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Research Article

Alues of Spectral and Temporal Indicators of Clinostatic Cardiointervalogram of Elite Skiers-Racers as A Reflection of The Synthesis of Non-Neuronal Acetylcholine by Cardiomyocytes

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Abstract:

The ski racers of the Tatarstan team (6 MS, 2 MSMC), including skier K.D., in 2019-2020. (during the one-year training macrocycle), heart rate variability (HRV) was recorded using the medical diagnostic system «VNS-Micro» (Neurosoft, Ivanovo) for 5 minutes in the supine position. The results of the study allow us to conclude that elite skiers have anti-apoptotic, antioxidant and anti-inflammatory systems of the myocardium, one of the components of which is non-neuronal acetylcholine (NN-ACh), and the values of the main spectral and temporal parameters of HRV of these athletes can be considered as indicators of the synthesis of NN-ACh in cardiomyocytes.

keywords: cross-country skiers; heart rate variability; periods of the training macrocycle; non-neuronal acetylcholine; anti-apoptotic system

Introduction

Currently, acetylcholine (ACh) has been shown to exhibit antioxidant, anti-inflammatory, and anti-apoptotic activity, which is probably due to its ability to increase the activity of the Nrf-2 transcription factor by activating M3-holinoreceptors and/or alpha7 HN- holinoreceptors [1]. As is known, the vagus predominantly innervates the sinoatrial and atrioventricular nodes, while the ventricles of the heart contain only single terminals [1]. This is clearly insufficient for the above-mentioned properties to manifest, especially during physical exertion, which is typical, for example, for active elite ski racers. It has been established that in the process of vital activity, human and animal cardiomyocytes acquire the ability to synthesize NN-ACh [2]. This is indicated by data on the expression of choline acetyltransferase in cardiomyocytes [2, 3], the choline-1 transporter, the vesicular transporter ACh [1-3], as well as the presence of mitochondria in cardiomyocytes, which are sources of choline and acetyl for the synthesis of ACh [4]. It has been shown that the low intensity of NN-ACh synthesis, i.e. its deficiency, is one of the causes of hypertension [3] or heart failure in type 1 and type 2 diabetes mellitus [2]. Therefore, there is a need for a clinical assessment of the formation of NN-Ach system in the human heart. According to [3], such spectral indicators of heart rate variability (HRV) how is the absolute power of LF- waves, i.e. low-frequency waves reflecting the effect on the heart of the sympathetic division (SD) of the autonomic nervous system (ANS), the absolute power of HF- waves, i.e. high-frequency waves reflecting the effect on the heart of the parasympathetic division (PD) of the ANS, as well as their ratio (LF/HF) may reflect the presence of synthesis of NN-ACh and its decrease in pathology. It is well known that elite skiers at rest are characterized by high activity of the PD ANS, as evidenced by data from clinostatic cardiointervalography (clino-KIG) [5], as well as an increase in the number of mitochondria in cardiomyocytes [6]. We assumed that the partially high activity of the PD ANS is due to the fact that ventricular cardiomyocytes of elite skiers acquire the ability to synthesize NN-Ach, which may be reflected by the values of a number of HRV indicators [5]. Earlier, we found [5] that the medians of such spectral indicators as the total power of the spectrum (TP) and the power of VLF

waves, as well as time indicators (RRNN, pNN50%, RMSSD) in elite skiers in comparison with athletes of other sports, reach maximum values and, what is especially typical for time indicators, they are relatively stable throughout the ski season for elite skiers. Therefore, these HRV indicators can be considered as indicators of the synthesis of NN-ACh in cardiomyocytes. Therefore, the purpose of this article is to present the values of spectral and temporal parameters of clinostatic cardiointervalography (CIG) of an elite skier K.D, who was a member of the national team of the Republic of Tatarstan in cross-country skiing, a 27-year-old master of sports (MS), the first author of the article), registered during all three periods of the annual cycle, including preparatory (84 registrations), competitive (74) and transitional (59) periods, as well as to present the values of the indicators of the klino-CIG of all members of the Tatarstan national team (including skier K.D), among which 6 MS and 2 MSMC and in which clino- CIG was performed in the preparatory period (62 registrations) and in the competitive period (44 registrations).

Research methods

The study was conducted from March 2019 to June 2020 inclusive. The age of the athletes ranged from 23 to 31 years old. Clino-CIG was registered at training camps, seven of which were held during the preparatory period, and three during the competition period (the day after the next competition day). The five-minute CIG registration was performed in a lying position, before breakfast, in comfortable conditions, using the portable medical diagnostic system «VNS-Micro» (Neurosoft, Ivanovo) and the Poly-Spectrum program (Neurosoft).

