Original Article

Modeling of functional support of sports activities of biathletes of different qualifications

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ABSTRACT

Quantitative assessment of the functional support of sports activities, as a reflection of the systematic approach, allows to identify the features of the body of athletes, to plan the training process and possible deviations in the action of multiple exogenous and endogenous factors. In accordance with the methodology of artificial intelligence and machine learning, the most informative indicators were determined, which determine the success of sports activities. This made it possible to determine the peculiarities of the functioning of the cardiovascular system of elite biathletes, which provides and limits physical performance. As a result of the research, functional models of high-, medium- and low-skilled biathletes have been built that will improve the training process. **Keywords:** Physical working capacity; Artificial intelligence; Data mining; Machine learning; Biathlon.

Cite this article as:
Priymak, S., Krutsevich, T., Pangelova, N., Trachuk, S., Kravchenko, T., Stepanenko, V., & Ruban, V. (2020). Modeling of functional support of sports activities of biathletes of different qualifications. *Journal of Human Sport and Exercise*, *in press*. doi:https://doi.org/10.14198/jhse.2021.161.12

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E-mail: tmfv@ukr.net
Submitted for publication October 18, 2019
Accepted for publication January 13, 2020
Published *in press* January 29, 2020
JOURNAL OF HUMAN SPORT & EXERCISE ISSN 1988-5202

doi:10.14198/jhse.2021.161.12

INTRODUCTION

The functions of artificial intelligence are the development and implementation of computer simulation methods for the implementation of diverse tasks in various fields of science and technology. The use of sophisticated analysis tools reveals features that cannot be identified in descriptive statistical methods of data interpretation. Artificial intelligence techniques have recently been used in the management of complex cybernetic systems associated with the training of physical education and sports professionals (Priymak, S. G., Zavorotynskyi, A. V., 2018). In particular, sophisticated machine learning methods and data mining in physical culture and sports analytics have a place to justify decision-making on diverse aspects of sports. (Wicker P., Breuer C., 2010).

The retrospective analysis of the investigated question points to a multifaceted approach to modelling the morpho functional state of the body of athletes of different sports. In particular, some papers address the following issues: modelling of heart rate parameters for assessing the performance of runners and cyclists in training sessions (Dimitri de Smet, Marc Francaux, Julien M. Hendrickx and Michel Verleysen, 2016); modelling of physiological processes that affect physical performance in training of track and field athletes and cyclists (Alonso F., Caraça-Valente J. P., González A. L., Montes C., 2002 D'Ascenzi F., Alvino F., Natali B. M., 2013); development of methods of quantitative assessment of pedagogical impact during exercise (Trachuk S. 2011; Churchill T. 2014; Krutsevich, T., Pangelova, N., Trachuk, S. 2019); optimization of cycling speed determined by the energy regime of training and competitive loads (Aftalion A., Bonnans J. F., 2014); development of methods of quantitative assessment of pedagogical impact in the form of physical activity (Churchill T. 2014); energy supply to the activity of volleyball athletes (Nosko, M. O., Danilov, O. O., Maslov, V. M., 2011; Pryimak Serhij, 2017); ranking of basketball players according to physical fitness using multicriteria decision-making methods (MCDM) (Dadelo, S., Turskis, Z., Zavadskas, EK, Dadeliene, R. (2014); model-target characteristics of physical fitness in the system of sports and health programming activities with teens (Krutsevich, T., et al., 2019; Priymak, S., 2003).

At the same time, as the authors rightly point out, in sports games there is a complexity of prognosis of the game role according to the morpho functional capabilities of the athlete. In the literature there is almost no data on the conditionality of the morpho functional state of the systems of the organism of biathletes, respectively, the success of professional activity, which determines the relevance of scientific search. These provisions provide for the creation of model characteristics of the morpho functional state of biathlon systems for the prediction of qualification.

Hypothesis

It is assumed that models of morpho functional state of systems of the body of biathletes will allow to predict success of sports activity.

Purpose of study

*P*redicting the success of biathlon athletes' sports activities according to the peculiarities of the morpho functional state of body systems.

MATERIAL AND METHODS

Participants

The study involved athletes (women n = 17 ages 19–21) attending the biathlon sports and pedagogical improvement group. All female students are members of the National teams of Ukraine and Chernihiv region.

Organization of research
The research was conducted on the basis of the laboratory of psychophysiology of muscular activity of the Taras Shevchenko National University "Chernihiv College".

