Training loads and heart rate variability of young skiers

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Abstract
Objective of the study was to evaluation of the changes in the relationships and fluctuations between the indicators of heart rate variability in young skiers during a training session.
Methods and structure of the study. Heart rate variability was assessed in 12 mass-class skiers aged 13,2±0,4 years using the MS FIT system (Medicalsoft, RF) before and after exercise in a sitting position. The training load was a cross-country run with an imitation of an uphill run alternating with running. Five series of 10 repetitions of an uphill run of 150 m with a slope of 7-9˚ were performed.
Results and conclusions. The correlation between the indicators of the heart muscle's performance undergoes a substantial transformation under the influence of physical exertion. The assessment of athletes' functional status and their performance solely based on quantitative HRV data, without considering the evolution of the correlation, can result in an erroneous interpretation of the findings.

Keywords: *performance, heart rate variability, young skiers, training process*

Introduction. Evaluation of physical performance, the degree of impact of the training load on the body of those involved is the most important component of the effectiveness of the training process [3].

Analysis of scientific and methodological literature shows that at present the condition and performance of athletes are assessed mainly using testing procedures with an assessment of the level of lactate in the blood and spirometry [3, 5]. At the same time, there is enough data in the literature indicating the possibilities of autonomous analysis of ECG data, which allow us to draw conclusions about the actual individual parameters of the functional state of athletes without the use of expensive equipment and invasive research methods [5].

One of the areas of assessing the adaptation processes in the body over a long period of time is the analysis of heart rate variability (HRV). According to the results of studies, HRV is an emerging property of interdependent regulatory systems that operate on different time scales, helping an individual to adapt to challenges of various natures. It is noted that the dynamics of HRV is a nonlinear system, the variability of which allows you to quickly adapt in an uncertain and changing environment [3].

HRV includes a number of time domain indicators, frequency domain indicators, and nonlinear measurements. According to a number of studies, there is a close relationship between the indicators of these areas, which allows for the formation of an optimal HRV level, which contributes to the process of self-regulation and adaptability to constantly changing environmental conditions [4, 5, 6].

Objective of the study was to evaluation of the changes in the relationships and fluctuations between the indicators of heart rate variability in young skiers during a training session.

Methods and structure of the study. The scientific work involved 12 mass-class skiers aged 12-15 years. Heart rate variability was assessed using the MS FIT system (Medicalsoft, RF) before and after exercise in a sitting position. The training load was a cross-country run with an imitation of an ascent alternating with running. Five series of 10 repetitions were performed in an ascent of 150 m with a slope of 7-9°. When assessing HRV, we analyzed the following parameters: heart rate (HR), standard deviation of normal sinus contractions (SDNN), root mean square of successive differences between normal heart contractions (RMSSD), number of adjacent NN intervals differing from each other by more than 50 ms (NN50), percentage of adjacent NN intervals differing from each other by more than 50 ms (pNN50), low-frequency range VF (0,04–0,15 Hz), high-frequency or respiratory range HF (0,15–0,40 Hz), LF to HF power ratio (LF/HF), and total HRV spectrum power (PT). Statistical analysis of the obtained results was performed using the IBM SPSS Statistics 27.0.1 software package with calculation of the Spearman rank correlation coefficient. The critical value at P 0,05 was 0,58, at P 0,01 – 0,71 [1].

Results of the study and discussion. The results of calculating the correlation matrix between the indicators of the time and frequency ranges of HRV recorded in the resting state are presented in Table 1.

The analysis of the obtained data shows that the values of the frequency and time ranges for a number of indicators have a strong relationship in the resting state of young athletes. Thus, the standard deviation of normal sinus contractions (SDNN) closely correlates with the time range indicators (RMSSD, NN50, pNN50), as well as with the HRV power indicators in the high-frequency range (HF), and the total power (TP). The obtained results are consistent with the data of the scientific and methodological literature [3, 5]. The researchers note that the SDNN values are equally influenced by both the sympathetic and parasympathetic systems. At the same time, in the conditions of short-term recordings at rest, the main source of variations is parasympathetically mediated respiratory sinus arrhythmia [6]. This is indicated by the correlation level of 0,87 between SDNN and HF. A number of relationships in the frequency domain are also noteworthy.