15 HRV parameters were analyzed. Among them are:

1) total spectrum power (TP), or total power, reflecting the power of rhythm fluctuations in the frequency range from 0.003 to 0.5 Hz, i.e. the total effect of SD and PD ANS on the heart rate, in which an increase in SD activity leads to a decrease of TP, and an increase in PD activity leads to an increase in TP;

2) absolute the power of fast (HF-) waves, ((hereinafter – APHF) reflecting the power of vibrations with a frequency from 0.15 to 0.40 Hz, which reflects the nature of the effect of the PD on the work of the heart;

3) the power of slow (LF-) waves (hereinafter - APLF), reflecting the power of vibrations with a frequency from 0.04 to 0.15 Hz, which indicates the nature of the influence of SD on the work of the heart;

4) the power of very slow (VLF-) waves (hereinafter – APVLF), reflecting the power of vibrations with a frequency from 0.003 to 0.04 Hz, which probably indicates the complex effect of SD and PD, as well as a number of biologically active substances (BAS) on the activity of the heart

5) The APLF /APHF ratio (hereinafter - LF /HF), reflecting the ratio of the influence of SD and PD on the activity of the heart;

6, 7 and 8) - are the relative power of HF-, LF-, and VLF- waves, respectively, expressed as a percentage of TP (hereinafter - respectively HF%, LF% and VLF%), which reflects the specific contribution of PD, SD and BAS to the regulation of cardiac activity;

9 and 10) the duration of normal R-R intervals (RRNN), which is analogous to heart rate (HR);

11) the ratio of consecutive NN-intervals, the difference between which exceeds 50 ms, as a percentage of the total number of normal (NN) R-R intervals (pNN50%);

12) the square root of the average the square of the differences in the values of consecutive pairs of NN intervals (RMSSD);

13) the standard deviation of all NN- intervals (SDNN);

14) the variation range, i.e. the difference between the maximum and minimum R-R intervals (MxDMn);

15) the stress index (SI,) which was calculated using the formula: SI = AMo / Mo × 2MxDMn, where AMo is the amplitude of the mode, i.e. the most common value of the R–R-intervals of ECG , expressed as % of all R-R intervals; Mo -is the absolute value of the mode (s), and MxDMn is the variation range, i.e. the difference between the maximum and minimum values of the R-R intervals As is known, with an increase in the influence of SD ANS on cardiac activity, values of SI increase, while the values of RRNN, pNN50%, RMSSD, SDNN, MxD Mn decrease, and with a decrease in the influence of SD the opposite changes occur. The differences between the indicators recorded in different periods of the annual cycle were evaluated using the Mann-Whitney criterion, considering them statistically significant at $p<0.05$, using the BioStat2009 Professional. 5.9.8 program (Analyst S oft).

The results of the study

The medians, as well as the 25th and 75th cents of all 15 clino- KIG indicators of the athlete K.D, registered in all three periods of the annual cycle, as well as clino- KIG indicators of all members of the Tatarstan national team, registered in the preparatory and competitive periods, are presented in the table. As can be seen from the table, all spectral indicators and most time indicators had maximum values in the preparatory period, or, conversely, minimum values (for example, the stress index), which indicates the dominant influence of the ANS on the heart activity of elite ski racers in the preparatory period. This applies to such indicators as TP, APHF, APLF, APVLF, VLF%, SI, RRNN, pNN50%, RMSSD, SDNN, MxDMn, and their change in the competitive period is explained by an increase in the activity of the sympathetic division (SD) during this period due to the formation of feelings of anxiety and responsibility for the result.

Ski racer K.D.			
KIG indicators	**The** preparatory period	**The** competition period	**The** transition period
TP, ms^2	9473 (6685/11037)	8047 (6940/9616)	6961 (5349/8416)*#
APHF, ms^2	3793 (2860/4579)	3519 (2805/4071)	3371 (2387/3896)*
APLF, ms^2	1962 (1307/2814)	2032 (1570/2619)	1480 (1072/2097)*#
APVLF, ms^2	2818 (2075/3874)	2622 (2023/3800)	1874 (1374/2582)*#
LF/HF, con.unn.	0,55 (0,39/0,66)	0,64 (0,46/0,74)	0,46 (0,35/0,59)#
HF%	44,7 (35/52)	41,7 (34/48)	47,3 (41/52)#
LF%	22,5 (18/26)	24,5 (20/29)*	21,7 (19/27)

