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Indicator PNN50% Cardiointervalogram Depending on the Specialization of the Training Process, Stage of the Annual Training Cycle and Other Factors (Literature Review)

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Abstract

The analysis of literature data and own research concerning the value of such an indicator of heart rate variability (HRV) is carried out as pNN50% registered in clinostats conditions, including in athletes. It is shown that the value of pNN50% in athletes, as a rule, is higher than in non-athletes. It depends on the sports specialization - it is maximal for endurance trainees and minimal for those who train muscle strength. It depends on the skill level - for skiers with an increase in skill level, the value of pNN50% increases. However, for elite skiers, it is relatively stable throughout the annual cycle. Thus, for the master of sports of Russia, skier - racer K.D, the median pNN50% in the preparatory period was 70.5%, and slightly but statically significantly decreases in the competitive period (68.8%) and remains at this level (68.9%) in the transition period. Similarly, for 8 members of the Tatarstan national ski team, the median pNN50% in the preparatory period was 68.8%, and in the competitive period - 65.1% ($p<0.05$). The decrease in the median pNN50% in the competitive period is explained by the formation of anxiety even among elite skiers. It was found that the value of pNN50% for elite skiers is relatively stable during the training camp (TC). Thus, the skier K.D. had a median pNN50% initially of 71.1%, in the middle of the TC - 72.9%, and at the end of the TC - 69.1%. In the study of the skier K.D., fixing the volume and intensity of training loads throughout the entire annual cycle, it was found that the median pNN50% positively correlates with the duration of the training load, performed in 1-3 heart rate zones, i.e. in conditions of aerobic energy supply (but this dependence is typical only for the preparatory period). The results of the review confirm the previously stated assumption that in the process of endurance training, an antiapoptic myocardial system is formed, which increases the survival of cardiomyocytes in endurance trainees. One of its components is probably non-neuronal acetylcholine. Its synthesis reflects not only the relative power of VLF waves, but probably also the value of pNN50%.

Keywords: Cross-country skiers; Heart rate variability; pNN50%, Periods of the training cycle; Non-neuronal acetylcholine; Anti-apoptotic system

Abbreviations: HRV: Heart Rate Variability; TC: Training Camp; TP: Total Power; SD: Sympathetic Department; PD: Parasympathetic Department; ANS: Autonomic Nervous System; BAS: Biologically Active Substances; SI: Stress Index; CMS: Candidate for Master of Sports; MS: Master of Sports; CIG: Cardiointervalogram; WP: Working Pulse

Introduction

Analysis of heart rate variability (HRV) in athletes, including those who train for endurance, is increasingly becoming part of the practice of sports [1-3]. The working Group of the European Society of Cardiology and the North American Society of Stimulation and Electrophysiology (EKO and NASPLE) recommended the use of several temporal and spectral HRV indicators [4]. About the spectral parameters of HRV, it is known [4,5] that:

a) The total power of the spectrum (TP), or Total Power, reflects the power of rhythm fluctuations in the frequency range from 0.003 to 0.5 Hz, i.e. the total influence of the sympathetic

(SD) and parasympathetic (PD) departments of the autonomic nervous system (ANS) and several biologically active substances (BAS).

b) The power of fast (HF-) waves, i.e. the power of vibrations with a frequency from 0.15 to 0.40 Hz, reflects the effect of PD on the heart.

c) The power of slow (LF-) waves, i.e. the power of vibrations with a frequency from 0.04 to 0.15 Hz reflects the nature of the effect on the heart of the SD, modulated by the baroreflex.

d) The power of very slow (VLF-) waves, i.e. the power of vibrations with a frequency from 0.003 to 0.04 Hz, probably indicates the complex influence of SD and PD, as well as several BAS on the heart, one of which, in our opinion, is non-neuronal acetylcholine [6,7].

e) The relative power of HF, LF and VLF waves, expressed as a percentage of TP, i.e. HF%, LF% and VLF%, reflects the specific contribution of the corresponding departments of ANS and BAS in the regulation of heart activity [4]. These HRV indicators, registered in clinostasis conditions, were evaluated by several authors in relation to athletes [1,5,8-10].