Thus, in the low-frequency to high-frequency power ratio, the highest correlation is observed between LF/HF and LF. It can be assumed that this indicates a greater contribution of low-frequency oscillations to this indicator.

At the same time, there is no consensus in the scientific and methodological literature on the interpretation of the LF/HF ratio data. The main assumption is that low-frequency power can be generated by the sympathetic nervous system, while high-frequency power can be generated by the parasympathetic nervous system [3, 5]. At the same time, there is data indicating that this assumption is controversial [6]. According to the data obtained, the contribution of LH to the LF/HF ratio is significantly higher, which is confirmed by the correlation relationship between these indicators, recorded at the level of 0,80. However, the correlation between the total power and high-frequency power is 0,81, which indicates a greater contribution of the parasympathetic component to this indicator.

After the completion of the training session, the correlation relationships between the recorded indicators changed significantly (Table 2). The analysis of the obtained results shows that the correlation value between the SDNN and LF indicators increased from -0,24 to -0,51, the relationship between SDNN and PT decreased from 0,98 to 0,41. Upon completion of the training work, the athletes showed no relationship between such indicators as NN50 and HF, NN50 and PT, while before the load the level of correlation between these indicators was 0,98 and 0.95, respectively. Also noteworthy is the increased relationship between the

Table 1. Correlation relationships between HRV indicators before the start of the training session

	SDNN	RMSSD	RR	NN50	pNN50	LF	HF	LF/HF	PT
SDNN									
RMSSD	0,87**								
RR	-0,32	0,70*							
NN50	0,92**	0,98**	-0,61*						
pNN50	0,87**	0,99**	-0,70*						
LF	-0,24	-0,12	0,16	-0,25	-0,12				
HF	0,87**	0,99**	-0,70*	0,98**	0,99**	-0,11			
LF/HF	-0,72*	-0,68*	0,50	-0,77**	-0,68*	0,80**	-0,68*		
PT	0,98**	0,81**	-0,23	0,85**	0,81**	-0,15	0,81**	-0,62*	

** The reliable level of the correlation coefficient is at p<0,05; ** The reliable level of the correlation coefficient is at p<0,01.*

Table 2. Correlation relationships between HRV indicators after a training session

	SDNN	RMSSD	RR	NN50	pNN50	LF	HF	LF/HF	CM
SDNN									
RMSSD	0,90**								
RR	-0,19	-0,10							
NN50	0,52	0,73**	0,54						
pNN50	0,87**	0,99**	-0,10	0,75**					
LF	-0,51	-0,18	0,59*	0,34	-0,13				
HF	0,69*	0,78**	-0,41	0,28	0,77**	-0,26			
LF/HF	-0,77**	-0,50	0,50	0,05	-0,45	0,93**	-0,50		
PT	0,41	0,43	-0,24	0,02	0,39	-0,01	0,76**	-0,19	

** The reliable level of the correlation coefficient is at P>0,05; ** The reliable level of the correlation coefficient is at P>0,01.*

low-frequency power (LF) indicators and the LF/HF ratio, while the relationship between the total power (PT) and the high-frequency power (HF) indicator decreases to 0,76.

The role of the respiratory rate (RR) also increases significantly in the final configuration of the relationships between the indicators. Thus, the correlation links between RR and NN50 from -0,61 are transformed into 0,54, which, in our opinion, indicates the role of the respiratory system in the regulation of HRV during physical exertion, and the correlation between RR and LF also increases significantly from 0,16 to 0,59. The information content of changes in the closeness of the relationship between instantaneous HR and the respiratory cycle for the early detection of overtraining in athletes was noted in the domestic literature [2].

Conclusions. The conducted study allows us to state that the relationships between the indices of cardiac muscle functioning significantly change under the influence of physical activity. According to the data of scientific and methodological literature, the analysis of HRV is actively used as a non-invasive method of assessing the functional state of athletes and their level of performance [5], at the same time, the assessment of only quantitative data without assessing the dynamics of the relationship, in our opinion, does not allow us to identify cause-and-effect relationships in the dynamics of the indices, which in turn can lead to an incorrect interpretation of the results obtained. Also, the dynamics of HRV is significantly affected by the age and level of training of those involved, which is also an important factor in the analysis of the data obtained.

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