Short communication

Modifications of the non-linear parameters of the heart rate variability related to the systematic practice of physical exercise

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ABSTRACT

Introduction: In recent years, the relationship between the systematic practice of physical exercise, cardiovascular dynamics and the functioning of the autonomic nervous system has been recognized.

Objective: To determine the modifications that non-linear parameters undergo in the autonomic cardiovascular regulation of the heart rate variability with the systematic practice of physical exercise.
Methods: A retrospective cohort analytical study was conducted from February 2016 to August 2018. Population and sample: 36 individuals (Group 1: 18 high- performance baseball athletes; Group 2: 18 medical students). The data were collected in the Biomedical Basic Sciences Laboratory at Medical school 1, University of Santiago de Cuba, through the 8-channel PowerLab polygraph, and stored using the Kubios Software version 3.0.4 Premium.
Results: Statistically significant differences between means were found in heart rate values ($p = 0.000$); SD1 ($p = 0.025$); SD2/SD1 ratio ($p = 0.007$); sample entropy ($p = 0.011$); short-term fluctuations α 1 ($p = 0.019$); mean line length ($p = 0.016$); max line length ($p = 0.001$); recurrence rate ($p = 0.034$); determinism ($p = 0.010$) and Shannon entropy ($p = 0.015$). The parameters of SD1 ($C = 0.906$) and sample entropy ($C = 0.712$) were significantly associated with a heart rate ≤ 70 beats per minute.
Conclusions: With the systematic practice of physical exercise, the non-linear parameters of the autonomic cardiovascular regulation of the heart rate variability undergoes modifications that respond to a better adaptability of the autonomic nervous system, and to a greater capacity to regulate cardiovascular function.

Keywords: heart rate variability, non-linear parameters, physical exercise, high-performance athletes.

INTRODUCTION

The recording of cardiac activity usually refers to the number of beats at a precise moment or previously determined time period. However, the time between beats is variable. This variation from beat to beat refers to the concept of Heart Rate Variability (HRV). The traditional method for measuring this variation is based on the calculation of the time difference between each of the R waves, better known as RR intervals.[1]

The mechanism responsible for the regulation of HRV is the autonomic nervous system, with HRV being proposed as an indicator of its status.[(2)]

The autonomic nervous system is organized into two subsystems or branches with opposite but complementary functions: sympathetic and parasympathetic or vagal. Both, by chronotropic, dromotropic and inotropic effect, act on the depolarization of the cardiac muscle and condition the sinoatrial node function. The sympathetic branch (noradrenaline) stresses the system increasing the heart rate and decreasing the HRV whereas the parasympathetic (acetylcholine) decreases the heart rate and increases the HRV. Both are interconnected by thousands of neurons and hundreds of ganglia that make up what some call the Cardiac Intrinsic Nervous System or cardiac brain.[(3)]

The relation "autonomic nervous system-cardiac function" must be considered, as a whole, by the great interaction that exists between both elements.

To evaluate the action of the autonomic nervous system, HRV has been used, which analyzes a time series of the variation in the duration of a beat with respect to the next. In addition, due to the use of digital signal processing systems, these time series can be analyzed by characteristics of its spectrum and by non-linear methods. Similarly, both HRV and heart rate at rest account for cardiovascular adaptations such as left ventricular hypertrophy and increased parasympathetic tone.[(4)]

Most studies of HRV in the field of sports have analyzed HRV responses to different training stimulations with the ultimate aim of maximizing training effectiveness and benefits. Some authors[3,5] have shown how HRV is a useful tool for maximizing adaptive responses and prescribing daily exercise.

During physical exercise, the sympathetic-vagal balance depends on the intensity and duration of the exercise.[3] In high-performance athletes or individuals who practice physical exercise systematically, there is a preconditioning of the autonomic nervous system to this activity, with a better cardiovascular adaptability to changes in rhythm and heart rate.

