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Comparative analysis of heart rate variability in short-distance and ultramarathon runners: implications for training optimization

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Abstract: *This study investigated heart rate variability (HRV) as a biomarker for assessing athletes' functional states and adaptation mechanisms to different training modalities. The objective was to develop a technology for monitoring and controlling the training process of runners using HRV indicators. Thirty participants were divided into two groups: Group 1 consisted of short-distance runners, and Group 2 included long-distance runners. HRV was assessed via electrocardiography using the "Varicard" system, while additional data were gathered through a Google Forms survey. Statistical analysis was conducted using SPSS software (version 13.0).*

Results *revealed minimal differences in heart rate between the two groups, with the resting heart rate being lower in long-distance runners. The low-frequency component (%LF) exhibited a more pronounced response to the orthostatic test in short-distance runners ($p<0.05$). Regression analysis demonstrated that factors such as age, alcohol consumption, and smoking led to an increase in LF% and a decrease in parasympathetic activity.*

HRV *effectively reflects the adaptive capacity of runners and can be employed to monitor and control training processes. Non-training factors, including nutrition, health status, perceived load tolerance, age, and gender, also influence HRV and must be considered when preparing runners. These findings highlight the critical role of HRV in optimizing athletic performance and tailoring individualized training strategies for short- and long-distance runners.*

Keywords: *heart rate variability, athletes, short-distance runners, long-distance runners, adaptation to physical exercise.*

INTRODUCTION

Track and field is one of the oldest sports, which was included in the Olympic Games of Ancient Greece (776 BC - 394 AD) and to this day, is included in the programs of the Olympic Games, World and European Championships. The International Association of Athletics Federations (IAAF) includes 214 national federations of six continental associations. Running remains the most popular and spectacular discipline of athletics, which is practiced by more than 600 million people in the world.

Under the influence of systematic athletic training, heart rate slows down due to enhanced parasympathetic modulation of cardiac automatism, accompanied by a tendency toward a reduction in arterial blood pressure. Regulatory changes in the autonomic nervous system explain this effect in the autonomic nervous system centers in trained runners at rest, which are linked to an increased parasympathetic tone. As a result, negative chronotropic and inotropic effects are observed, ultimately leading to a decreased heart rate (Aubert et al., 2003). Moreover, a correlation has been observed between the intensity of negative chronotropic influences and the nature of the training regimen (Gronwald et al., 2021). The development of endurance in long-distance runners is associated with an increased tone of the parasympathetic division of the autonomic nervous system (Rogers et al., 2021). In contrast, anaerobic training loads in sprinters do not suppress the sympathoadrenal system, as the predominant activation of the humoral pathway is maintained, along with unchanged catecholamine metabolism (Rogers & Gronwald, 2022; Schaffarczyk et al., 2022).

E.P. Ilyin (2004) emphasizes that theoretical understanding of human adaptive capacities significantly lags behind actual achievements. This is evidenced by advancements in sports and other fields of activity that were once deemed unattainable. One of the most extreme forms of physical activity is trail running, which involves off-road races covering distances of 100 km or more. A specialized discipline within trail running is skyrunning, which consists of mountain races conducted at high altitudes or featuring significant elevation gain (Ovsyannikova et al., 2020). Another emerging and rapidly growing endurance discipline is the backyard ultra, a race format in which athletes must complete a 6,700-meter loop every hour, restarting at the top of each hour, until only one runner remains on the course (Marathonec, 2023). Additionally, traditional annual ultramarathon competitions are held on stadium tracks, featuring continuous running events lasting 6, 12, 24, 48, and even 72 hours. It is essential to highlight that such remarkable achievements in endurance sports necessitate a highly developed level of physiological system functionality to sustain performance over extreme durations.