Research methods
The features of vegetative heart rate regulation were studied on the basis of the analysis of HRV indices of 5-7-minute electrocardiogram fragments using the Polar RS800 heart rate monitor (Polar Electro, Finland). Data analysis was performed using Kubios HRV 2.1 software (Kuopio, Finland). The artefacts and extrasystoles were removed from the electronic record by manual method. The following HRV indicators were analysed: RRNN, SDNN, RMSSD, pNN50 (Mikhailov V. M., 2000; Priymak Serhij, 2017). Among the indicators of spectral (frequency) analysis of heart rate variability (HRV) and cardiointervalography (CIG) were evaluated: total power spectrum (Total Power, TP), high frequency power (High Frequency, HF), low frequency (Low Frequency, LF) and ultra-low frequency (Very Low Frequency, VLF) components, the contribution of these components to the total power of the spectrum, as well as the ratio of LF to HF waves, calculated in accordance with absolute (ms2) units (LF HF^{-1}, units). Registration of the studied parameters was carried out in accordance with the recommendations of a joint meeting of the European Society of Cardiologists and the North American Society of Electrical Stimulation and Electrophysiology on common standards for the analysis of heart rate variability. Peripheral oxygen saturation (SpO_2,%) was determined using a photoplethysmographic technique using an Ohmeda Biox 3700e Puls-Oximeter (Ohmeda, USA) heart rate monitor integrated with a computer for continuous pulse wave monitoring with the ability to record, analyse and interpret results (Galkin M., Zmievskoy G., Laryushin A., Novikov V., 2008; Priymak S., 2018). Pulse wave parameters were recorded using a photoplethysmographic sensor on the distal phalanx of the 3 fingers of the left hand at rest (basal conditions) in a sitting position synchronous with the heart rate parameters. The following parameters were recorded: pulse wave duration, s (T_{PH}); duration of the dicrotic phase of the pulse wave, s (T_{DF}); the duration of the anacrotic phase of the pulse wave, s (T_{AF}); duration of the filling phase, s (T_{FN}); duration of the systolic phase of the cardiac cycle, s (Tsist.) duration of the diastolic phase of the cardiac cycle, s (Tdiast.); pulse wave reflection time, s (TV); pulse wave amplitude, mind. units (APH); dichroic wave amplitude, mind. units (ADX); incisor amplitude, mind. units (AI); stiffness index, $m \cdot s^{-1}$ (IL). During the recording of the above indicators, the subject was limited to the influence of audio-visual stimuli using a light-coloured black fabric mask and sound-absorbing headphones that did not create discomfort. The PWC_{170} sample was run on a VE-02 bicycle ergometer using 2 loads of 5 min duration with a 3 min rest period between loads in accordance with its performance standards (Belotserkovskiy Z., 2005). Assessment of the level of physical performance was carried out on the basis of calculation of absolute (kGm $\cdot min^{-1}$) and relative (kGm min^{-1} kg^{-1}) values of PWC_{170}, in accordance with the body weight of the subject. At rest, after the 1st and 2nd loads, in the restitution phases (3 minutes after the 1st and 7 minutes after the 2nd loads) the above indicators were determined. In order to identify the maximum functionality in women, the phases of the ovarian-menstrual cycle (OMC) were taken into account, the frequency of which significantly influences the indicators in the state of relative rest and the reactivity of the organism's systems to the dosed physical activities. Biathletes with unstable OMCs were excluded from testing. Testing was conducted in the middle of the designated phase, which determines the maximum manifestation of the functional and physical abilities of biathletes. Athletes were familiarized with the content of the tests and agreed to conduct them. In conducting comprehensive surveys, Ukraine's legislation on health care, the 2013 Helsinki Declaration, the European Society Directive 86/609 on the participation of people in biomedical research were adhered to.

Statistical analysis
One of the machine learning methods, the decision tree, was used to classify biathletes by qualification. To this end, Python software (v. 3.6.3 Anaconda custom) with the Skelit machine learning module (scikit-learn,

v. 0.19.1) was used using the decentrication method (Müller A., Guido S., 2017). With this methodological approach, a solution tree was built, indicators were found that affect the differentiation of athletes by qualification.

RESULTS

To achieve this goal, the team of athletes was divided into 2 datasets - training and test, which allowed to develop a model of morpho-functional state of the organism, which details individual indicators according to the qualification and dominance of the mode of energy supply of the activity. In particular, on the training set the correctness of classification was 100.0%, the test set - 61.1%, which in our opinion is optimal and allows us to explain the hierarchy and the range of fluctuations of features (Figure 1). Increasing or decreasing the depth of the decision tree leads to a deterioration of the general property of the tree, in particular, the correct classification of the group of athletes on the test dataset (Figure 1). As a result of the analysis, the two most influential features were identified that differentiate the biathlete by qualification with a high probability - highly qualified, medium skilled, low skilled and dominated by energy supply in the implementation of the activity. A subgroup of highly qualified biathletes was formed of athletes with sports titles Honoured Master of Sports of Ukraine, Master of Sport of Ukraine of international class, Master of Sport of Ukraine; a subgroup of middle-qualified - sports ranks of the candidate for master of sports of Ukraine and the first sports category; a subgroup of the low-skilled - the second and third sports categories.