While records in recreational athletes or well-trained athletes suggest that HRV might be valid for evaluating adaptations in endurance sports, the data obtained in elite athletes with a long sports history are not consistent. In this type of population, it has been observed how parasympathetic activity levels are reduced during rest periods.[5]

It is currently accepted that physical exercise has important cardio-protective effects. These have been associated with the activation of various mechanisms aimed at restoring myocardial function and reversing the autonomic imbalance. However, it has not been fully clarified if physical exercise actually improves the HRV and restores the autonomic balance.[6]

The variations experienced by non-linear parameters of Heart Rate Variability with the systematic practice of physical exercise have not been clearly determined. Their knowledge can contribute to establishing cut-off points for an ideal cardiac function both in elite athletes and in people who do not practice sports according to non-linear parameters of heart rate variability.

Objective

To determine the modifications that non-linear parameters undergo in the autonomic cardiovascular regulation of Heart Rate Variability with the systematic practice of physical exercise.

METHODS

A retrospective cohort analytical study was conducted from February 2016 to August 2018, in the Laboratory of Basic Biomedical Sciences, Medical School 1 of the University of Medical Sciences of Santiago de Cuba.

The study population was made up of young male individuals between the ages of 17 and 19, who were high-performance baseball athletes from the youth team of Santiago de Cuba and first- and second-year medical students at the University of Medical Sciences of that province (N = 36).

Two groups were established for each variable, one that was composed of the athletes of the youth baseball team as a group exposed to the systematic practice of physical exercise (n = 18) and another composed of medical students as a group not exposed to the systematic practice of physical exercise (n = 18). The individuals of this last group were matched by age and sex with the first one, and selected in a stochastic way through a simple random sampling so that a 1:1 ratio was obtained, which avoid the biases inherent in the selection.

Exclusion criteria

- Individuals with current diseases that could interfere with the physiological cardiovascular dynamics or the regulation of this by the Autonomic Nervous System.
- Individuals who did not agree to participate in the study.

Definition of the independent variable

- Systematic practice of physical exercise, which was collected as background in all high-performance baseball athletes of the youth team of the province of Santiago de Cuba

Variables

Heart rate (in beats per minute) (beats/min), Standard Desviation 1 (SD1), Standard Desviation 2 (SD2), Relationship Standard Desviation 2 / Standard Desviation 1 (SD2/SD1), Approximated Entropy, Sample Entropy, Short-term fluctuations α 1, Long-term fluctuations α 2, Correlation Dimension, Mean line length (in Beats), Recurrence rate (in percentage), Determinism, Shannon Entropy, Multi-Scale Entropy Minimum, Multi-Scale Entropy Maximum and exposure to the systematic practice of physical exercise.

Experimental procedure and collection of data

Data were collected during February and March 2016 in the Laboratory of Basic Biomedical Sciences, Medical School 1 of the University of Medical Sciences of Santiago de Cuba, through the 8-channel PowerLab® polygraph (ADInstruments), and stored by Kubios® Software version 3.0.4 Premium. This period of coincides with the pre-competitive stage of the athletes of the provincial youth baseball team who were training to participate in the XXXIII National School Games, and with the start of the second semester of first- and second-year medical students.

Each measurement was recorded by the same person in the Body-Level Measure section of the already mentioned laboratory of Basic Biomedical Sciences, with the purpose of minimizing the errors of methodology.

At the beginning of the session of the electrocardiographic recordings in the morning (08:30- 12:00 hours), the subjects were placed on a comfortable stretcher, located in a room with controlled temperature between 24 and 27 degrees Celsius and dim light. Under these conditions, they were allowed to rest for 10-15 minutes until achieving a better adaptation to the conditions of the room.

The electrodes corresponding to the limb leads were placed to record the electrocardiographic tracing for 5 minutes. The electrical signal was collected by the 8-channel PowerLab® polygraph of Australian production by the company ADI instruments (2016); then it was digitized at a sample rate of 1000 samples/second (1 kHz) using the Software Kubios®, version 3.0.4 Premium (2018), of Finnish production. This software package enables the tabulation and export of the records to the MatLab 2016® programming package of the MathWork Company, and its file in PDF format for easier analysis and interpretation of the information.