Athletes strive for excellence, often pushing their bodies through intense training schedules (Durandt et al., 2006). This constant pressure without adequate rest can lead to a state of overtraining, which can take weeks or months to recover from, much longer than early overtraining (Cochrane, 2004; Kiss et al., 2015; Kenneally et al., 2018). When overtraining occurs, the autonomic nervous system responds to the constant stress placed on the body by activating the sympathetic-adrenal system. On the other hand, overtraining depletes the body's physiological resources, leading to a reduced capacity for recovery (Aubert et al., 2003; Cornforth et al., 2015).

Furthermore, one of the primary factors contributing to thanatogenesis in cases of sudden cardiac death among young athletes is the insufficiency of compensatory-adaptive mechanisms. The main cause of this phenomenon is the chronic overload of the cardiac muscle due to intensive training. Initially, short-term compensatory mechanisms are activated; however, these processes are highly energy-consuming. When sustained over prolonged periods, they disrupt metabolic processes in cardiomyocytes, ultimately compromising cardiac function.

This is where HRV monitoring becomes critical (Mal'tsev et al., 2010; Minnis, 2015; Sammito & Böckelmann, 2016; Korobeynikov et al., 2018; Kölling et al., 2019). By identifying early signs of HRV disruption, athletes and coaches can adjust training plans, incorporate more recovery strategies, and prevent the detrimental effects of overtraining (Hynynen et al., 2006; Cornforth et al., 2015; Augustine & Howard, 2018; Boullosa et al., 2020). All of this points to the importance of measuring HRV in improving the performance of exercise programs in athletes.

HRV can be affected by various non-training factors such as medication, co-morbidities, alcohol and cigarette use, sleep quality, etc., which need to be considered when planning the training process for runners (Lukaski, 2004; Brooks et al., 2005; Paul & Garg, 2012; Strüven et al., 2021; Lundstrom et al., 2023).

Problems of the study.

The study of the functional characteristics of athletes engaged in extreme forms of physical activity represents a large-scale biological experiment aimed at determining the true capabilities of the human body. The findings of such research can contribute to the comprehensive study of human physiological potential. A comparative analysis of heart rate variability in relation to other factors influencing the training process arises from the necessity of understanding cardiovascular adaptation to physical exertion of varying intensity. This is particularly relevant, as the cardiovascular system often serves as a limiting factor in determining the intensity and duration of physical workloads. The assessment of systemic functional levels and the identification of trends in their improvement with the enhancement of physiological capacity constitute a pressing challenge in contemporary physiology of muscular activity.

The purpose of the study is to conduct a comparative analysis of heart rate variability (HRV) indicators to identify the most significant parameters for assessing cardiovascular adaptation to physical exercise of varying duration. Additionally, the study aims to determine key factors contributing to the optimization of the training process among runners with different specializations.

Hypothesis:

- HRV indices are different in short distance runners and long-distance runners which need different training programs.
- Heart rate variability (HRV) indicators in runners are influenced by auxiliary factors such as sleep quality, smoking, supplementation, and other lifestyle variables, which are, in turn, dependent on the nature of training loads.
- Considering HRV characteristics in combination with additional influencing factors can serve as a foundation for developing advanced training optimization strategies for runners with different specializations.

MATERIALS AND METHODS

The study was conducted at the Laboratory of Human Abilities of the Moscow City University from November 2023 to January 2024. The study involved 30 people aged between 25 and 35 years, of whom equal proportions were male and female. They were divided into 2 groups depending on their level of physical activity and specific sports activities. Group 1 - short-distance runners (competitive distances up to 1 kilometers). Group 2 - long-distance runners (competitive distances over 42.2 kilometers, including ultramarathoners, competitive distances over 100 kilometers). The athletes were tested at the same time (10 a.m.) after breakfast before their first training session. All athletes had the same pre-competition preparation period.

The biomedical research has been conducted in accordance with the ethical principles of the Helsinki Declaration of the World Medical Association (WMA) of 1964 (as amended in 2008). The inclusion of athletes in the study group has been carried out based on a written signed and dated Informed Consent Form. The informed consent has been drawn up in accordance with the laws of the Russian Federation, the GCP rules and the principles of the Helsinki Declaration of the BMA (Food and Drug Administration, 1995).