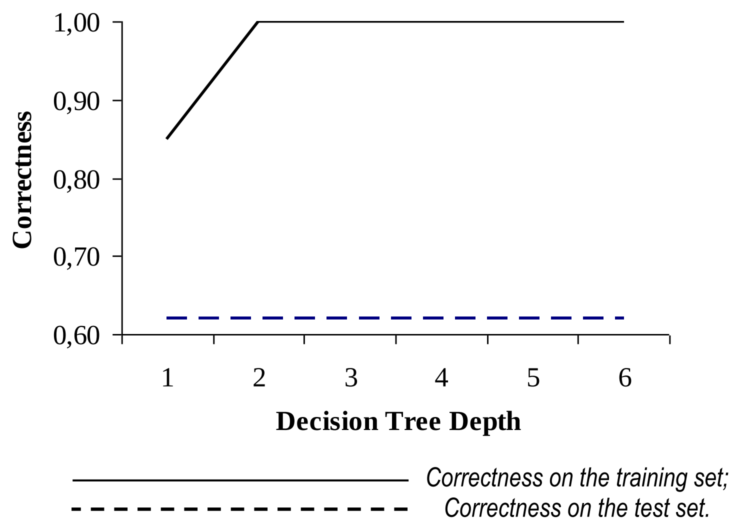
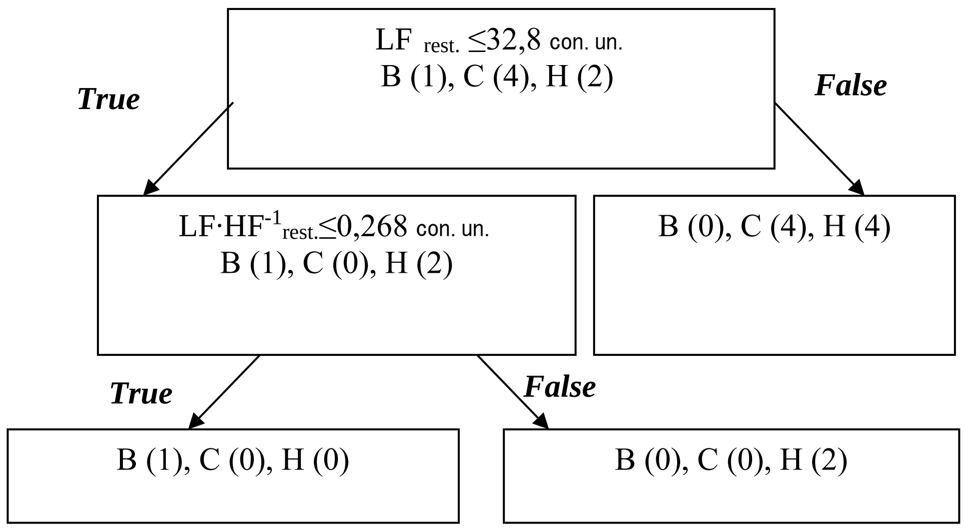


Figure 1. The correctness of the model on the training and test datasets of the morpho functional state of the systems of the biathlon.

Biathletes are separated by the power of the low frequency component of the HRV spectrum (Low Frequency, con.un.) and the ratio of the values of the low frequency and high frequency components of the rhythm (LF HF^{-1}, units) in the restitution phase after performing the PWCl70 sample (Figure 2). The most informative feature to determine the features of the morpho functional state of biathlon systems is the relative low power frequency of the HRV spectrum (Low Frequencyrest. Nu) after performing the PWC170 test, which separates two subgroups of 20 athletes with ranges of fluctuations5 within the ranges of fluctuations 20.95 -32.76 con.un. (3 persons) and 51.06-70.34 con.un. (4 persons) (Figure 2).

The first subgroup, characterized by a lower relative power of the LF component of the HRV spectrum, combines low- and intermediate-skill athletes in which the trait ranges are in the range of 20.95-28.52 con.un. and 28.62-32.76 con.un. in accordance. The second subgroup, characterized by higher values of this trait, (51.06-70.34 con.un.), Is formed of highly qualified athletes.



