Journal of Physical Education and Sport ® (JPES), Vol. 21 (issue 6), Art 473, pp. 3496 - 3503, December 2021
online ISSN: 2247 - 806X; p-ISSN: 2247 – 8051; ISSN - L = 2247 - 8051 © JPES

Original Article

Cardiac diagnostics of student-athletes by the HRV method

IVAN BOCHARIN[1], MAXIM GURYANOV[2], MIKHAIL KOLOKOLTSEV[3], ANTON VOROZHEIKIN[4], ANDREY GRYAZNYKH[5], ELENA ROMANOVA[6], YAROSLAV KISELIV[7]
[1,2,7] Department of physical culture and sport, Privolzhsky Research Medical University, Nizhny Novgorod, RUSSIA
[3]Department of Physical Culture, Irkutsk National Research Technical University, RUSSIA
[4] Department of Information Technologies, Kaliningrad Institute of Management, RUSSIA
[5]Humanities Institute of Northern Studies, Yugra State University, RUSSIA
[6] Department of Physical Education, Altai State University, Barnaul, RUSSIA

Published online: December 30, 2021
(Accepted for publication December 15, 2021)
DOI:10.7752/jpes.2021.06473

Abstract
In sports practice, the method of monitoring the heart rate variability (HRV) of athletes is used to control, correct and personalize the training process. However, scientific research on the cardio-assessment of the adaptive capabilities of the organism of student-athletes to increased psychophysical stress is not enough. Purpose of the study: to conduct a comprehensive HRV-testing to determine the level of vegetative balance and adaptive reserves of the organism of student-athletes. ***Materials & Methods***. The research project involved 55 students of the Volga Research Medical University in Nizhny Novgorod (Russia) at the age of 18-20 years. Of these, 23 people were engaged in fitness aerobics (fitness group) and 22 students were engaged in swimming (swimmers group). The training process took place 4 times a week for 2 hours. Testing of HRV indices was carried out at the beginning of the school day, in a state of physiological rest, after two months of systematic training. For registration and analysis of HRV parameters, we used a hardware sports testing system "Medical Soft" (version "MS FIT Pro", Russia). Registration of heart rate at rest (HBR) was carried out, the results of statistical and spectral indicators of the heart rate of athletes SDNN, RMSSD, pNN50 were analyzed, the total power of the spectrum (TP), the power of the spectrum in the region of low (LF), high (HF) and very low frequencies were determined. (VLF), the vegetative balance index (LF / HF) and the integral parameter of the stress index (SI) were calculated. The normality of the distribution of parameter values was assessed using the Shapiro-Wilk test. ***Result***. During the complex hardware testing of students involved in various sports, different levels of statistical and spectral values of heart rate variability were recorded in athletes of various specializations. Compared with the results of the examination of athletes in the fitness group, the group of swimmers had lower SDNN, RMSSD, pNN50 indices, a higher HBR level, their total spectrum power was reduced, the ratio of waves of different frequencies (LF, HF, VLF) was not in optimal range. The stress index was outside the upper limit of the physiological range. The results obtained allow us to assume that the students of the fitness group have a higher level of fitness and adaptive capabilities, in comparison with the representatives of the water sport. ***Conclusions.*** The use of the HRV technique allows a sports doctor and coach to determine the state of the vegetative balance and adaptive capabilities in the body of student-athletes, to promptly correct the training process program in order to prevent the development of serious complications from the cardiovascular system of trainees.
Key Words*:* **physical loads, training regime, sports testing system, Heart Rate Variability (HRV), adaptive reserves**

Introduction

Human sports activity associated with the training process or competitions is accompanied by the maximum mode of operation of various functional systems of the body (Malikov et al., 2021). As established by Vira et al. (2018), Kolumbet et al. (2021), an athlete's achievements depend both on the training process effectiveness and on the state of the physiological reserves of his body, in particular, on the work of the cardiovascular system. Insufficient activity of this system is one of the reasons for low results in sports competitions (Lisenchuk et al., 2019). It is the reserves of the cardiovascular system that make it possible to increase an athlete's physical performance with the help of adaptive and compensatory regulatory mechanisms (Guzii et al., 2021).