VLF%	32,6 (24/39)	32,8 (26/40)	27,7 (22/36)*#
SI, con.un.	13,2 (10/18)	15,6 (12/20)	22,1 (16/25)*#
RRNN, ms	1497 (1453/1540)	1477 (1412/1523)*	1467 (1398/1502)*
HR, b/min	40,0 (38/41)	40,6 (39/42)	40,8 (39/42)*
pNN50%	70,5 (66/73)	68,8 (62/71)*	68,9 (65/72)
RMSSD, ms c	108 (97/120)	101 (94/111)*	96 (91/107)*
SDNN, ms	92 (84/104)	90 (81/101)	77 (73/87)*#
MxDMn, ms	0,549 (0,439/0,609)	0,509 (0,421/0,606)	0,403 (0,348/0,463)*#
The national team **of the** Republic **of** Tatarstan			
TP, ms ^{2}	9923 (6658/14428)	7864 (6855/9396)*	-
APHF, ms ^{2}	4082 (2576/6335)	3077 (2054/4021)*	-
APLF, ms ^{2}	2057 (1119/3202)	1728 (1278/2733)	-
APVLF, ms ^{2}c^2	3138 (1818/5611)	2754 (2074/4156)	-
LF/HF,, con.un.	0,50 (0,34/0,65)	0,65 (0,44/0,80)*	-
HF%	43,6 (32/52)	37,2 (28/45)*	-
LF%	19,9 (14/25)	22,7 (17/29)*	-
VLF%	34,1 (24/45)	38,5 (30/48)	-
SI, , con.un.	13,7 (10/20)	17,9 (12/22)*	-
RRNN, ms	1430 (1291/1515)	1490 (1405/1523)*	-
HR, b/min	42,0 (39/46)	40,2 (39/42)*	-
pNN50%	68,8 (58/75)	65,1 (58/70)*	-
RMSSD, ms	110 (92/135)	96 (86/105)*	-
SDNN, ms	99 (84/123)	87 (79/95)*	-
MxDMn, ms c	0,562 (0,451/0,636)	0,485 (0,406/0,564)*	-

Table: The median, 25 and 75 values of the klink-KING indicators for the ski racer K.D., during three training periods and the national team of the Republic of Tatarstan during two training periods.

Note: the national team of the Republic of Tatarstan was not studied during the transition period. * - statistically significant differences with the preparatory period, # - statistically significant differences with the competitive period, p>0.05.

Discussion

According to [5,8], the clino- CIG indicators of the athlete K.D. and the rest of the Tatarstan team members, reflecting the effect of ANS on heart activity, are much higher than those of novice skiers, discharge skiers, and non-athletes, and even higher than those of elite athletes in sports that do not require high endurance. The research results presented in this article suggest that elite skiers develop an anti-apoptotic system in the myocardium during long-term training, which prevents myocardial damage under the influence of periodic activation of beta1-adrenergic receptors and the production of reactive oxygen species (ROS), which cause oxidative stress. The components of this system are probably NN-ACh, as well as antioxidants such as free amino acids (histidine, tryptophan, tyrosine), dopamine, serotonin, prostaglandins (PGF2alpha and PGE2,) nitric oxide, melatonin, and other substances. We realize that in order to strictly prove the production of NN-ACh, of course, it is necessary to conduct a study of HRV parameters in ski racers, combined with an assessment of the activity of participants in the synthesis of NN-ACh, including cholineacetyl transferase, the choline-1 transporter and the vesicular ACh -transporter. In the meantime, we can only state a priori that the values of the majority of clino-CIG indicators of elite skiers recorded in the preparatory period, including TP, APHF, APLF, APVLF, VLF%, as well as SI, RRNN, pNN50%, RMSSD, SDNN, MxDMn are markers of the synthesis of NN-ACh in the myocardium. In general, the fruitfulness of the idea of the synthesis of NN-Ach in the human myocardium is obvious, especially taking into account clinical data on the deficiency of synthesis of NN-Ach as one of the causes of hypertension [3] or heart failure in type 1 and type 2 diabetes mellitus [2]. Given that factors such as choline acetyltransferase, the choline-1 transporter, the vesicular Ach- transporter, and mitochondria are involved in the synthesis of NN-ACh, and the effectiveness of Ach depends on the activity of acetylcholinesterase and the endogenous blocker of M-cholinergic receptors (EBMHR), it can be assumed that the rate of synthesis of NN-ACh in humans and its effectiveness may vary. This, in particular, may explain the presence of different types of autonomic regulation of cardiac activity in non-athletes and athletes, noted by N.I. Shlyk [7], as well as the success in sports of those athletes who are naturally capable of producing NN-Ach. According to our data [8], there are 7 members of the Tatarstan national team, including athlete K. D. throughout the ski season, they had type IV heart autonomic regulation (according to the classification of N.I. Shlyk), and 1 member of the national team had type III.

Conclusions:

1. Over the years, ski racers develop anti-apoptotic, antioxidant and anti-inflammatory systems of the myocardium, one of the components of which is non-neuronal acetylcholine; this manifests itself in the form of the formation of sports vagotonia, which reaches a maximum in elite skiers.
2. 2. The values of many spectral and temporal parameters of clino-CIG characteristic of elite skiers in the preparatory period, can serve as markers of the formation of synthesis of NN-ACh and can be used in clinical practice as a standard for

the maximum level of production of NN-ACh in a healthy person.

Contribution of the authors

Kataev Denis Anatolyevich, Master of Sports of Russia in Cross-country skiing, postgraduate student of the Department of Biology and Methods of Teaching Biology, Vyatka State University; coach-teacher of the Kirov Regional State Autonomous Institution of Additional Education "Perekop Olympic Reserve Sports School".. The author's contribution: registration of a cardiointervalogram in the field, analysis of its parameters, writing a text, literature analysis.

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