Information Dimension of the Heart Function Parameters during Stress Test

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Abstract

If we want correctly specify human physiological state, it is very important to evaluate the changes of main systems participating in different functions. In this work we are analyzing parameters that characterize these systems, their functional relations, counting information dimension and searching for differences in various investigated groups of persons (sportsmen, healthy persons, patients with ischemic heart disease).

The study showed that means of information dimensions in studied groups with different physical activity significantly differs. Mean of information dimensions did not differ between groups of different age and for men and women.

1. Introduction

"All parts of body stay healthy, developed and slower get old, when they are used in moderation and do usual tasks. If these parts of body do nothing and stay without tasks, they leave not trained, tend to illness and quick get old". 460 – 400 year before the Christ said Hippocrates. Today we know that if we exercise correctly and in time, the possibility to get ill is smaller and if we get ill, the exercising stops progress of illness and helps to restore our health.

The main aim of this study was to calculate information dimension for the parameters of integrated health evaluation model (these parameters show different human physiologic functions). Also we tried to evaluate behavior of this dimension in various investigated groups of persons - sportsmen, healthy persons and patients with ischemic heart disease.

2. Methods

The investigated contingent consisted of three groups: sportsmen (159 tests of men, 53 tests of women), asymptomatic persons (113 tests of men, 210 tests of women) and patients with ischemic heart disease (61 tests of men). Asymptomatic persons were divided into 6 groups according to gender and age (20–30, 30–40 and 40–50 years). Groups of investigated persons and the mean of their age are given in Table 1.

Table 1. The number and age of investigated groups (M±SEM).

Group	Number	Age (M ± SEM)
Sportsmen	159	23.56 ± 0.40
Sportswomen	53	24.88 ± 0.65
Men	113	36.05 ± 0.60
20-30	27	28.37 ± 0.56
30-40	55	35.36 ± 0.35
40-50	31	43.97 ± 0.60
Women	210	33.97 ± 0.53
20-30	66	25.17 ± 0.44
30-40	100	35.14 ± 0.28
40-50	44	44.52 ± 0.50
Patients with ischemic heart disease	61	52.44 ± 1.56

The physical load was performed by provocative incremental bicycle ergometry (modified Brooce protocol). Bicycle ergometry was started with 50W intensity and the power was increased every minute by 50W for men and 25W for women, and cycling frequency 60 cycles per minute was used. The loading was performed till the submaximal heart rate or appearance of clinical symptoms indicating the test cessation. The computerized 12 lead ECG analysis system "Kaunas-Load", developed at the Institute of Cardiology, Kaunas University of Medicine was used [1].

We used the model of integral health evaluation [2] (Figure 1). It integrates changes of three functional elements: P – periphery system, R – regulation system (brain), S – supplying system (heart, blood-vessel system). Relation between these systems can be specified

by several parameters, but we used the simplest and easier calculated ECG and ABP parameters: heart rate (HR), JT interval, systolic (S) and diastolic (D) blood pressure.

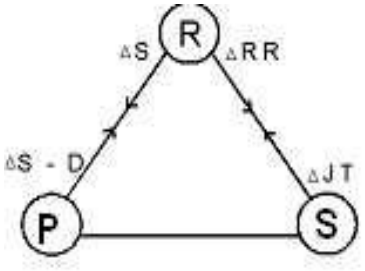

Figure 1. Integrated model for functional state evaluation.

Also we studied proportions between parameters: $\frac{S-D}{S}, \frac{JT}{RR}$, where *RR = 60/HR*.

Initial data – discrete measurements in each level of load and rest for all discussed parameters.

For calculation of information dimension at first discrete points we interpolated with cubic interpolation spline [3]. Then we calculated function values in particular step h (h=0.01). During the research we found that information dimension depended on particular parameters values interval (for example heart rate can be from 50 to 220 beats per minute, JT interval can be from 0.15 to 0.36 second). So according to 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 by means of following algorithm [4, 5].