The athlete's body is characterized by the ability to perform economical functional work in a state of physiological rest, to significantly mobilize all functional systems during exercise and to fully recover (Dupuy & Dugué, 2018). Students-athletes can be attributed to the risk group: they have a high level of psycho-emotional tension and stress associated with a significant amount of educational material and intensive study of various disciplines (Deschodt-Arsac et. al., 2018) and additionally experience training and competitive loads

Corresponding Author: ELENA ROMANOVA, E-mail: romanovaev.2007@mail.ru

(Kudryavtsev, et. al., 2016). Therefore, this category of sports youth requires special monitoring of their body's functional systems and physical health state. The materials of the research by Nuuttila et al. (2017) indicate significant vegetative rearrangements in the athlete's body under the influence of physical exertion of different volume and intensity, which are performed according to the training process program.

In sports practice, methods of analyzing an athlete's vegetative status and heart rate variability state are widely used (Shlyk, 2016; Guzii et al., 2020; Christiani et al., 2021). Heart rate variability (HRV) is the variability of time intervals between heart systoles. It allows determining the state of load tolerance (short-term adaptation) or assess the reserve capabilities of the body (long-term adaptation). HRV is a marker of the autonomic nervous system activity and shows the level of balance between the sympathetic and parasympathetic nervous systems.

The method of heart rate variability analysis allows the coach to make a conclusion about the effectiveness or efficiency of the conducted training process program and the amount of physical activity (Adams et.al., 2018; Aparecida Maria Catai et.al., 2020). Thus, the study of the functions of the body using HRV method gives the coach and the sports doctor important information about the state of the regulatory systems and adaptation reserves of an athlete's organism. Besides, it allows to predict the success of his\her athletic performance.

Determination and analysis of the parameters of regulatory mechanisms are at the heart of pre-nosological diagnostics, and also allows studying the functional status and adaptive reserves of the athlete's body, the speed of his\her reaction to various internal and external stimuli (Kogame et. al, 2020). Normally, the work of the heart is carried out with the help of autonomous regulation (Castellani, 2015). Some indicators of HRV are associated with the activation of various links of heart rate regulation RMSSD, IAB, IAPR and VLF, as reported by Guzii et. al. (2020). When the activity of the cardiovascular system is disrupted, central control mechanisms are activated to return the body to normal and balance it with the external environment, which is associated with the tension of all regulatory mechanisms (Perkins et. al., 2017; Hayano et. al., 2019).

Consequently, the greater the centralization of the control mechanism, the greater the physiological «price» of human adaptation to various factors and amounts of physical exertion (Sergio Jiménez Morgan, & José Arturo Molina Mora, 2017), There is a trend towards the emergence of a state of overstrain and overtraining, therefore timely monitoring of the work of the regulatory systems of the athlete's body is necessary. Despite the fact that the issue of the HRV method use in sports practice has been studied, the scientific literature does not fully present the materials devoted to the study of vegetative balance in student-athletes (Misigoj Durakovic et. al., 2016). Therefore, the study of HRV for the control, correction and personalization of the educational and training process in student-athletes seems relevant. We believe that hyperloading on a student-athlete's body can not only reduce athletic achievements, but also lead to a deterioration in health and be the cause of death. **Research aim** is to conduct comprehensive HRV testing to determine the level of vegetative balance and adaptive reserves of the student-athletes' body.

Materials & Methods

Pedagogical supervision was carried out at the end of 2020 at the Medical University of Nizhny Novgorod (Russia) in compliance with anti-covid measures. Out of 55 young men aged 18-20, 23 students were engaged in fitness aerobics (fitness group) and 22 students were engaged in swimming (swimmers group) 4 times a week for 2 hours. All participants of the project were members of the university's sports teams. The consent of the young men to participate in the research project was received. Students' rights were respected.

HRV indicators testing was carried out at the beginning of the academic day, in a state of physiological rest, after two months of systematic training loads. The hardware system of sports testing «Medical Soft» (variant «MS FIT Pro», Russia) was used for registration and analysis of HRV parameters.

The results of statistical and spectral indicators of athletes' heart rate were analyzed: standard deviation of N-N intervals from the mean value (SDNN); resting heart rate heart rate at rest (HBR); square root of the mean squares of the differences between adjacent N-N intervals (RMSSD); percentage of intervals differing from the mean value by 50 ms or more (pNN50); total spectrum power (TP); spectrum power in the low frequency region (LF); spectrum power in the high frequency region (HF); very low frequency spectrum power (VLF); index of vegetative equilibrium (LF/HF); integral parameter of the presence or absence of a stress state (SI).