To assess the body's adaptive capabilities, ECG recording was performed in accordance with the "International Standard" proposed by the North American Society of Electrophysiologists and the European Society of Cardiology in 1996. The study of heart rate variability in athletes was conducted using the "Varicard" computer system. HRV parameters have been measured in the state of relative rest and in response to a functional test for both groups. The time domain method is a low-error approach that examines factors such as standard deviation of the NN interval (SDNN), percentage of consecutive NN intervals, the difference between which exceeds 50 mc (pNN50), and the square root of the mean squared differences of successive NN interval (RMSSD). The frequency domain method is a rapid approach that considers three general peaks: VLF (<0.04 Hz), LF (0.04-0.15 Hz), and HF (0.15-0.4 Hz). In the non-linear method, the entropy score is calculated as a reliable measure. This study employed both time domain and frequency domain methods to assess the status of athletes.

Interpretation of the results of the study of heart rate variability (HRV) was carried out taking into account the activity of the heart rate regulation circuits (R.M. Baevsky, 1997). The sympathetic channel of regulation was assessed by such indicators as % LF, % VLF. The parasympathetic channel of regulation is characterized by RMSSD, % HF. The ratio of the activity of the autonomic nervous system departments can be assessed by SDNN, LF/HF. The degree of centralization in the control of the heart rhythm was determined by the HR, SI indicators. The total activity of neurohumoral influences on the heart rhythm was revealed by the TP indicator.

To assess the influence of auxiliary factors on HRV, a questionnaire was developed, which included several sections:

1. sports history;
2. signs of autonomic disorders (A. Veyn, 2000);
3. health;
4. pernicious habits;
5. nutrition and supplements.

The initial results of the pilot testing of individual methodologies were presented in the proceedings of the International Conference (A. Nalobina, O. Ivashchenko, 2017), and since then, these methodologies have been employed in more than 50 studies (according to data from the Russian Science Citation Index). Statistically significant direct correlations between the indicators of all methodologies, as well as their associations with other variables, attest to their convergent validity. Reliability was assessed using Cronbach's α coefficient, along with Raykov's ρ coefficient (Raykov, 1997), which is also known as McDonald's ω (McDonald, 1999) when derived from a factor model. The internal consistency indices ($\alpha = 0.72$, $\rho = 0.73$) indicated a satisfactory level of reliability for the questionnaire.

Statistical processing of research results.

An assessment of the nature of the data distribution using the Shapiro-Wilk and Kolmogorov-Smirnov criteria made it possible to consider the distribution of heart rate variability data as close to normal in all the samples under consideration and to apply parametric statistics methods (the arithmetic means of the samples were considered as indicators of position, and the standard deviation as an indicator of variation). To assess the differences in cardiac rhythm parameters in the selected groups, a one-dimensional multivariate analysis of variance (General Linear Model, Univariate) was used, followed by Tukey's post-hoc test. Differences were considered statistically significant at P-values <0.05.

Multiple linear regression was used to evaluate the questionnaire data to examine the relationship between the response results and each of the HRV indicators to understand the importance of each factor. In this statistical process, a code is assigned to each qualitative variable. SPSS (13.0) software was used for statistical calculations.

RESULTS

In the process of a typical stress response (and in our case, stress is physical activity), several hierarchical levels can be distinguished that support the optimal functional state of a person:

1. Higher nervous activity, which ensures the change of the dynamic behavioral stereotype.
2. The autonomic nervous system (the system of neurohumoral regulation), This system affects the involuntary functions of the body, such as heart rate, respiration, and digestion.
3. Morphological changes in organs and systems that determine physical performance and work capacity.

Despite the great difference in the training process, the results show that there is a small difference in the cardiac indices of short- and long-distance runners, and the only differentiating factor is the resting heart rate (table 1). One of the reasons for this fact is the long-term mechanisms of adaptation to physical activity, which have common features in athletes of different sports. On the other hand, the high spread of indicators (sigma) indicates the heterogeneity of the group and the presence of individual-typological features of the athletes' bodies.

