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Research of Heart Rate Variability in Sprinters

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Abstract

This article examines and analyses Heart Rate Variability (HRV) in short-distance runners. Sports are known to increase total HRV, with athletes having relatively higher variability than the general population. The Autonomic Nervous System (ANS) is divided into two subsystems: the sympathetic being activated during exercise and the parasympathetic during rest. In this research, their behaviour during training (physical exertion) can be considered stress for the body. During exercise, HRV decreases, RR intervals become shorter and more uniformand heart rate increases due to increased sympathetic and decreased parasympathetic activity. During rest and recovery, HRV begins to rise. The inability to return HRV to pre-exercise levels within a reasonable time is considered a chronic impairment in the activity of the ANS, which can lead to overtraining. Avoiding overtraining will improve athletes' athletic performance and prevent injuries. The application of spectral analysis performed the analysis of pre- and post-exercise HRV of 5 short-distance runners. Power spectral analysis represents the distribution of heart rate variation as a function of frequency. The frequencies used are Very Low (VLF), Low (LF) and High (HF), each of which is associated with a specific physiological cause. The assessment of HRV was made on 10-minute (two 5 minutes records) recordings recorded by an electrocardiographic device. From the performed experiment, it is noticed that the specifics of the behaviour of the autonomic nervous system and, from there, of the HRV of power runners differ from other athletes. The results of the analysis of HRV during athletes' training may be a valuable tool in evaluating the effects of athletes' activity, such as cumulative fatigue or improvement in cardiorespiratory fitness and exercise tolerance.

Keywords: HRV • ANS • Sprinters • Spectral analysis

Introduction

One of the problems faced by athletes today is overtraining and injuries. With the help of appropriate software, it is possible to track the load, which will improve sports performance and reduce injuries. Monitoring changes in the Autonomic Nervous System (ANS) and, hence, heart rate will allow the coach to watch the training process of their athlete/trainee closely. In sports, the behaviour of the autonomic nervous system is of particular importance. Which, in turn, consists of two subsystems: the Sympathetic (SNS) and Parasympathetic (PSNS) nervous systems [1-3]. The first of these controls the body's reactions due to stressful situations, such as mental and physical exertion, which leads to an increase in heart rate. The second subsystem controls the "rest" function and has the opposite parts of the sympathetic nervous system. It restores the body to calmness, which is characterized by a decrease in heart rate. The main factors influencing HRV are age, gender, ethnic origin, etc. From a person's birth to adolescence, HRV increases. As age increases, the variability begins to decrease. Studies have been done on how the HRV changes during the day. It has been established that at night, the HRV increasesand in the morning, it begins to decrease. The human race also affects overall variability, with African Americans having higher variability than white race. This factor is essential when studying the impact of heart rate variability on athletes. It is known that the Negroid race is the most durable, which affects sports achievements, whether it is sprinters or athletes running long distances [4]. The relationship between the two subsystems of the ANS depends very much on the volume and intensity of the training itself [3]. Depending on the exercise, the sympathetic lobe may increase the heart rate in proportion to the exercise. The HRV assay can replace the anaerobic threshold assay. At the higher loads, a more excellent disturbance of the ANS sympathivigial imbalance was found [3]. It has been proven that the parameters of the HRV are directly related to the physical load [1-3].

The purpose of the study is to follow the influence of sports/running on the ANS and, from there on, the HRV in sprinters. In this case, the sport is a warm-upand the essential part is running two sections of 200 meters with rest in between. Mathematical analysis was performed by spectral method.