The calculation and analysis of the data obtained was carried out in accordance with the age parameters and standards in the field of HRV developed by the working group of the European Society of Cardiology and the North American Society of Stimulation and Electrophysiology (Task Force of the European Society of Cardiology and the North American Society of Pacing and Electrophysiology. Heart rate variability. Standards of Measurement. Physiological interpretation and clinical use, 1996). The research materials were processed using the licensed software package Statistica 6.0. The Shapiro-Wilk criterion was used to determine the normality of the parameters values distribution. The Student's criterion was used to assess the significant intergroup differences in the samples. The differences were considered statistically significant at $p<0.05$.

Results

The method of testing on the Medical Soft hardware complex allows for a short time to study the HRV indicators and conduct a digital analysis of the athletes' heart rate variability (Fig. 1).

Fig. 1. Sample of the HRV protocol obtained using the sports testing system MedicalSoft «MS FIT Pro», (Russia)

The protocol received on the device display after the examination shows the main indicators for a preliminary conclusion about the state of the athletes' heart rhythm regulatory mechanisms. The RMSSD parameter in the swimmer group was 23.7% lower than in the fitness group students (28.37 and 37.21 ms, respectively), $p<0.05$. The level of SDNN (the total effect of vegetative regulation) in swimmers was 33.2% lower than in students of the fitness group (35.53 and 47.34 ms, respectively), $p<0.05$, (Fig.2).

The obtained results suggest that the students of the fitness group have a higher level of fitness compared to the representatives of the water sport. This is further confirmed in the interpretation of the RMSSD parameter results, which showed the presence of a higher level of heart rhythm autonomous regulation in representatives of fitness aerobics. In the group of swimmers, there is a tendency to slight overstrain of the regulatory systems of the body due to the shift of the RMSSD parameter beyond the lower limit of the normal range, which can be expressed in a decrease in the activity of the heart muscle autonomous regulation in these athletes.

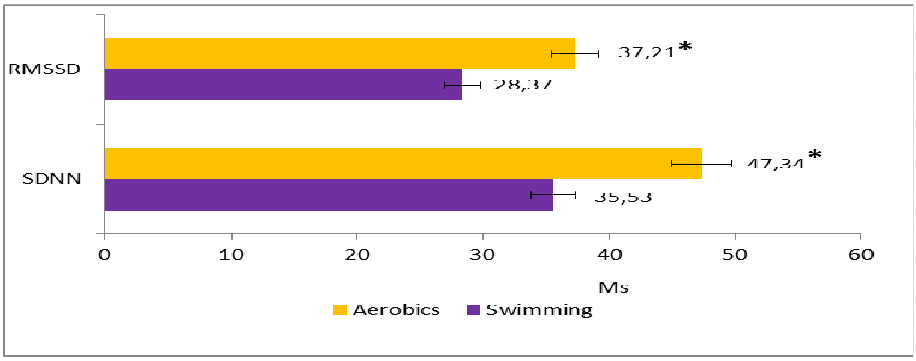

Fig. 2. Параметры Students-athletes' RMSSD и SDNN parameters (ms)

Note. * - the differences are significant, $p<0,05$

The HBR and pNN50 values indicators characterizing the heart rate variability degree in representatives of different sports also showed a heterogeneous picture (Fig. 3).

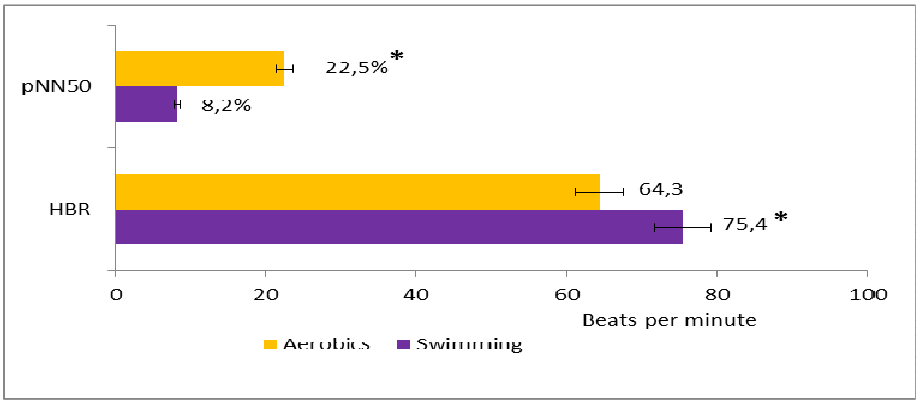

Fig. 3. HBR (beats per minute) and pNN50 (%) parameters of students-athletes
Note. * - the differences are significant, p<0,05

