive vital systems of human organism [1].

Human organism adaptation to physical load peculiarities and opportunities is an actual task of physiology, sports and clinical medicine. The solution of this task is tight-knit to human functional state evaluation [2].

During bicycle ergometry work we can evaluate the functionality of the human organism. The main task was to find the complexity measure for ECG RR interval, which could integrally and simple evaluate organism reaction to physical load.

2. Methods

The investigated contingent consisted of 15 asymptomatic women (20-45 years old), regularly participating in aerobics exercise program. There were used the standard stress test method of provocative incremental bicycle ergometry work [3]. For evaluation of cardiovascular system reactions the ECG analysis system "Kaunas – Load", developed at the Institute of Cardiology was used.

We divided all data in two processes – load ant recovery - rest (the loading was performed till the sub maximal heart rate or appearance of clinical symptoms, indicating the test cessation, rest – 5 minutes after the loading). We used RR intervals (ms) during every cardio – cycle.

We calculated two different complexity measures for each investigative individually (separate for load and rest periods) – information dimension and allometric complexity coefficient.

For calculation of information dimension at first discrete points we interpolated with cubic interpolation spline. Then we calculated function values in particular step *h* (h = 0, 05).

During the research we found that information dimension depended on particular parameters values interval, so according intervals of possible changes, we normalized the initial data. Then we made the return map using calculated function values. After that, we calculated the information dimension for this map. There is algorithm for calculating information dimension [4].

Consider a square grid (box size ε) superimposed on an observed point pattern. Within each occupied grid unit, the number of points n_i is counted. Each count is then expressed as a proportional value:

$$P_i(\varepsilon) = \frac{n_i}{N},$$

where N is the total number of points in the set.

The "information function" is defined as:

$$I \equiv -\sum_{i=1}^{N_\varepsilon} P_i(\varepsilon)\ln[P_i(\varepsilon)],$$

where N_ε is the number of occupied boxes (quadrates) of size ε. $P_i(\varepsilon)$ is the natural measure, or probability that element i is populated, normalized so that $\sum_{i=1}^{N_\varepsilon} P_i(\varepsilon) = 1$. The information dimension is then defined as

$$d_{\inf} \equiv -\lim_{\varepsilon\to 0}\frac{I}{\ln(\varepsilon)} = \lim_{\varepsilon\to 0}\sum_{i=1}^{N_\varepsilon}\frac{P_i(\varepsilon)\ln[P_i(\varepsilon)]}{\ln(\varepsilon)}.$$

The higher value of information - higher complexity- means better organism adaptation to physical load.

For calculation allometric complexity coefficient we divided all data to the same size intervals (10 discrete points) and calculated averages (μ) and variances (σ^2). The relation between averages and variances is called allometric [5]. Algebraic expression between average and variance could be defined as power function:

$$\sigma^2 = l\mu^k,$$

where parameters k and l defines the character of dependence. All our data satisfied this hypothesis (p< 0, 05). We used the least squares method and logarithmic function for the lining [6] the dependence between averages and variances:

$$Log(\sigma^2) = k\,Log(\mu) + l.$$

The slope of logarithmic dependence we called the allometric complexity measure.

According to B J West [5], we hypothesized, that if the slope is negative, the complexity of the process is low and organism reaction to physical load is inadequate, if positive – the complexity is high and all organism systems interact together.

For comparison of complexity measures of load and rest periods we used nonparametric Wilcoxon test for two related samples. According to age, we divided investigated contingent into 2 groups: 20-30 (n=8, age average 25, 1) and 40-50 (n=7, age average 44, 3) years old. We compared the complexity measures between these groups and used nonparametric Mann – Whitney test for two independent samples [7].

3. Results

We calculated information dimension and allometric complexity coefficient for each investigative individually (separate for load and recovery periods).

In Figure 1 is given an example of allometric complexity coefficient calculations during load period.

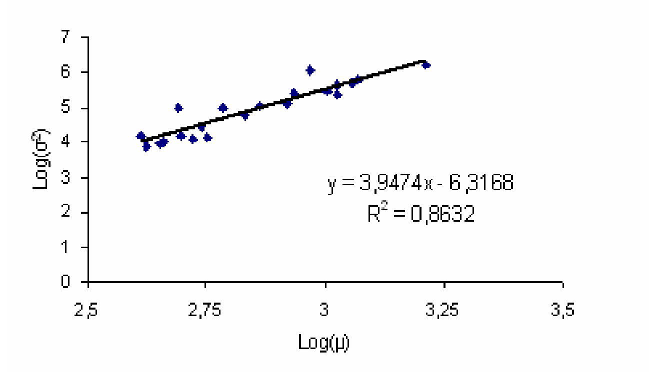

Figure 1. Allometric complexity coefficient calculation for load period for one investigative .