Note: H - highly skilled; I - intermediate; L - low-skilled; LFrest - the power of the low frequency component of HRV (Low Frequency, con.un.) In the restitution phase after performing the PWC_{170} test; LF HF^{-1}rest - the ratio of low-frequency and high-frequency components of HRV (LF HF^{-1}, con.un.) in the restitution phase after performing the PWC_{170} sample.

Figure 2. Biathlete Differentiation Solution Tree by Qualification.

Since individual components of the spectral analysis of heart rate variability are characterized by the dominant frequency range, power and ratio of HRV components, subgroups are distinguished according to a differentiating characteristic that allows to characterize the energy supply of sports activities of biathletes of different qualifications.

In the basal conditions of highly qualified biathletes, a relatively high total power of the spectrum (Total Power = 8449.47 ± 351.11 ms^2) is distinguished, which is formed by the dominance of the power of the low- (VLF = 3524.60 ± 399.32 ms^2; 40.80 ± 3.77%) and high-wave (HF = 3017.41 ± 529.94 ms^2; 31.87 ± 2.30%) component and low-wave recession (LF = 1907.45 ± 141.45 ms^2; 27.34 ± 2.55 %), which causes the balance of the activity balance of parasympathetic / sympathetic influences in the regulation of heart rhythm (LF · HF^{-1} = .99 ± .06 ppm) (Table 1). In them, with slight differences in the duration of the pulse wave (.68-6.57%), there is a prolonged systolic (8.02-14.57%) phase due to the shortening of the diastolic (15.03-16.96%) on the background of its smaller amplitude values (4.55-9.05%), dicrots (37.92-40,23%), incisors (43.60-46.91%). Such a pattern indicates the high elasticity of the vascular wall in highly qualified biathletes, as indicated by the stiffness index, which is lower by 27.23-33,66% compared to athletes of other qualifications (Table 2).

In the restitution phase after the PWC170 trial, all biathletes have a significant under-restoration of the HRV spectral capacities (VLF, ms^2; LF, ms^2; HF, ms^2; TP, ms^2) while maintaining the dominance of the sympathetic or parasympathetic level of regulation depending on qualifications. In the highly skilled there is a shift in the ratio of power to the low- (47.34 ± 6.78%) and high-wave (37.63 ± 3.39%) components due to the recession of the low-wave (15.03 ± 2.92%) (Table. 1).

Table 1. Low Frequencyrest (con.un.) Restriction of the Power of the Low-Wave Component in the Restitution Phase after Performing the PWC_{170} Sample to Individual Biathlon HRV Indicators.

Indicators	Definition status	Low $Frequency_{rest.}$			Δ. %		
		≤32.8 con.un.		>32.8 con.un.	H-C Ls-Ms	H-B Ls-Hs	C-B Ms-Hs
		Low skilled	Medium skilled	Highly skilled			
		20.95-28.52	28.62-32.76	51.06-70.34			
		24.24±2.85	30.68±2.08	54.68±8.48	26.57	125.58	78.23
VLF . $m{\cdot}s^2$	Basal	3514.24±616.21	1135.07±386.85	3524.60±399.32	-67.70	.29	210.52
	Restitution	33.41±7.26	456.47±21.21	82.98±6.88	1266.27	148.37	-81.82
LF. $m{\cdot}s^2$	Basal	2287.11±245.56	1602.15±102.51	1907.45±141.45	-29.95	-16.60	19.06
	Restitution	38.76±12.05	450.80±22.64	371.00±28.42	1063.05	857.17	-17.70
HF. $m{\cdot}s^2$	Basal	4258.26±687.78	2060.27±350.57	3017.41±529.94	-51.62	-29.14	46.46
	Restitution	123.02±19.12	1180.02±161.20	310.62±26.62	859.21	152.50	-73.68
Total Power. $m{\cdot}s^2$	Basal	10059.62±475.96	4797.49±639.93	8449.47±351.11	-52.31	-16.01	76.12
	Restitution	195.19±58.43	2087.29±162.64	764.60±91.64	969.36	291.72	-63.37
VLF. %	Basal	37.63±1.25	23.67±.03	40.80±3.77	-37.10	8.42	72.37
	Restitution	21.50±1.20	22.76±1.41	15.03±2.92	5.86	-30.09	-33.96
LF. %	Basal	25.66±2.49	36.99±2.51	27.34±2.55	44.15	6.55	-26.09
	Restitution	18.91±1.76	20.97±3.07	47.34±6.78	10.89	150.34	125.75
HF. %	Basal	36.71±1.24	39.34±2.53	31.87±2.30	7.16	-13.18	-18.99
	Restitution	59.59±2.64	56.27±2.34	37.63±3.39	-5.57	-36.85	-33.13
$LF{\cdot}HF^{-1}$. con.un.	Basal	.87±.01	1.09±.06	.99±.06	25.29	13.79	-9.17
	Restitution	.32±.05	.37±.02	1.40±.08	15.63	337.50	278.38
PWC_{170} ·weight. kg^{-1}. $\cdot min^{-1}\cdot kg^{-1}$		17.19±1.34	20.50±1.36	21.39±1.75	19.26	24.43	4.34