Despite systematic training, the HBR parameter in swimmers approached the upper limit of the standard range and amounted to 75.4 beats per minute. In the athletes in the fitness group, the HBR value was 14.7% lower and amounted to 64.3 beats per minute (p<0.05). This suggests a more economical operation of regulatory mechanisms in student-athletes engaged in aerobics.

In the fitness aerobics group, the value of the pNN50 index in students was 63.5% higher than in the swimmers group (22.5% and 8.2%, respectively), p<0.05. The values of the pNN50 index obtained in both groups further confirm the difference in the functional characteristics of the examined students (Fig. 3).

The obtained results of HBR and pNN50 study in a group of students-swimmers characterize a more active involvement of central mechanisms in the heart rhythm regulation, which indicates signs of the initial stage of overtraining development. The parameters of the spectral analysis of heart rate variability characterize the total power of the spectrum, which reflects the total activity of neuro-humoral influences over the heart rhythm. In our study, representatives of swimming have lower values (p<0.05).

In this case, the total power (TP) is defined as the sum of the capacities in the LF, HF and VLF ranges. It should be noted that normally the spectrum structure is represented as HF>LF>VLF. Therefore, the use of the method of the heart rhythm spectral analysis allows us to establish the presence of vegetative balance, the predominance of sympathetic or parasympathetic nervous systems activity and the type of heart rhythm control - vegetative or central.

The low-frequency component (LF) power has a relative value of 51.94% for students of the swimming group, for athletes of the fitness aerobics group, the LF value was 1.7 times less (31.26%), p<0.05. This suggests that the processes of LF regulation in swimmers occur with the help of non-specific regulation mechanisms (Fig. 4).

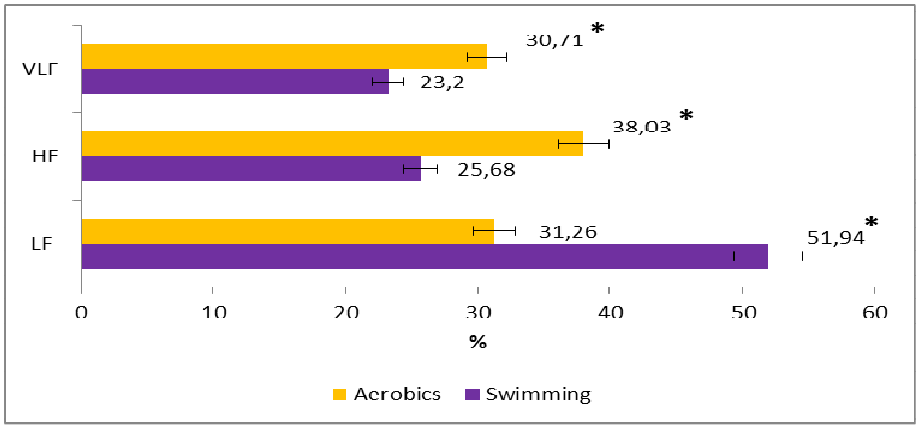

Fig. 4. Students-athletes' spectral analysis indicators (%)
Note. * - the differences are significant, p<0,05

The power of the high frequency spectrum (HF) characterizes the activity of the autonomic innervation of the heart activity according to the degree of inhibition of the autonomous regulation circuit activity. In the group of swimmers HF was 25.68%, which is 32.5% lower than in the athletes of the fitness aerobics group (38.03%). The VLF indicator, which characterizes the power of the spectrum in the range of very low

frequencies, is 30.71% at rest for students of the fitness aerobics group and is in the physiological norm. The athletes of the swimming group have a VLF index lower by 24.5% and is 23.2%, p<0.05, Fig.4. The VLF indicator also characterizes the presence of a suprasegmental level of the heart regulation and an energy-deficient state. A low VLF value in representatives of water sports indicates a tendency to develop psycho-emotional tension.