Table 1. *Comparison of heart rate variability in a state of relative rest in an experimental group depending on sports specialization*

Indicator	Short distance (n=11)		Ultra marathon (n=11)		The validity of the differences (P)
	mean	sigma	mean	sigma	
HR (bpm)	68.45*	8.92	59.09*	8.26	0.0122
SDNN, mc	77.45	35.83	66.49	36.68	0.2533
RMSSD, mc	78.90	53.57	64.72	58.04	0.2882
TP, mc^2	8267.25	10292.42	4882.18	6616.20	0.1960
pNN50, %	37.52	20.87	29.85	24.88	0.2318
SI, a.u.	73.91	55.86	84.27	56.00	0.3415
HF, %	45.9	14.00	35.64	17.75	0.0835
LF, %	37.85	11.74	45.76	15.43	0.1059
VLF, %	16.24	7.83	18.65	5.85	0.2224
LF/HF, a.u.	0.98	0.55	1.95	1.72	0.0518
LF, mc^2	3149.68	4930.41	2062.76	3160.82	0.2819
HF, mc^2	3308.09	4218.37	1523.16	2007.31	0.1205
VLF, mc^2	1009.70	1409.71	794.25	1211.94	0.3589

Legend: HR - Heart Rate; SDNN - Standard Deviation of the NN interval; RMSSD - Root Mean Square of Successive Differences; TP- Total Power; pNN50 - Percentage of NN50; SI- Stress Index; HF - High-Frequency Power; LF - Low-Frequency Power; VLF - Very-Low-Frequency Power.

(*) - the validity of the differences at a p-value < 0.05.

To better understand this fact, an analysis of the HRV indices in response to the orthostatic test was conducted (table 2,3).

Table 2. *The reaction of heart rate variability indicators in response to a functional test in short-distance runners*

Indicator	in a state of relative rest		Orthostasis		increase, %
	mean	sigma	mean	sigma	
HR (bpm)	68.45	8.92	83.72	14.35	22.30
SDNN, mc	77.45	35.83	374.18	894.96	383.12
RMSSD, mc	78.90	53.57	370.63	889.94	369.74
TP, mc^2	8267.25	10292.42	11357.72	23989.86	37.38
pNN50, %	37.52	20.87	14.35	16.29	-61.75
SI, a.u.	73.91	55.86	169.27	134.37	56.33
HF, %	45.90	14.00	21.37	15.36	-53.44
LF, %	37.85	11.74	54.90	15.50	45.04
VLF, %	16.24	7.83	23.72	16.78	46.05
LF/HF, a.u.	0.98	0.55	3.74	2.36	281.63
LF, mc^2	3149.68	4930.41	2900.89	3819.24	-7.89
HF, mc^2	3308.09	4218.37	1720.48	2750.54	-47.99
VLF, mc^2	1009.70	1409.71	4744.70	13439.80	369.91

Legend: HR - Heart Rate; SDNN - Standard Deviation of the NN interval; RMSSD - Root Mean Square of Successive Differences; TP- Total Power; pNN50 - Percentage of NN50; SI- Stress Index; HF - High-Frequency Power; LF - Low-Frequency Power; VLF - Very-Low-Frequency Power.