We have analyzed the literature data and the results of our own research (mainly of ski racers) concerning such spectral indicators of HRV athletes as the total power of the spectrum, or TP [6,7,11,12], absolute and relative power of LF- waves [6,13], absolute and relative power of HF- waves [6,11,12], absolute and relative power of VLF- waves [6,7]. We were able to confirm [6,11-13] that the values of TP-, HF-, LF- and VLF- waves, as well as VLF%, recorded under clinostasis conditions, reflect the effect of ANS on the heart; at the same time, it was suggested that the value of VLF% reflects the intensity of synthesis of non-neuronal acetylcholine by cardiomyocytes [6,7,11], and the values of LF% and HF% reflect the state of anxiety in connection with upcoming starts [6,12,13]. A direct dependence of the median TP on the volume of training loads, expressed in km of travel (Vkm), as well as on the power of training loads, judging by the working pulse, - the higher the volume and the higher the load power, the higher the median TP [6]. A direct dependence of the median absolute power of VLF- waves on the volume of the training load (Vkm) and its power, expressed in the value of the working pulse (N_{WP}), was also revealed [6].

The analysis of the HRV spectral parameters of elite ski racers allowed us to formulate an idea about the formation of the anti-apoptic myocardial system during endurance training, the components of which can probably be free amino acids (histidine, tryptophan and tyrosine) [14], as well as dopamine [15]; serotonin [16]; non-neuronal acetylcholine [6,7,11,17]; prostaglandins $PGF2_{ALFA}$ and PGE2 [18]; nitric oxide [19-21]; melatonin [22] and other BAS. With the participation of this system, the survival of cardiomyocytes increases in conditions of high training loads and preconditioning occurs. About the time indicators of HRV, we considered such indicators as the stress index (SI) or the stress index of regulatory systems [23] and the duration of normal RR intervals, i.e. RRNN (ms), or a more familiar indicator - heart rate (beats per minute) [24]. Both indicators reflect the ratio of SD and PD of ANS activity. With an increase in the activity of SD, the values of SI and heart rate increase, and with an increase of activity of PD, the opposite dynamics is observed [5].

The analysis of SI and RRNN/HR confirms our previous observations and conclusions [6,7,11,12], as well as data from other authors [25,26] that athletes training for endurance, especially elite ski racers, are characterized by high activity of PD, which is manifested during registration HRV in the conditions of clinostasis. We have shown that the value of SI is inversely dependent on the volume and intensity of training loads [23], and RRNN/HR positively depends only on the volume of training load (Vkm, Vmin), especially in the preparatory period [24]. The inverse dependence of RRNN/HR on the load volume (Vmin) revealed during the competition period confirms the formation of emotional stress [24], which we showed earlier with respect to HF% and LF% [6].

In addition, based on the analysis of SI indicators and absolute power of VLF- values, according to which it was proposed to indirectly determine the type of autonomic regulation of cardiac activity [27,28], it was found that in elite ski racers it does not change throughout the entire annual cycle and is estimated, according to the classification of NI Shlyk [28], as pronounced autonomous regulation, i.e. vagotonia. This article analyzes the information in the literature and its own data regarding such a temporary HRV indicator as pNN50%. It represents the ratio of consecutive NN intervals, the difference between which exceeds 50 ms, as a percentage of the total number of NN intervals (NN are normal RR intervals, i.e. not extrasystoles and not artifacts). This indicator reflects the effect of PD on the heart rhythm, including sinus arrhythmia associated with breathing. When dominated SD of ANS, its values decrease, and when dominated PD of the ANS, they increase [5,29-31]. The purpose of this review is to provide information about the values of pNN50% for athletes depending on several factors, including sports specialization, and for ski racers on the volume and intensity of training load during the preparatory, competitive and transitional periods of the ski season.