The relationship between the autonomic nervous system and heart rate variability

The HRV shows information about the activity of the ANS. When it increases, it means that the body adapts and recovers better. When the HRV is lower, it leads to a slower recovery. On the other hand, each person has a unique HRV, which means that a higher value is only sometimes better or worse. The higher the athlete's overall HRV, the faster he recovers. The coach can monitor the athlete's condition and, from there, can determine the degree of load and the required rest time. In many cases, the trainer cannot know the reason for the change of the HRV, which can be caused by various types of stress (physical, mental, chemical and others). The increase in HRV results from decreased heart rate at rest, i.e. the parasympathetic nervous system is activated. There are two mathematical methods for analyzing HRV - linear and non-linear [5]. Linear methods are used most often because they are standardized [6]. These methods are divided into time and frequency. Frequency measurements are a collection of measurement techniques that indicate the presence of electrical impulses at specific frequencies. They are most commonly used to track post-workout recovery. With their help, the behaviour of the autonomic nervous system and the dominant subsystem can be easily tracked.

Methodology

Spectral method

Through spectral analysis, the energy of the investigated signal (RR interval series) is presented as a function of frequency. A two-dimensional graph is drawn, with frequency on the abscissa and energy distributed as a function of frequency on the ordinate. In the present article, the non-parametric

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Fast Fourier Transform (FFT) method was also used for the analysis, applying a Welch periodogramand as a result, the RR intervals, in this case, overlapped by 50%. To remove the error "blurring the the spectrum", which represents wrong information when analyzing the ECG intervals. Henning's window function is used. The FFT is calculated for each segment and finally averaged. The more pronounced a component is, the more peaked it will be. With the help of spectral analysis, the fluctuations of the heart rate variability can be evaluatedand the different components of the heart rhythm can be visualized graphically. In spectral analysis, the following three frequency components are mainly considered [4-8]:

- HF – High Frequency (0.15 - 0.4 Hz)
- LF – Low Frequency (0.04 – 0.15 Hz)
- VLF – Very Low Frequency (0.017 – 0.04 Hz)

Data

The object of this study are five sprintersand a mathematical analysis of 5-minute recordings recorded with a Holter device before and after running two sections of 200 meters was performed. An ECG holter and software are used to generate the RR time intervals. The Holter device is compatible with the Windows OS versionand thus, exercise control can be carried out, i.e. the functional state of the cardiovascular system can be evaluated during the recording. The application of this research methodology will provide the coach with more complete information about the workload and the progress of the traineeand from there, the sports performance will be improved. In athletics, there are three types of runners: short, middleand long-distance runners. It is assumed that the behaviour of ANS in each of them will be specific. To describe the results in this article, sprinters of different ages (from 18 to 58 years) are studied. Since they are similar runners, it is possible to compare them and apply a spectral analysis method. All runners participating in this study were subjected to the same load to determine the HRV and evaluate the ANS.

Results

With the help of ECG recording, it is possible to track the entire training cycle of the trainer. The behaviour of the ANS described in this article is realized through two recordings of ECG data: during rest (before exercise) and after exercise. The recordings were for 5 minutesand the mathematical analysis was performed using the spectral method and the Welch plot. The values of the spectral components are determined, after which their significance is evaluated. It is noticed that at rest, the variability is higher than that after the run. Active training may lead to a progressive increase in parasympathetic activity and a decrease in sympathetic output. It is hypothesized that sympathetic activity in the most trained athlete will result in the lowest levels of HRV. When an athlete trains, his body goes through stress. To make the body more resilient, the nervous system also goes through stress. The stress and recovery cycle is essential here. It is necessary to calculate the load and rest correctly, i.e., recovery. The body should be given enough time to recover. Athletes and special forces are known to have both a solid sympathetic response and a strong parasympathetic pulse at rest. Their variability is not like that of ordinary people. Athletes with the highest HRV during running show rapid exhaustion of physical forces and give the lowest results in training. Studies done on middle-distance runners show that after the build-up of an allostatic load as a result of training, the HRV decreases. During the recovery, the HRV has risen. If it is necessary to determine the load of a competitor, the first record is important, which will serve as a base for the others. It is recommended to make several recordings over a more extended period and then average the values. One of the trainee did three recordings, illustrated in Figure 1, Figure 2 and Figure 3, where the percentage ratio of spectral frequencies is shown. Figure 1 shows the frequencies before the athlete starts actively participating in athletics. Figure 2 and Figure 3 related to this study refer to the cases of the running of two sections of two hundred meters with a one-month difference between them. What was noticed was that his HRV was significantly reduced during and after the run. The LF/HF ratio is highest in the second recording (Figure 2), .e., the athlete was in optimal shape. With the third recording (Figure 3), it was noticed that the difference has decreased, i.e. it gives a weaker result than the second one. In reality, the time he gave the athlete for running the two sections was slower. In the first and last case, sympathetic activity is slightly dominant.