In the medium- and low-skilled there are similar differences that indicate the dominance of parasympathetic influences on HRV regulation. In the restitution phase, they are characterized by the dominance of high-wave (HF = 56.27-59.59%) components with recession over- and low (VLF = 21.50-22.76%; LF = 18.91-20.97%), which causes a sharp shift in the balance toward the parasympathetic effects (LF HF^{-1} = .32-.37 ppm). Highly qualified biathletes have a significantly higher relative level of physical performance (4,34-24,43%) (Table 1).

Since the dominance of the low-wave component (LF, %), which is characterized as stressful and is of particular importance in the mobilization of the body in the implementation of speed-force exercises that take place in sprinting disciplines, it can be argued that for the body of highly qualified biathletes is an energy-intensive mode. R. Simões and co-authors note that the positive dynamics of LF in the exercise sample correlates with the level of lactate and indicates the mobilization of glycolytic opportunities that occur in high-speed sports (Simões, R. P., et al., 2013).

Table 2. Power correspondence of the low-frequency component of HRV in basal conditions (Low Frequency basal, con.un.) to the amplitude-time parameters of the pulse wave of biathletes, depending on qualification.

Indicators	$\text{Low Frequency}_{basal}$			Δ. %		
	≤32.8 con.un.		>32.8 con.un.	H-C Ls-Ms	H-B Ls-Hs	C-B Ms-Hs
	Low skilled	Medium skilled	Highly skilled			
	20.95-28.52	28.62-32.76	51.06-70.34			
	24.24±2.85	30.68±2.08	54.68±8.48	26.57	125.58	78.23
T_{PH}. s	.877±.091	.883±.043	.825±.091	.68	-5.93	-6.57
T_{DF}. s	.627±.011	.623±.063	.548±.017	-.64	-12.60	-12.04
T_{AF}. s	.250±.051	.260±.020	.278±.026	4.00	11.20	6.92
T_{FN}. s	.140±.013	.141±.013	.125±.004	.71	-10.71	-11.35
$T_{sist.}$. s	.305±.057	.324±.044	.350±.039	6.23	14.75	8.02
$T_{diast.}$. s	.572±.017	.559±.087	.475±.030	-2.27	-16.96	-15.03
T_V. s	.165±.052	.183±.057	.225±.040	10.91	36.36	22.95
A_{PH}. con.un.	23.789±.637	24.967±.633	22.707±.715	4.95	-4.55	-9.05
A_{DX}. con.un.	15.356±1.348	15.950±.550	9.533±.853	3.87	-37.92	-40.23
A_I. con.un.	15.544±1.030	14.633±.033	8.253±.032	-5.86	-46.91	-43.60
I_L. $m \cdot s^{-1}$	9.40±1.48	10.31±.34	6.84±.43	9.68	-27.23	-33.66

Table 3. Compliance of the vasosympathetic balance factor in the restitution phase ($LF \cdot HF^{-1}$rest., con.un.) after performing the PWC_{170} sample with individual HRF biathletes.

Indicators	Definition status	$LF \cdot HF^{-1}_{rest.}$		Δ. %
		>.268 con.un.	≤.268 con.un.	
		Medium skilled	Low skilled	
		.244-.265	.303-.487	
		.254±.011	.396±.062	55.91
$LF \cdot HF^{-1}_{rest.}$. con.un.		.43±.01	1.31±.14	204.65
Total Power. ms^2	Basal	11680.49±543.07	5470.95±950.86	-53.16
	Restitution	1924.65±21.61	931.35±79.05	-51.61
VLF. %	Basal	29.37±2.72	33.83±1.78	15.19
	Restitution	28.25±1.92	17.84±1.09	-36.85
LF. %	Basal	21.20±1.28	36.18±1.54	70.66
	Restitution	14.58±1.69	23.17±1.92	58.92
HF. %	Basal	49.43±.45	29.98±1.54	-39.35
	Restitution	57.17±2.23	58.99±2.24	3.18
IV. con.un.	Basal	11.82±.380	42.67±1.826	260.88
	Restitution	233.32±51.29	281.52±18.23	20.66
$PWC_{170} \cdot$ body weight. Kg^{-1}. кGм·$min^{-1} \cdot kg^{-1}$		20.12±1.75	17.45±1.51	-13.27