The low values of the SDNN, RMSSD, pNN50 and VLF parameters, established in student swimmers, allow us to assume the development of their initial stage of overwork, which requires medical monitoring and correction of the training process program. Analysis of the results of our project showed that the vegetative equilibrium index (LF/HF) in swimmers is 1.9 times higher than the index of LF/HF in students in the fitness aerobics group. Consequently, swimmers have a higher level of sympathetic stimulation of the myocardium at rest at the time of examination (Fig.5).

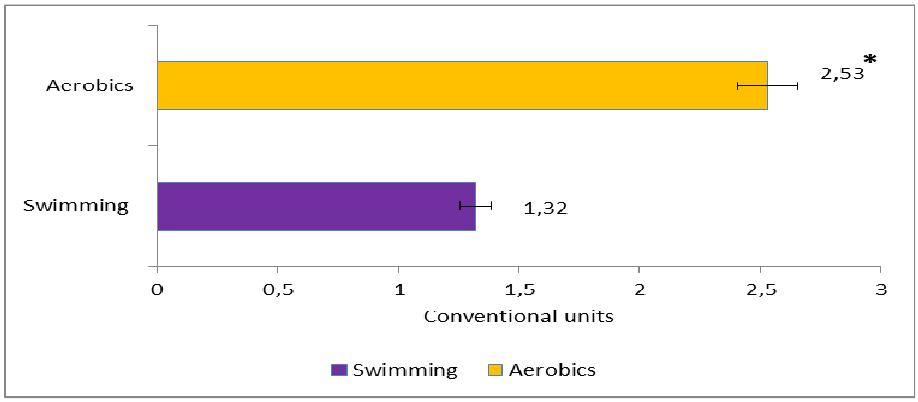

Fig. 5. Students-athletes' vegetative equilibrium index (LF/HF) (conventional units)
Note. * - the differences are significant, p<0,05

The degree of the athlete's body regulatory systems tension was determined by the value of the stress index (SI), Fig. 6.

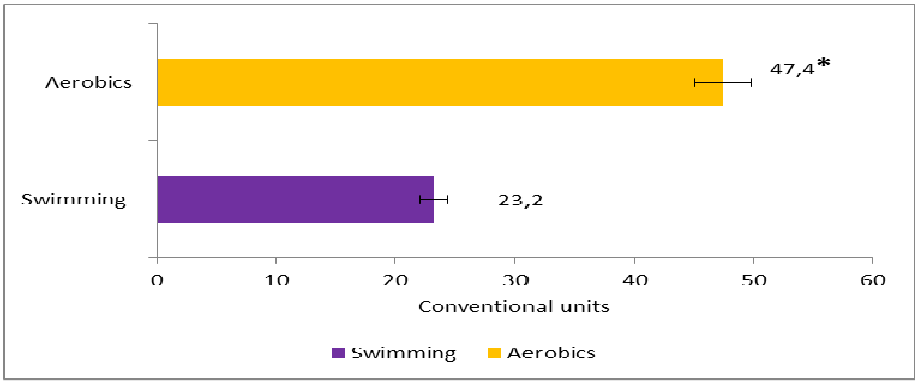

Fig. 6. Students-athletes' stress index (SI) (conventional units)
Note. * - the differences are significant, p<0,05

For swimmers, the SI index was 23.2 conventional units, which is by 51.1% less than for athletes in the fitness group (47.4 conventional units), p<0.05, Fig.6.
The sports testing conducted by us using the HRV method showed the possibility of operational monitoring of the students' of various sports specializations cardiovascular system functional state for the educational and training process correction.

Dicussion

Various factors of the training process can affect the functional state of the athletes' body. In addition to the development and improvement of general and special physical fitness, tactical and technical skills, the training process should take place within the framework of countering the athlete's overtraining and overstrain (Brenee et.al., 2020; Malikov et.al ., 2021). One of the ways to prevent undesirable health complications in athletes, as a result of training activities, is regular medical and pedagogical monitoring of the functional state of the cardiovascular system of the body engaged (Nuuttila et.al., 2017). For this purpose, methods of testing heart

rate variability (HRV) Shlyk (2016), Misigoj Durakovic et.al. (2016), estimates of blood pressure variability between heartbeats (Guzii et.al., 2020) or other methods of registration and analysis of the physiological parameters of the athlete's body are used.