Table 3. *The reaction of heart rate variability indicators in response to a functional test in ultramarathon runners*

Indicator	in a state of relative rest		Orthostasis		increase, % mean
	mean	sigma	mean	sigma	
HR (bpm)	59.09	8.26	74.18	12.15	25.53
SDNN, mc	66.49	36.68	70.05	52.57	5.35
RMSSD, mc	64.72	58.04	63.28	64.64	-2.22
TP, mc^2	4882.18	6616.20	4568.43	4797.53	-6.42
pNN50, %	29.85	24.88	10.42	15.70	-65.09
SI, a.u.	84.27	56.00	167.45	125.33	98.70
HF, %	35.64	17.75	29.26	23.71	-17.90
LF, %	45.76	15.43	46.08	18.76	0.69
VLF, %	18.65	5.85	24.66	16.31	32.22
LF/HF, a.u.	1.95	1.72	3.58	3.88	83.58
LF, mc^2	2062.76	3160.82	1210.39	1267.95	-41.32
HF, mc^2	1523.16	2007.31	2003.15	3532.65	31.51
VLF, mc^2	794.25	1211.94	593.98	316.88	-25.21

Legend: HR - Heart Rate; SDNN - Standard Deviation of the NN interval; RMSSD - Root Mean Square of Successive Differences; TP- Total Power; pNN50 - Percentage of NN50; SI- Stress Index; HF - High-Frequency Power; LF - Low-Frequency Power; VLF - Very-Low-Frequency Power.

The transition from a resting state to an orthostatic position triggers an increase in heart rate due to the activation of the sympathetic nervous system. This system is responsible for the body's "fight-or-flight" response and prepares the body for physical activity or stressful situations.

In the context of athletes, maintaining proper heart function during posture changes is crucial for optimal performance. As expected, factors associated with sympathetic nervous system activity, such as heart rate, increase during this transition. This increase is necessary to meet the demands of increased blood flow and maintain blood pressure.

Conversely, factors related to parasympathetic nervous system activity, which is responsible for “rest and digest” functions, tend to decrease during the transition from rest to standing. This temporary shift in autonomic nervous system balance allows the body to prioritize immediate physiological needs associated with the change in posture.

It’s important to note that the extent of these changes may vary among athletes depending on individual factors such as fitness level.

At first glance, when examining the tables, there appears to be a significant difference in the change in numbers obtained between short-distance and long-distance runners. According to such indicators as RMSSD; TP; VLF%, HF, LF runners have different reactions to the standard test. There is also a different degree of expression of the reaction to the standard test in runners of different specializations, which is clearly visible from the following parameters: SDNN (382.12 and 5.35), %LF (45.04 and 0.69), LF/HF (281.63 and 83.58). Only in such indicators as HR, pNN50, SI the results are very close.

However, to determine the difference in the percentage change in activity of each HRV index with the transition from rest to orthostatic state, the p-value was measured. In this section, due to the great importance of the change in each factor, the percentage change was considered. P-values are mentioned for each index (table 4).

Table 4. *The significance levels of intergroup differences in the percentage change in the activity of each heart rate variability (HRV) parameter during the transition from a resting state to an orthostatic position (as assessed using the Mann-Whitney criterion)*

Indicator	HR	SDNN	RMSSD	TP	PNN50	SI	% HF	% LF	% VLF	LF/ HF	LF	HF	VLF
P-values	0.33	0.13	0.13	0.26	0.43	0.13	0.065	0.042*	0.11	0.18	0.21	0.16	0.17

Legend: (*) - the validity of the differences at a p-value < 0.05.

The only factor that should be considered as a difference between ultramarathon runners and sprinters is %LF. LF power is dependent on the activity of the sympathetic and parasympathetic nervous systems. In the context of HRV analysis, the observation of a significant difference in LF with other parameters remaining relatively constant requires a closer look at the underlying mechanisms. This pattern suggests that the sympathetic nervous system (SNS) may be the primary driver of the observed physiological changes. The significant decrease in LF HRV combined with minimal changes in other parameters may reflect a predominant increase in PNS activity. In the context of comparing HRV data between ultramarathon runners and sprinters, the observed significant decrease in LF HRV (41%) among ultramarathon runners during the transition from rest to standing compared to a smaller decrease (7.89%) among sprinters. ultramarathon runners can cause damage to the heart and muscles, and ultramarathon runners experience more inflammation than sprinters. This inflammation can be caused by muscle damage as they work for long periods of time.