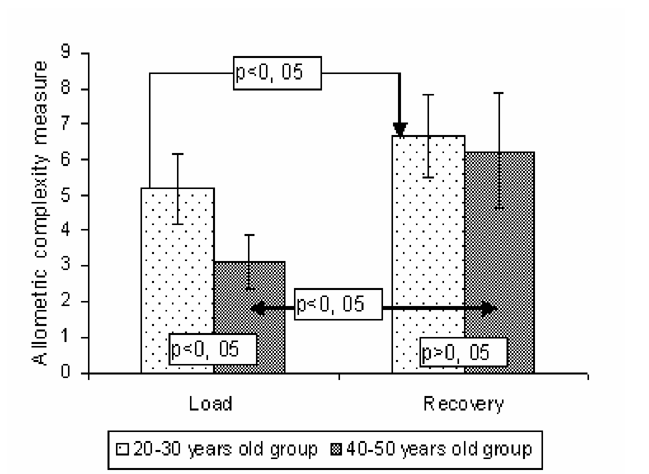

Figure 2. Allometric complexity coefficient (mean ± SD) of studied groups for load and recovery processes.

For all tested women RR interval allometric complexity coefficient was positive (p< 0, 05). Also we showed that RR interval allometric complexity during load was significantly lower comparing with recovery for both groups (Figure 2). We showed that allometric complexity of load process of young women (20-30 years old) is significant higher. But during recovery the difference was not significant. Statistical tests results are presented in Table 1 and Table 2.

Table 1. Nonparametric Wilcoxon test for two – related samples – comparison of allometric complexity measure of RR interval during load and recovery.

Group	Statistics value	p value
20 – 30 years	-3, 06	0, 002
40 – 50 years	-2, 02	0, 043

Table 2. Nonparametric Mann - Whitney test for two independent samples – comparison of allometric complexity measure between age groups.

Process	Statistics value	p value
Load	-1, 89	0, 04
Recovery	-0, 53	0, 64

We showed that RR interval information dimension during load was significantly lower comparing with recovery for both groups (Figure 3).

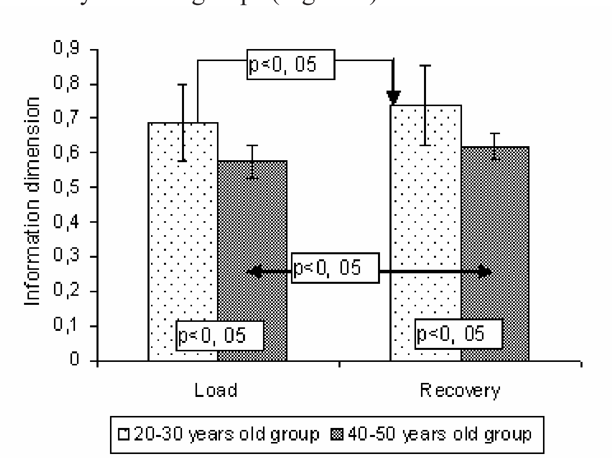

Figure 3. Information dimension (mean ± SD) of studied groups for load and recovery processes.

We showed that information dimension of load process of young women (20-30 years old) is significant higher [8]. During recovery the difference, conversely to allometric complexity measure, was also significant. Statistical tests results are presented in Table 3 and Table 4.

Table 3. Nonparametric Wilcoxon test for two – related samples – comparison of information dimension of RR interval during load and recovery.

Group	Statistics value	p value
20 – 30 years	-2, 99	0, 03
40 – 50 years	-2, 06	0, 04

Table 4. Nonparametric Mann - Whitney test for two independent samples – comparison of information dimension between age groups.

Process	Statistics value	p value
Load	-2, 05	0, 04
Recovery	-1, 97	0, 04

4. Discussion and conclusions

The study showed that both complexity measures – information dimension and allometric coefficient indicated that young women RR interval complexity was higher. That means all organism better adaptation to physical load. More intensive aerobics exercise training could cause it.

We found, that despite age, RR interval complexity during recovery was significant higher than during load. During recovery more organism systems interact together by way of compensation to physical load. That means higher complexity level [9].

We can conclude, that both studied complexity measures – information dimension and allometric coefficient could be used as RR interval complexity measures, which defines all organism adaptation to load. We found, that it is better to use allometric coefficient, because the calculations are greatly simple.

Both studied complexity measures needs a lot of data. To use them for very short time intervals is not possible because of low accuracy of evaluations.

Acknowledgements

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