The second level of the decision tree distinguishes the group of middle- and low-skill biathletes by the ratio of low-frequency and high-frequency components of the rhythm ($LF \cdot HF^{-1}$, con.un.) in the restitution phase after performing the PWC_{170} sample (Figure 2, Table 3). The first subgroup, characterized by lower values of the integral index (.254 ± .011 con.un.), unites medium-skill biathletes in which the range of the characteristic varies within .244-.265 con.un. (2 of 3). In the second subgroup, with low values of the trait (.396 ± .062 con.un.), there are low-skilled athletes with a range of fluctuations within .303-.487 con.un. (3 of 4) (Table 3).

A characteristic feature of a mid-level biathlete body is the dominance of the high-wave component of HRV in the basal conditions and in the restitution phase (49.43 ± .45% and 57.17 ± 4.23%, respectively) with a relatively high contribution to the total power of the spectrum (Total Power, MS2), which differs from the low-skilled by 53.16-51.61% depending on the status of determination (Table 3).

They are dominated by parasympathetic regulation of HRV in basal conditions, in contrast to low-skilled biathletes who have a tendency to sympathetic. This assumption confirms the voltage index of regulatory systems (IV, dm), which in basal conditions in the middle skilled indicates a tendency to vagotonia (11.82 ± .380), and in the restitution phase is less significant (by 20,66%). than in low-skill athletes (Table 3).

The low-skilled are characterized by the equilibrium contribution of all components of the HRV regulation spectrum (VLF / LF / HF = 33.83% / 36.18% / 29.98%) under basal conditions with a relatively lower total power (Total Power, ms^2) mid-level biathletes (by 53.16%) (Table 3). In the restitution phase, the tendency for smaller values of the total HRV spectral power persists with the offset of the balance toward the high-wave component of the spectrum (HF, %) (Table 3).

If in the restitution phase the ratio of low to high-wave constituents ($LF \cdot HF^{-1}$, con.un.) indicates the dominance of parasympathetic regulation, then in basal conditions a sharp shift towards sympathicotonia is observed. This difference in functional support for the implementation of the activities is related to the nature of training and, especially, competitive regimes of energy supply in biathlon, which differ from the same lengths of men, running time and intensity in men.

Unlike men, women have a shorter distance of 15-20 %, which leads to a greater speed of movement, determining a greater proportion of the anaerobic component when performing competitive exercises. This is consistent with the assumption that the sympathetic component of HRV regulation dominates in highly qualified biathletes who have a relatively higher level of physical performance at the expense of low- and low-wave components at high elasticity of the vascular wall.

DISCUSSION

Athlete training is a multi-purpose, specially organized process. The training process includes the development and improvement of special physical and mental qualities; mastering certain motor skills characteristic of this type of sports activity. All this must be taken into account when planning and conducting training in higher sports teams (Priymak, S., et al., 2017; Priymak S., et al., 2019).

Modelling is also used in physical education, it helps to adjust the proper standards for a particular student, selecting various means of influence for the development of power, speed and strength qualities, general endurance, using those types of exercises that interest schoolchildren. Target models of the physical condition of schoolchildren have a quantitative characteristic, which is expressed by indicators of physical performance, individual indicators of physical fitness, which are directly related to the functional characteristics of somatic health, which determine the energy potential of a biosystem (Trachuk, 2011; Krutsevich, Pangelova, Trachuk, 2019).

For a specific type of sporting activity, such as biathlon, there is a specific morpho functional state of the body's systems that determines the success of a professional program. The morpho functional state of the organism's systems is characterized by the correspondence of the peculiarities of the structure and functionality in the performance of metered physical activities.

These criteria make it possible to reduce the expenditure of elite athletes training to achieve a high level of professional success. This is of particular importance in the type of skiing - biathlon. It combines a high level of mastery of physical abilities and skills with static dynamic function. This function is realized when moving on distance, firing on fire lines, orientation in space. The peculiarities of the morpho functional state are one of the main indicators that significantly influence the success in competitive activity. Therefore, in the vast majority of athletes who achieve victory have a high level of morpho functional capabilities of the body in a particular sport.

At the same time, the morpho functional provision of the performance of metered physical loads of athletes can determine their capabilities and prospects in the initial stages of long-term training (Priymak, S., et al., 2017; Priymak S., et al., 2019). Thus, athletes of high-speed sports (martial arts, sports) dominate the central (cerebral), and cyclic athletes - autonomous regulation of heart rate. The difference in rhythm regulation is more pronounced in dynamic exercises compared to static exercises (Gavrilova, E., 2015). Aerobic-dominated athletes have the highest rates of heart rate variability. They have higher values of SDNN, RMSSD, pNN50 and HF, lower values of the LF coefficient HF^{-1} (Sztajzel, J., et al., 2008). The lowest sympathetic activity was found in triathlon athletes (Bersenev, E., 2008).