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

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

For the comparison of calculated information dimension, we compared the means of two populations. We assumed that distribution of information dimensions is normal, so we used two - sample t - test for means [6].

$$\begin{cases} H_0 : \mu_X = \mu_Y \\ H_1 : \mu_X \neq \mu_Y \end{cases}$$

Before that we did two-sample t-test for variances.

3. Results

The means of information dimension for all parameters (mean ± standard deviation) are presented in Table 2 and Table 3.

Table 2. Means for investigated men groups.

	Patients with ischemic heart disease	Asymptomatic men of different age	Sportsmen
(S-D)/S	0.48±0.12	0.65±0.14	0.77±0.13
JT/RR	0.54±0.13	0.62±0.11	0.64±0.11
RR	0.56±0.12	0.61±0.10	0.68±0.12
JT	0.56±0.12	0.62±0.11	0.67±0.10
S	0.70±0.12	0.73±0.11	0.77±0.08
S-D	0.55±0.13	0.65±0.13	0.81±0.12

Table 3. Means for investigated women groups.

	Asymptomatic women of different age	Sportswomen
(S-D)/S	0.58±0.14	0.70±0.15
JT/RR	0.63±0.12	0.68±0.11
RR	0.58±0.09	0.72±0.12
JT	0.61±0.11	0.72±0.09
S	0.61±0.11	0.71±0.11
S-D	0.53±0.14	0.69±0.15

The means of information dimension of different investigated parameters for all studied groups of men are shown in diagram form (Figure 2).

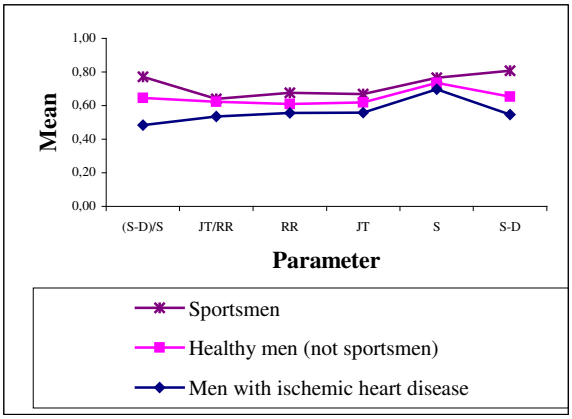

Figure 2. Means of information dimension for studied men groups.

In Figure 2 we can see, that means for all parameters differs – means of information dimension for patients with ischemic heart disease are smaller than means in sportsmen group. For some parameters $(\frac{S-D}{S}, S-D)$ we can see even different tendencies compared with other parameters.

Two-sample t-test for means showed that in most cases means of information dimension significantly differs $(p < 0.05)$ between investigated groups of men, the same for women. RR interval significant differences for various groups are presented in Table 4.

Table 4. Two-sample t-test for mean of RR interval.

Compared groups		t	p
Patients with ischemic heart disease	Asymptomatic men of different age	3.185	0.002
Patients with ischemic heart disease	Sportsmen	6.596	<0.001
Asymptomatic men of different age	Sportsmen	4.802	<0.001
Asymptomatic women of different age	Sportswomen	5.905	<0.001

Mean of information dimensions did not differ between groups of different age $(p > 0.05)$, the same for men and women (Table 5).

Table 5. Two-sample t-test for mean of RR interval in different age groups.

Compared groups		t	p
Men 20-30	Men 30-40	0.521	0.604
Men 20-30	Men 40-50	0.573	0.569
Men 30-40	Men 40-50	0.502	0.599
Women 20-30	Women 30-40	0.870	0.386
Women 20-30	Women 40-50	1.056	0.295
Women 30-40	Women 40-50	0.529	0.598

Existing difference between groups with different physical activity and absence of it in groups of different age and gender but with the same physical fitness could point out conclusion, that studied information dimension could be used as a measure of human functional state or healthiness. It integrates all features of reaction to load – the load and recovery as well.

4. Conclusions

The information dimension detects new and earlier unstudied information in medicine. It separates out investigated persons according to gender, disease and physical activity. But information dimension does not depend on age in the investigated groups of asymptomatic persons (men and women).

References

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