Thus, we selected the HRV indicators that characterize the most typical mechanisms characteristic of the process of long-term adaptation of runners: HR, PNN50, SI, LF. In regression analysis, R refers to the correlation coefficient between the dependent variable (Y) and the predicted variable (x). In this study the questions of questionnaire are considered as X and HRV indices as Y. Multiple linear regression was used to examine the relationship between questionnaire results and each of the HRV indices and understand how important each factor is.

%LF is a factor that is an indicator of the sympathetic nervous system. A change in %LF at relative rest has a reliable correlation with the following survey results (table 5).

Table 5. *Correlation Data: %LF at Relative Rest and Survey Responses*

Survey Response	Lower %LF at Relative Rest	Higher %LF at Relative Rest
Alcohol consumption		-0.62
Chronic disease		-0.18
Discoloration of fingers or toes		-0.032
Drinking sports drinks	0.19	
Feeling good after a hard workout	0.84	
Feeling of energy and strength		-0.26
Feeling of improved physical fitness	0.69	
Getting older		-0.28
More sweating	0.65	
More water consumption	0.367	
Typical symptoms of anxiety		-0.24

The provided results suggest that increasing age, alcohol consumption, and smoking lead to an increase in %LF and a decrease in parasympathetic activity. Conversely, consuming more vegetables and water is associated with a decrease in %LF, which is generally considered favorable. In general, LF increases when transitioning from the supine position to orthostatic position. A pronounced increase in LF% may indicate excessive sympathetic activation, which could be detrimental and gradual LF increase upon standing in healthy individuals indicates a normal cardiovascular response to gravity.

The stress index (SI) tends to increase with age, reflecting a decline in parasympathetic nervous system activity and an increased susceptibility to stress. A change in SI at relative rest has a reliable correlation with the following survey results (table 6).

Table 6. *Correlation Data: Stress Index at Relative Rest and Survey Responses*

Survey Response	Lower Stress Index at Relative Rest	Higher Stress Index at Relative Rest
Being in competition phase		0.61
Being in recovery phase	-0.65	
Chronic diseases		0.66
Discoloration of fingers or toes		0.51
Drinking coffee and tea	-0.162	
Excessive sweating		0.307
Getting older		0.02
Male gender		1.09
More alcohol consumption	-0.34	
More training frequency	-0.335	
More vegetable consumption	-0.78	
More water consumption	-0.15	
Tendency to facial redness		0.05
Typical symptoms of anxiety		0.469

Index (SI) should increase with a change in position from supine to standing. This increase indicates normal sympathetic nervous system activity in response to postural changes and excessive SI increase could signify excessive stress or cardiovascular issues.

No or a reduced SI increase might indicate sympathetic nervous system weakness or other health problems. Therefore, it cannot be definitively stated whether a higher or lower changes in SI is better therefor the results of questionnaire cannot properly define the effective factors because sometimes too much increase means that autonomic nervous system does not work well and sometimes increase means better function of sympathovagal system. The results we obtained in this study indicate that SI depends on the period of the training process. The pre-competition period is characterized by higher SI values, and the recovery period is characterized by the lowest ones.

PNN50 quantifies parasympathetic nervous system function. A change in PNN50 at relative rest has a reliable correlation with the following survey results (table -7).

Table 7. *Correlation Data: PNN50 at Relative Rest and Survey Responses*

Survey Response	Lower PNN50 at Relative Rest	Higher PNN50 at Relative Rest
Alcohol consumption		1.169
Coffee or tea		0.64
Discoloration of fingers and toes	-0.81	
Excessive sweating	-0.27	
Feeling of fitness increase	-0.1	
More training frequency		0.45
More typical symptoms of anxiety	-0.45	
Protein consumption before training	-1.33	
Protein food after exercise		0.82
Sport drink		0.41
Vegetable consumption		1.4
Water consumption		0.28
Well-being feeling after hard exercise		0.26

Notably in this part is the positive effect of alcohol consumption. It should be considered that alcohol consumption can have complex effect on PNN50.