Hardware monitoring of human heart rate variability indicators allows quick obtaining information about the functional state of regulatory systems and the level of adaptation of the body to environmental factors or to physical exertion of various directions (Hayano et al., 2019). Therefore, this technique is widely used in clinical practice and sports medicine (Christian et al., 2021). After our testing of HRV, it was found that the values of heart rate indicators (HBR), which are outside the physiological norm, were significantly higher in the student-athletes of the swimming group, the values of SDNN, RMSSD, pNN50 and VLF were significantly lower than in the athletes of the fitness group.

The characteristic of the HRV switching speed is the pNN50 indicator, which records the percentage of heart contractions intervals that differ from the previous one by 50 ms or more. The students of the swimmer group have this indicator by 63.5% more than the students of the fitness group ($p<0.05$). We believe that the swimmers participating in our project have an increased risk of developing cardiac arrhythmia. The students of the swimming group have a heterogeneity of spectral rhythm analysis patterns , which is expressed in a decrease in the total power of the spectrum, an uneven distribution of the relative values of low, very low and high frequency waves. This distribution tended to increase the maladaptation of the vegetative equilibrium index and the stress index parameter in accordance with the sympathetic or parasympathetic type of regulation, as evidenced by studies by other authors (Shlyk, 2016). The athletes of the aerobics group have a high-frequency oscillation rhythm. This indicates that the functional fitness and reserve capabilities of the body of athletes from this group are significantly higher than those of student-athletes engaged in swimming.

We believe that the central mechanisms of heart rhythm regulation dominate in the swimmers we examined. These athletes have a spectrum power indicator value in the very low frequency range (VLF) below the physiological norm, compared with the results of testing athletes of the fitness group. The power ratio of the spectrum of low and high frequencies (LF/HF) is considered as the main spectral indicator of vegetative maintenance of cardiorhythm. We found that the students of the swimming group have a shift of the LF/HF spectrum towards the voltage of the central regulation of the heart. We agree with the opinion of Britton et al. (2019) that athletes with such a regulation mechanism should be under the supervision of coaches and doctors and periodically undergo a HRV-method examination. In athletes with a sufficient training level, the stress index parameter (SI) ranges from 25 to 70 conventional units. In this range of SI values, there are indicators of project participants engaged in fitness aerobics, whose stress index value is 47.4 conventional units. A lower value of the stress index was found in athletes in the swimming group (23.2 conventional units). This shows that the swimmers' body is in a state of overstrain and overtraining.

The predominance of central mechanisms of heart regulation in student swimmers leads to a tendency to disrupt the adaptation mechanism and the appearance of an initial stage of overtraining in athletes, which is presented in the research materials of other authors (Flatt et al., 2020). We believe that the HRV method allows the doctor and the coach to determine the state of the vegetative balance in the athlete's body, to make timely adjustments to the training program to prevent the development of serious cardiovascular complications (Perkins et al., 2016; Drezner et al., 2019). The results of this research project are consistent with the materials of our previously published works on the survey of student-athletes of other sports specializations (Martusevich et al., 2020). Various factors and circumstances of the training process can affect the functional state of the body of athletes. In addition to the development and improvement of general and special physical fitness, tactical and technical skill, the training process should take place within the framework of countering the athlete's overtraining and overstraining (Brenee et al., 2020; Malikov et al., 2021).

Conclusions

After conducting noninvasive complex testing of two groups of student-athletes engaged in fitness aerobics and swimming, significantly different indicators of statistical and spectral values of heart rate variability were recorded.

Athletes of the swimming group had lower values of SDNN, RMSSD, pNN50, total spectrum power, low adaptive level of functional reserves and a higher level of heart rate. They were dominated by the central mechanism of regulation of the heart, compared with the results of athletes of the fitness group. In swimmers, the wave ratios of different frequencies (LF, HF, VLF) were not in the optimal range, the stress index index went beyond the upper limit of the physiological range. Thus, the swimmers' body was in a state of overstrain and overtraining. We believe that the volume or intensity of physical activity was overestated in the training program of the athletes of the swimming group. In the fitness group, physical activity corresponded to physical and functional capabilities and was comfortable for the students' body.