Statistical Analysis

The data obtained were stored and processed in the statistical package "StatisticalPackage for Social Sciences" (SPSS) version 21 for Windows. The means were compared through the Mann Whitney U test assuming that the distribution of the variables was different from the normal distribution by the sample size. The results are shown as mean plus standard deviation (Mean + SD). It was decided that there were statistically significant differences between the means of each variable when the value of $p < 0.05$.

The discriminatory capacity of each variable that proved to be statistically significant to be associated with a heart rate less than or equal to 70 beats per minute was valued because this value means an optimal cardiovascular state since the heart is capable of pumping the blood to all body tissues with a low number of beats per minute, but within normal limits, which denotes an adequate force of contraction of the ventricles and an integrity of the cardiovascular system. This was proved through the C statistic (area under the ROC curve). Generally, a variable with a C statistic ≥ 0.70 has an acceptable associative capacity. For the C statistic estimation, the authors used the ROC curve processing technique, in the SPSS Software. All data processing was made with a reliability of 95%.

Ethics

The research was approved by the ethics committee of the lead institution. All ethic principles were rigorous accomplishead according to the Helsinki principles. Each individual signed an informed statement and personal identification data was not published.

RESULTS

Table 1 shows the comparison of the means of the non-linear parameters of HRV analyzed in athletes and students according to the Mann Whitney U test. There were significant differences between the two groups in the variables Heart Rate, Standard Desviation 1 (SD1), SD2 / SD1, Sample Entropy, Short-term fluctuations α 1, Mean line length (Beats), Max line length (%), Recurrence rate (%), Determinism and Shannon Entropy.

The discriminatory capacity of each variable that proved to be statistically significant to be associated with a heart rate less than or equal to 70 beats per minute (≤ 70 beats/min) was assessed by analyzing the area under the ROC curve, which can be seen in the Fig. 1 It is observed that the values corresponding to the areas under the curve are different from each other. Values under the curve above 0,70 can be considered as a significant associative value. The value of SD1 was established at 0,906, showing an excellent associative capacity for a heart rate ≤ 70 beats/min. The value corresponding to Sample Entropy was set at 0,712, which shows an acceptable associative capacity.

Table 1- Areas under the ROC curve corresponding to the statistically significant parameters associated with a lower heart rate (≤ 70 beats/min)

Test Result Variables	Area	Standar Error [a]
SD1 (ms)	0.906	0.053
SD2/SD1	0.149	0.064
Sample Entropy	0.712	0.089
Short-term fluctuations α 1	0.236	0.082
Mean line length (Beats)	0.285	0.087
Max line length (%)	0.142	0.063
Recurrence rate (%)	0.302	0.086
Determinism	0.253	0.081
Shannon Entropy	0.255	0.085

Source: statistical processing.
[a] Under the non-parametric assumption.