The Value of pNN50% Depending on the Level of Motor Activity (athletes in comparison with non-athletes)

Hockey players and non-athletes: J Sztajzel et al. [32] studied 14 hockey players, 12 endurance athletes and 12 non-athletes;

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although the authors do not give specific values of pNN50%, they note that it was statistically significantly higher in athletes than in non-athletes. VM Mikhailov [5] revealed higher values of pNN50% in hockey players (n=20, 16 years old) in comparison with schoolchildren of the same age who do not play sports (n= 29, 15 years old); respectively, the values were 51.6% and 9.8%.

Cyclists and non-athletes: According to [33], in 15 high-level cyclists (age 21), the pNN50% value was 38%, and in healthy non-athletes of the same age - 16%. B Pluie et al. [34] showed that in 12 male cyclists, the pNN50% value was 41%, and in non-male cyclists - 30%.

Athletes and non-athletes: Without giving specific values of the pNN50% indicator, [35] note that 58 track and field athletes (24 years old) had a higher pNN50% value before the 2004 Olympic Games than non-athletes. According to [36], 16 elite middle- and long-distance runners had a pNN50% higher value than 13 non-athletes. Kiss O et al. [37] it was shown that the value of pNN50% in athletes engaged in track and field running, cycling and canoe (n=138; 28 years old) It was 24.2%, which was statistically significantly higher than for non-athletes (n=100; 28 years old), in whom it was 14.4%.

Powerlifting (power triathlon): Kalabin OV, Spitsin AP [38] showed that in 19 powerlifters the pNN50% value was statistically significantly lower than in non–athletes (n=20) - 7.6% versus 17.5%.

Athletes and non-athletes. Arshinova NG et al. [39] revealed statistically significant differences between athletes (19 years old, 1-2 adults, n=11), and healthy men of the same age (n=12), respectively – 57.0% vs. 21.6%. It was shown [40] that athlete (CMS, MS, MSMC) swimmers have a pNN50% value of 38.0%, skiers – 64.9%; wrestlers 41.5%; and non–athletes - 29%.

In general, almost all the authors cited above [5,32-37,39,40] agree that athletes have a value of pNN50% higher than non-athletes. This means that motor activity contributes to an increase in the value of pNN50%. The exception is the data that powerlifters have a pNN50% lower value than non-athletes and lower than athletes of other sports [38].

The value of pNN50% depending on the age of athletes

According to [27], based on the results of a study of schoolchildren and athletes aged 7 to 18 years, the values of pNN50% do not depend on age and training experience, but are determined by the innate type of regulation of cardiac activity, which will be described in more detail below (section 9).

The value of pNN50% depending on the duration (“length of service”) of sports and the level of sportsmanship

Morales J, et al. [41], without giving specific values of pNN50%, it is noted that international-level judo wrestlers had pNN50% values higher than national-level wrestlers. Berkoff D, et al. [35] is reported that high-class athletes have pNN50% higher values than amateur athletes. According to [42], 9 athletes at the international level had pNN50% values higher, than 8 athletes at the national level (56% versus 37%). F.B. Litvin, et al [43], examining 16 skiers (18-25 years old), found that for first-graders at the beginning of the training camp (TC) and after its completion, the value of pNN50% was 32.5% and 58.3%, respectively; for candidate for master of sports (CMS) - 66.9% and 70.5%; for master of sports (MS) - 70.3% and 72%. This indicates that the pNN50% value increases with the growth of sportsmanship. A Pogodin, G Aleksanyants [44], examining basketball students, showed that the value of pNN50% in dischargers was 18.8%, in CMS – 25.8%, and in MS – 67.8%. However, in several studies, the dependence of the pNN50% value on the level of athletic skill was not revealed. Thus, [37] report that the values of pNN50% do not statistically differ between master athletes and elite athletes, both groups were formed (n=138; 28 years old) from runners, cyclists and canoeists. N Arshinova et al. [39] did not reveal statistically significant differences between 9 masters (MS, CMS) and 11 dischargers (1-2 adult category) of different sports, respectively, the values of pNN50% were 29.6% and 57,0%. And in the third group of works it is claimed that with the growth of sports skills, the values of pNN50% decrease. Thus, [38] showed that in 8 masters of sports in powerlifting, the pNN50% values were 5%, and in powerlifters (n=11) - 9%, but these differences were statistically insignificant.