Studying the individual portrayal of HRV athletes, taking into account the orientation of the training process, in preparation for the competition can give the trainer valuable information and help predict the performance of athletes. According to D. J. Plews and his co-authors, even the dynamics of rhythm variability within one week gives fairly reliable information about the course of the body's adaptation to the training process. (Plews, D. J., et al., 2013).

CONCLUSIONS

In the basal conditions of highly skilled biathletes, a relatively high total spectrum power is distinguished, which is formed by the dominance of the power of the low- and high-wave components and the low-wave recession, which causes the balance of activity of parasympathetic / sympathetic influences in the regulation of rhythm. Low-skilled biathletes are characterized by the equilibrium contribution of all components of the HRV regulation spectrum in basal conditions with relatively lower overall power compared to intermediate-level biathletes.

In the restitution phase after the PWC_{170} trial, all biathletes have a significant under-restoration of the HRV spectral capacities while maintaining dominance of the sympathetic or parasympathetic control, depending on qualifications.

A characteristic feature of an intermediate-level biathlete body is the dominance of the high-wave component of HRV both in the basal conditions and in the restitution phase with a relatively high contribution to the overall power of the spectrum. Their reticulatory system is characterized by a longer pulse wavelength due to prolonged diastole and shortened systole with greater amplitudes of diprotherapy and incisor with a slight difference in the amplitude of the pulse wave, which causes a relatively high blood flow velocity.

AUTHOR CONTRIBUTIONS

Conceptualization, SP, TK, NP; Methodology, SP, TK, NP; Data collection, SP, VR; Statistical analysis, SP, ST, KT; Writing-Original Draft Preparation, ST, TK, VS VR; Writing-Review & Editing, ST, TK, VS VR. All authors were involved in manuscript development.

SUPPORTING AGENCIES

No funding agencies were reported by the authors.

DISCLOSURE STATEMENT

The authors state that there are no conflicts of interest.

REFERENCES

About Approval of Procedure for Conducting Clinical Trials of Medicinal Products and Expert Evaluation of Materials Pertinent to Clinical Trials and Model Regulations of the Ethics Committees: Ministry of Health of Ukraine; Order dated September 23, 2009, №690 [Electronic resource] Access mode: http://zakon3.rada.gov.ua/laws/show/z1010-09/paran16

Aftalion, A.; Bonnans, J.F. (2014). Optimization of running strategies based on anaerobic energy and variations of velocity. SIAM Journal of Applied Mathematics, 74-5, 1615-1636. https://doi.org/10.1137/130932697

Alonso, F., Caraça-Valente, J. P., González, A. L., Montes, C. (2002) Combining expert knowledge and data mining in a medical diagnosis domain. Expert Systems with Applications, 23 (4): 367–375. https://doi.org/10.1016/s0957-4174(02)00072-6

Belotserkovskiy, Z. B. (2005) Ergometric and cardiological criteria of physical capacity of sportsmen. Moskva, Sovetskiy sport, 312 s.

Bersenev, E. Y. (2008) Sports specialization and features of heart rate vegetative regulation. Heart rate variability: theoretical aspects and practical application. Abstracts of All-Rus. symp. P. 42-45.

Churchill, T. (2014) Modelling athletic training and performance: a hybrid artificial neural network ensemble approach [PhD Thesis], University of Canberra, 238.

D'Ascenzi, F., Alvino, F., Natali, B.M., Cameli, M., Palmitesta, P., Boschetti, G.,Bonifazi, M. & Mondillo, S. (2014). Precompetitive assessment of heart rate variability in elite female athletes during play offs. Clinical physiology and functional imaging, 34 (3), 230-6. https://doi.org/10.1111/cpf.12088

Dimitri de Smet, Marc Francaux, Julien M. Hendrickx and Michel Verleysen (September 2016). Heart rate modelling as a potential physical fitness assessment for runners and cyclists. Proceedings of the Machine Learning and Data Mining for Sports Analytics Workshop at ECML/PPKD. Riva del Garda, Italy.

EEC (1986). Council Directive 86/609/EEC of 24 November 1986 on the approximation of laws, regulations and administrative provisions of the Member States regarding the protection of animals used for experimental and other scientific purposes. Official Journal of the European Communities, L358, 1-29.