It is also possible to compare several athletes, in which case they should be sprinters - short-distance runners and perform the same sports load (running two sections of two hundred meters). After recording the time intervals from the holter, a spectral method is applied that calculates the frequency components. The LF/HF ratio can be used to determine which part of the ANS is dominant. If the value of the second record is lower, it follows that the parasympathetic system is prevalentand conversely, if the ratio is greater, it follows that the sympathetic system is more active. The percentage ratio between the averaged spectral frequencies of the five is shown in Figure 4 (before and after running). After an analysis of several competitors, it is possible to obtain a difference between the heart rates of each of them, which is due to the degree of fatigue from the workout. The VLF component of the analysis corresponds to the sympathovagus balance and has a unique characteristic. Two of the participants in this study produced very interesting results. One showed very low post-run variabilityand the other showed high resting and post-run sympathetic indices. It is assumed that the first athlete shows the most significant resistance and struggle against "danger". Its dominant component during rest and after running is VLF. The other subject had a dominant LF component before and after running. Some of the studied parameters have statistical significance, determined by t-test, since the p-value is less than 0.05. These are the normalized units of Table 1: LF[nu], HF[nu]. LF/HF ratio has no statistical significance - NS. The indicators are presented in normalized units, where it is observed that the low frequencies and the ratio are lower after physical exercise. On the other hand, the high frequency has lower indicators before running. Figure 5 shows the FFT plot of the low variability sprinter. In Figure 6, the subject with the dominant sympathetic nervous system is at rest and after the run. The physical load determined the coach, who is 58 years old and continue, to compete and win medals for Bulgaria on Figure 7. The

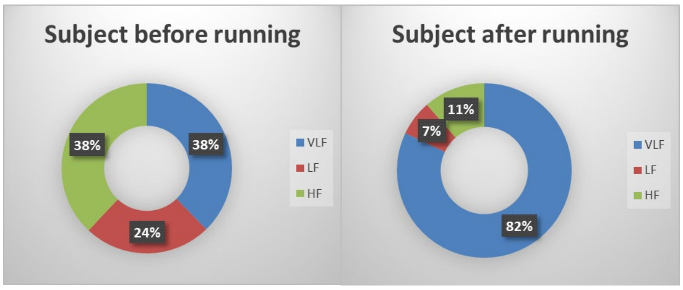

Figure 1. Beginner's spectral analysis.

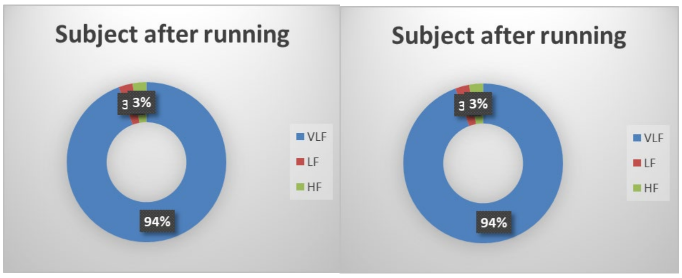

Figure 2. Spectral analysis of an athlete trained after 5 months.

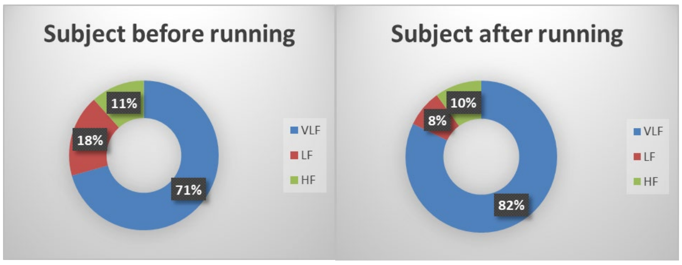

Figure 3. Spectral analysis of an athlete trained after 6 months.