Low to moderate amounts of alcohol may have different effects than high quantities. Type of alcohol is also important (beer, wine, spritis, etc.)

DISCUSSION

HRV indicators reflect the state of adaptive capabilities of the runners' body well, which can be used to assess functional indicators and manage the training process. The state of long-term adaptation to training loads is characterized by high activity rates of the parasympathetic division of the ANS (HF, PNN50) and high heart rate variability (SDNN, TP) and low stress index (SI) values.

These findings are consistent with our previous scientific research in this field (Dakuko et al., 2020; Kalsina & Nalobina, 2018; Nalobina, 2020). Other researchers have established that high values of indicators associated with parasympathetic activity, such as HF and pNN50, are correlated with better adaptation to physical exertion and more effective recovery in athletes. For instance, a study published in the *European Journal of Applied Physiology* demonstrated that training based on daily heart rate variability (HRV) measurements contributes to improved endurance and aerobic performance in professional runners. Furthermore, studies indicate that a decrease in HRV may be associated with increased sympathetic activity and insufficient recovery, potentially leading to overtraining conditions. For example, research published in *Sports Medicine - Open* found that reduced HRV is linked to higher training intensity and inadequate recovery in endurance athletes (Carrasco-Poyatos et al., 2022; Nuuttila et al., 2024).

At the same time, specific HRV indicators have been identified that can be used as specific markers considering the specifics of the sports discipline: short-distance runners or ultramarathon runners. For ultramarathon runners, the most significant indicator is HR, which was significantly ($p<0.05$) lower than that of short-distance runners. And for short-distance runners, the most important is the response of the cardiovascular system to the orthostatic test, which consists in an increase in %LF- frequency.

Non-training factors such as nutrition, health, subjective feelings of load tolerance, age, gender, etc., affect HRV values. This must be considered when training runners. We have received reliable information about which additional factors help athletes achieve high sports results, and which hinder this. The most important things in the diet of athletes are: sufficient amount of vegetables, sufficient amount of protein in food after training, proper drinking regime. From the health side, the absence of diseases, the absence of symptoms of cold fingers are important.

Of the subjective symptoms, the well-being after training, the feeling of increased physical strength and performance are important.

It may be useful for nutritionists and coaches of ultra runners to include high-protein foods in their training plans to help prevent heart problems. On the other hand, another important point is that strenuous training and long-distance running may be harmful to these people. The survey found that even when athletes feel strong and energetic, it is possible that their autonomic nervous system is not functioning properly. Having more anxiety symptoms does not necessarily mean that the autonomic nervous system is not functioning properly, but it does not rule out the possibility of problems in this system. It is possible that people's different physical reactions to anxiety are due to individual differences. In general, by consuming more water and vegetables, athletes can improve their overall health and well-being, which may help improve the function of their autonomic nervous system. Moreover, the effects of alcohol depend on various factors, as mentioned earlier, and it is impossible to predict its effects without having more accurate information about it. The exact effect of coffee or tea consumption on the nervous system remains unclear. Further research is needed. This study found that athletes who consumed a protein-rich meal after exercise tended to perform better, although more research is needed to confirm this. In addition, frequent training appears to have a very positive effect on the autonomic nervous system, and the model developed reported a positive effect on each factor. It is important to consider the athlete's age when prescribing a training program, as aging has a negative effect on cardiovascular factors. It may be better to focus on increasing the frequency of training rather than the duration of exercise to improve the health of the autonomic nervous system in these athletes.

CONCLUSION

Training process management based on HRV indices allows to objectively assess the adaptive capabilities of runners taking into account their sport specialization. Taking into account additional factors affecting the activity of different parts of the autonomic nervous system, such as nutrition, rest regime and age of the athlete, can help to optimize the training process for runners of different specializations. This study will be useful for both coaches and sports physicians.

Conflict of interest
The authors state no conflict of interest.

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