Galkin, M. Zmievskoy, G., Laryushin, A., Novikov, V. (2008) The heart conditions diagnosis based on the analysis of photoplethysmogram using dual plethysmograph. Photonics, V3, p. 30-35.

Gavrilova, E. A. (2015) Sport, stress, variability: monograph. Moskva, Publishing House «Sport», 168 p.

Krutsevich, T., Pangelova, N., Trachuk, S. (2019) Control of physical preparedness of schoolchildren using index. Journal of Physical Education and Sport, 2019, Vol.19 (issue 2), pp. 1145 – 1152. https://doi.org/10.7752/jpes.2019.02166

Krutsevich, T., Pangelova, N., Trachuk, S. (2019) Model-target characteristics of physical fitness in the system of programming sports and recreational activities with adolescents. Journal of Physical Education and Sport® (JPES), Vol 19 (Supplement issue 1), 242-248. https://doi.org/10.7752/jpes.2019.s1036

Mikhailov, V. M. (2000). Heart rate variability: practical experience of usage that method. Ivanovo, Ivanovo State Medical Academy, 290 p.
Müller, A., Guido, S. (2017). Introduction to Machine Learning with Python: A Guide for Data Scientists. O'Reilly, 392 p.
Nosko, M. O., Danilov, O. O., Maslov, V. M. (2011). Features of conducting a training process during classes with students in sports improvement groups: [sports games]. Physical education and sports in higher educational establishments under organization of credit-module technology. Kiev, 115-134.
Plews, D. J., Laursen, P. B., Stanley, J., Kilding, A. E., Buchheit, M. Training adaptation and heart rate variability in elite endurance athletes: opening the door to effective monitoring, Sports Med. 2013, Vol. № 9, P. 773-781. https://doi.org/10.1007/s40279-013-0071-8
Priymak Serhij, Kolomiets Nataliia, Goletc Vitaliy. Modeling of the morphofunctional state of the biathletes body. Journal of Physical Education and Sport® (JPES), Vol.19 (issue 2), Art 173, pp. 1193-1199, 2019. https://doi.org/10.7752/jpes.2019.02173
Priymak, S. (2003) Simulation of physical training parameters of the adolescents in the process of physical training [PhD Thesis], Lviv : LDUFK, 24.
Priymak, S. G. (2018). Sports and pedagogical improvement of students: morphofunctional conditionality of activity. Chernigiv, AT PVK Desna, p. 292.
Priymak, S. G., Terentieva, N. O. (2017). Somatologic characteristics of biathlon students' body constitution in predicting of their successfulness. Pedagogics, psychology, medical-biological problems of physical training and sports; 21(4): 192-199. https://doi.org/10.15561/18189172.2017.0408
Priymak, S. G., Zavorotynskyi, A. V. (2018). Classification tree and their application for classification of students of various groups of sports and pedagogical improvement. Scientific Herald of Kherson State University, Series Pedagogical Sciences, Kherson, Helvetica, LXXXII, V 3, P. 230-233.
Pryimak Serhij (2017). Energy supply of game activity of the students specializing in volleyball. Physical activity, health and sport, №4 (30). P. 19-31.
Simões, R. P., Castello-Simões, V., Mendes, R. G., Archiza, B., Santos, D. A., Machado, H. G., Bonjorno, Jr. J. C., Oliveira, C. R., Reis, M. S., Catai, A. M., Arena, R., Borghi-Silva, A. (2013) Lactate and Heart Rate Variability Threshold during Resistance Exercise in the Young and Elderly. International Journal of Sports Medicine, 34(11), 991-996. https://doi.org/10.1055/s-0033-1337946
Sztajzel, J., Jung, M., Sievert, K. (2008). Cardiac autonomic profile in different sports disciplines during all-day activity. Sports Med. Physiol. Fitness. Vol. 48, №4, P. 495-501.
Task Force of the European Society of Cardiology and the North American Society of Pacing and Electrophysiology (1996). Heart rate variability. Standarts of Measurement. Physiological interpretation and clinical use. Circulation, V.93, P. 1043–1065. https://doi.org/10.1161/01.cir.93.5.1043
Trachuk, S. (2011) Modelyuvannya rezhymiv ruxovoyi aktyvnosti molodshyx shkolyariv u procesi fizychnoho vyxovannya [Modeling of the motor activity regimes of junior schoolchildren in the process of physical education]. Extended abstract of Doctor's thesis. – Kyiv : NUPES [in Ukrainian].
World Medical Association Declaration of Helsinki (2013). Ethical Principles for Medical Research Involving Human Subjects. World Medical Association, JAMA; 310(20): 2191-2194. https://doi.org/10.1001/jama.2013.281053