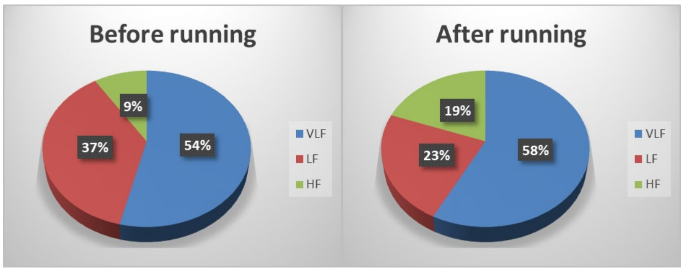

Figure 4. Two groups before and after running.

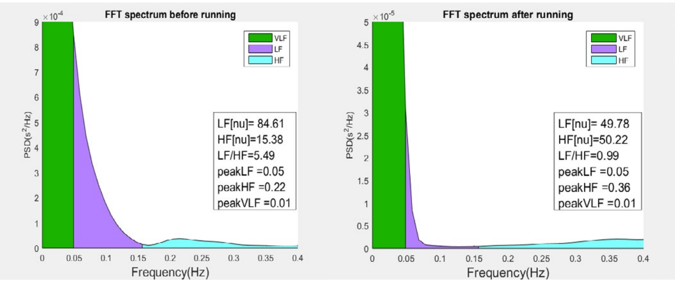

Figure 5. Lowest variability runner.

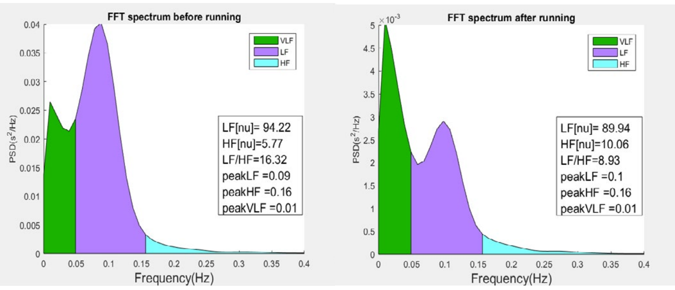

Figure 6. Runner with a dominant sympathetic nervous system.

Figure 7. Short distance sprinter.

Table 1. Comparative analysis between two groups of people: Group 1 (rest) and Group 2 (after running) by applying the fast Fourier transform method.

Variable	Group 1 Mean ± SD	Group 2 Mean ± SD	p-value
LF [nu]	77.25 ± 14.29	52.91 ± 17.14	(0.0406)<0.05
HF [nu]	22.74 ± 14.29	47.08 ± 17.0	(0.0406)<0.05
LF/HF ratio	5.974 ± 6.04	1.8 ± 2.3	NS

fastest was a sprinter, 18 years old, who ran the distances with ease (Figures 1-7) and (Table 1).

Conclusion

The creation and use of suitable software through mathematical methods for the evaluation of HRV can be of help to the coach and the competitor. The idea is to determine the optimal load to avoid overtraining and injuries. One of the appropriate mathematical methods for the analysis of HRV is spectral analysis. It can be used to determine which system is dominant: SNS or PSNS. In the article, two groups of exercisers were studied at rest and after physical exertion in the case of warm-up and two sections of 200 meters. The subjects were sprinters and performed the same load, which led to similar results obtained by the mathematical method associated with increasing and decreasing spectral components. Two participants produced very interesting results related to extremely low variability and a dominant sympathetic nervous system. Some of the parameters in the case of normalized units have statistical significance determined by t-test since the p-value is less than 0.05. It is normal for the HRV of runners to differ from that of ordinary people because their ANS reacts differently.

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