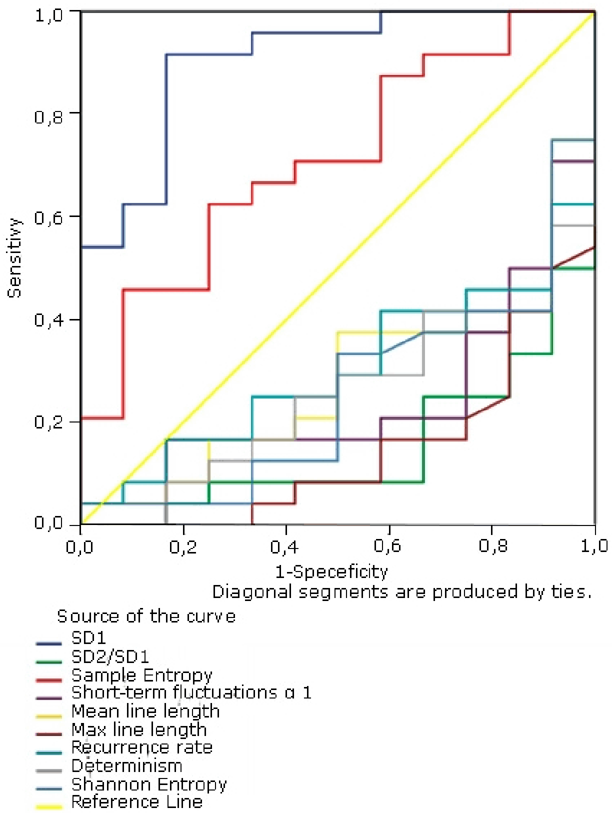

Fig. 1- ROC curves corresponding to the statistically significant parameters associated with a heart rate 70 beats/min.

DISCUSSION

The results of the present study show the modifications that some non-linear parameters of the HRV undergo in relation to the systematic practice of physical exercise.

Reimers et al [7] reported that neither an increase in resting parasympathetic tone nor a decrease in response to beta-adrenergic stimulation contribute to the decrease in HRV after regular exercise or systematic physical activity in humans, so that the authors of the present study consider that the differences between means of the variables analyzed respond to a change in the cardiovascular dynamics of the group exposed to systematic physical exercise, conditioned by a better balance of autonomic nervous system, and not to an autonomic cardiovascular imbalance in the group not exposed to regular physical activity.

When taking into account the psychic stress, it would be logical to conclude that the group of medical students presents higher levels of stress, due to the constant exposure to exams and evaluations, but the period in which the measurements were made coincides with the beginning of the semester, moment that constitutes the least stressful of the school year. However, this period coincides with the critical precompetitive stage, in which athletes must perform athletically to the maximum, since their performance in this stage depends on their participation in National Scholar Games, which is a stressful element in this group of individuals.

Deschodt-Arsac et al [8] in a recently published study showed that anxiety states and autonomic function might be improved by short-lasting cardiac coherence training, which brings improved resistance to stressful situations.

SD1 was significantly different in both groups of individuals. Weippert et al [9] mentioned that the significant differences of absolute spectral powers of the increase of SD also demonstrates the distinct autonomic heart rate modulation under the different contraction modes. Together, these results speak for an increased dual autonomic cardiac modulation under regular exercise goad.

Multiscale measures of HRV have generated a great deal of interest, but a systematic approach is required in order to identify appropriate measures that may be of benefit in the early identification of diseases of clinical importance to the practitioner.[10] In the present study, differences were found between the means of these non-linear measurements, as well as Shannon Entropy and Multi-Scale Entropy Maximum.

Sample Entropy was significantly associated with a better cardiac function, so it is concluded that this parameter is affected when the heart is exposed to better autonomic regulation. These results do not coincide with Weippert's [9], which indicated that a change of sympatho-vagal balance towards a sympathetic dominance increases regularity and thus reduces entropy values.

CONCLUSIONS

With the systematic practice of physical exercise, the non-linear parameters of the autonomic cardiovascular regulation of the Heart Rate Variability undergo changes in the values of: Heart Rate, Standard Desviation 1 (SD1), SD2/SD1 ratio, Sample Entropy, Short-term fluctuations α1, Mean line length, Recurrence rate, Determinism and Shannon Entropy, which respond to a better adaptability of the autonomic nervous system, and to a greater capacity to regulate the cardiovascular function.

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Conflicts of interest

The authors declare no conflicts of interest.

Author Contributions

Victor Ernesto González-Velázquez: conception and design of the study, analysis of the data, interpretation of the data, drafting the article. Lázaro Cobiellas-Carballo: conception and design of the study, analysis of the data, interpretation of the data, critical revision of the manuscript. Roxana María Rebustillo-Escobar: interpretation of the data, critical revision of the manuscript. Walfrido Semanat-Gabely: interpretation of the data, critical revision of the manuscript. David de J. Bueno-Revilla: collection of data, critical revision of the manuscript. Erislandis López-Galán: collection of data, critical revision of the manuscript. Miguel E. Sánchez-Hechavarría: conception and design of the study, collection of data, critical revision of the manuscript. All authors have read and approved the final manuscript.