Therefore, in order to prevent the further increase of overstrain and overtraining of the athletes' body and the appearance of possible cardiovascular complications, adjustments should be made to the program of the swimming training process.

Given the high informativeness, objectivity and accessibility of the HRV method for determining the vegetative balance and adaptive reserve capabilities of the body, this method can be recommended for use in scientific and practical projects in other sports for medical and pedagogical control of those engaged in physical culture and sports.

Conflicts of interest

The author declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

References:

Adams, J.A., Patel, S., Lopez, J.R., & Sackner, M.A. (2018). The effects of passive simulated jogging on short-term heart rate variability in a heterogeneous group of human subjects. *J Sports Med,* 1 Okt, 4340925, DOI:10.1155/2018/4340925

Aparecida Maria Catai, Carlos Marcelo Pastre, Moacir Fernades de Godoy, Ester da Silva, Anielle Christine de Medeiros Takahashi, & Luiz Carlos Marques Vanderlei (2020). Heart rate variability: are you using it properly? Standardisation checklist of procedures. *Braz J Phys Ther,* 24(2), 91-102. DOI: 10.1016/j.bjpt.2019.02.006

Brenee K. Rockholt, Gregory J. Grosicki, & Andrew A. Flatt (2020). Resting and exercise-related heart rate responses to high intensity interval training in women: A pilot study. *Journal of Physical Education and Sport*, Vol.20 (5), Art 375, pp. 2760-2764. DOI:10.7752/jpes.2020.05375

Britton, D.M., Kavanagh, E.J., & Polman, R.C. (2019). Validating a self report measure of student athletes' perceived stress reactivity: associations with heartrate variability and stress appraisals. *J Front Psychol,* 10, 1083, DOI: 10.3389/fpsyg.2019.01083

Castellani, J.W., Tipton, M.J. & Castellani, J.W. (2015).Cold Stress Effects on Exposure Tolerance and Exercise Performance. *Compr Physiol.,* 6(1), 443-469. DOI: 10.1002/cphy.c140081

Christiani, M., Grosicki, G., & Flatt, A. (2021). Cardiac-autonomic and hemodynamic responses to a hypertonic, sugar-sweetened sports beverage in physically active men. *Appl Physiol Nutr Metab*, 24, 1-7. DOI: 10.1139/apnm-2021-0138

Deschodt-Arsac, V., Lalanne, R., Spiluttini, B., Bertin, C., & Arsac, L.M. (2018). Effects of heart rate variability biofeedback training in athletes exposed to stress of university examinations. *PLoS One*, 13(7), e0201388, DOI: 10.1371/journal.pone.0201388

Drezner, J.A., Peterson, D.F., Siebert, D.M., Thomas, L.C., Lopez Anderson, M., Suchsland, M.Z., Harmon, K.G., & Kucera, K.L. (2019). Survival after exercise related sudden cardiac arrest in young athletes: can we do better? *Sports Health,* 11(1), 91–98. DOI: 10.1177/1941738118799084

Dupuy, O., Douzi, W, Theurot, D., Bosquet, L., & Dugué, B. (2018). An Evidence-Based Approach for Choosing Post-exercise Recovery Techniques to Reduce Markers of Muscle Damage, Soreness, Fatigue, and Inflammation: A Systematic Review With Meta-Analysis. *Front Physiol*, 9(403), 403. DOI: 10.3389/fphys.2018.00403

Flatt, A., Allen, J., Bragg, A., Keith, C., Earley, R., & Esco, M. (2020). Heart rate variability in college football players throughout preseason camp in the heat. *International Journal of Sports Medicine*, 41(9), 589- 595

Guzii, O., Romanchuk, A., & Mahlovanyy, A. (2020). Post-loading dynamics of heart rate variability indices in highly qualified athletes in the formation of overstrains by sympathetic and parasympathetic types. *Art Med,* 4(16), 28-36. DOI: 10.21802/artm.2020.4.16.28

Hayano, J., Yuda, E. & Hayano, J. (2019). Pitfalls of assessment of autonomic function by heartratevariability. *J. Physiol Anthropol*, 38(1), 3. DOI: 10.1186/s40101-019-0193-2.

Kogame, N., Ono, M., Kawashima, H., Tomaniak, M., Hara, H., Leipsic, J., Andreini, D., Collet, C., Patel, M.R., Tu, S., Xu, B., Bourantas, C.V., Lerman, A., Piek, J.J., Davies, J.E., Escaned, J., Wijns, W., Onuma, Y., Serruys, P.W., & Kogame, N. (2020). The Impact of Coronary Physiology on Contemporary Clinical Decision Making. *JACC: Cardiovascular Interventions,* 27, 13(14), 1617-1638. DOI: 10.1016/j.jcin.2020.04.040.

Kolumbet, A., Ishchenko, H. , Kozeruk, Y. , Zukova, G. , Kurdybakha, O., & Goletc, A. (2021). Optimization of functional adjustments of the oxygen supply system in the body of young skilled athletes during long-term athletic training. *Journal of Physical Education and Sport*, 21 (5), Art 338, pp. 2515-2523. DOI:10.7752/jpes.2021.05338

Kudryavtsev, M.D., Kramida, I.E., Iermakov, S.S., & Osipov, A.Yu. (2016). Development dynamic of healthy life style personality component in relatively healthy students. *Physical education of students,* 6, 26-33. DOI: 10.15561/20755279.2016.0603

Lisenchuk, G., Zhigadlo, G., Tyshchenko, V., Odynets, T., Omelianenko, H., Piptyk, P., Bessarabova, O., Galchenko, L., & Dyadechko, I. (2019). Assess psychomotor, sensory-perceptual functions in sport games. *Journal of Physical Education and Sport*, 19(2), Art 175, 1205-1212. DOI:10.7752/jpes.2019.02175

Malikov, N., Tyshchenko, V., Bogdanovska, N., Savchenko, V., Moskalenko, N, Ivanenko,S., Vaniuk, D., Orlov, A., & Popov, S. (2021). Functional fitness assessment of elite athletes. *Journal of Physical Education and Sport*, Vol. 21 (1), Art 36, pp. 374 – 380. DOI:10.7752/jpes.2021.01036

Martusevich, A.K., Bocharin, I.V., Gur'yanov, M.S., & Mamonova S.B. (2020). Particularities of heart rate variability in students-athletes of different sport specialty. *Modern methods of diagnosis and treatment ,* 3 (64), 81-85 (in Russian)

Misigoj Durakovic, M., Durakovic, Z., & Prskalo, I. (2016). Heart rate corrected QT and JT intervals in electrocardiograms in physically fit students and student athletes. *Ann Noninvasive Electrocardiol,* 21(6), 595–603. DOI: 10.1111/anec.12374

Nuuttila, O., Nikander, A., Polomoshnov, D., Laukkanen, J., & Häkkinen, K. (2017). Effects of HRV-guided vs. predetermined block training on performance, HRV and serum hormones. *Int J Sport Med*, (38), 909-920. DOI: 10.1055/s-0043-115122

Perkins, S.E., Jelinek, H.F., Al Aubaidy, H.A., & de Jong, B. (2017). Immediate and long term effects of endurance and high intensity interval exercise on linear and nonlinear heart rate variability. *J Sci Med Sport,* 20(3), 312-316. DOI: 10.1016/j.jsams.2016.08.009

Sergio Jiménez Morgan, & José Arturo Molina Mora (2017). Effect of Heart Rate Variability Biofeedback on Sport Performance, a Systematic Review. *Appl. Psychophysiol. Biofeedback*, 42(3), 235-245.

Shlyk, N. (2016). Management of athletic training taking into account individual heart rate variability characteristics. *Hum Physiol,* 42(6), 655-64. DOI: 10.1134/S0362119716060189

Task Force of the European Society of Cardiology and the North American Society of Pacing and Electrophysiology. Heart rate variability. Standarts of Measurement. Physiological interpretation and clinical use (1996). *Circulation*, 93, 1043-1065.

Vira, B., Zharska, N., Matviyas, O., Rybak, L., & Bazyliak, N. (2018). Features of cardiovascular system indices of women's football players as a function of their hormonal status. *Journal of Physical Education and Sport*, 18(2), Art 113, pp. 769 – 774. DOI:10.7752/jpes.2018.02113