So, the literature data is ambiguous. Some authors say that the values increase with increasing length of service and the level of sports skill [35,41-44], others say that the values of pNN50% do not depend on the length of sports [37, 39], and others say that the values of pNN50% decrease as the level of sports skill increases [38].

The value of pNN50% depending on the type of sports specialization

Football players: According to [45], 13 football players of the second division of the Spanish championship (18-28 years old) had a pNN50% value of 41.5%.

Volleyball players: MM Mikhailov, a professional volleyball player and Olympic champion (ZMS), had an average pNN50% of 38.7% [46].

Track and field athletes: For students involved in athletics (1st and 2nd adult grades), pNN50% is 24.3% [5].

Orienteering (orienteers): In 8 orienteering athletes of the international level, the pNN50% value was 56% [42].

Endurance athletes: Maltsev A et al. [47] reported that in 27 highly qualified athletes developing endurance, the pNN50% value was higher than in 17 athletes developing strength (but the values

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are not given). Vikulov AD et al. [40] did not reveal statistically significant differences between 20 swimmers and 33 wrestlers in terms of pNN50% (it was 38.0 and 41.6%, respectively). Sztajzel J et al. [32] found no differences in pNN50% between 12 endurance athletes and 14 hockey players.

Ski racers: At 8 ski racers (1 adult, KMS) the value of pNN50% is 23% [48]. Among 66 highly qualified skiers (CMS, MS, MSMC), pNN50% values reach 64.9% [40]. Similar values were obtained by us (they are described in more detail below) - for elite ski racers, members of the Tatarstan national team, the median pNN50% varied from 65.1% to 68.8%, including for an elite ski racer, a member of the Tatarstan national team, MS, athlete K.D. (the first author of this article), pNN50% values they ranged from 68.8% to 70.5%. So, for ski racers, the value of pNN50% in clinostasis conditions, judging by the literature data, varies from 23.0% to 70.5%. Such a spread of pNN50% values can be determined by many factors: the level of athletic skill; the period of the annual cycle – as described in more detail below in section 6.

Generalization: So, an analysis of the literature shows that the highest values of pNN50% are registered among elite skiers-riders of high qualification [40]; Kataev DA et al., this study], among orienteers [42]. Lower pNN50% values are typical for football players [45], wrestlers and swimmers [40] and for volleyball players [46], for track and field athletes [5], as well as for cross-country skiers [48]. The lowest values of pNN50% are probably typical for athletes training to develop muscle strength [47].

Value of pNN50% depending on gender

With regard to gender differences, the data are few and ambiguous. Thus, [49] showed that the pNN50% indicator has identical dynamics in male and female representatives up to the age of 12, and after this age, the pNN50% indicator acquires gender dependence. Silvetti M, et al. [50], who studied 57 boys, as well as 46 girls, identified 4 groups: 1-5 years old; 6-10 years old; 11-15 years old and 16-20 years old; they showed that up to the age of 10, pNN50% increases regardless of gender and motor activity. Saleem S, et al. [51] in a study of healthy non–athletes volunteers, no statistically significant differences were found between women (pNN50% - 12%) and men (pNN50% – 14%). Yu L Venevtseva, et al. [52], examining 60 girls and 40 boys (6th year students at the medical institute), found no differences between them, respectively, the value of pNN50% was 16.4% and 17.2% ($p>0.05$). Mikhailov VM [5], examining girls and boys of 14-16 years old who do not play sports, noted that for 38 girls the pNN50% values were statistically significantly higher than for 29 boys (17.0% vs. 9.8%). However, [53], examining short-track athletes (KMS, MS), among whom there were 7 boys and 4 girls aged 16-22, showed that the values of pNN50% in boys were higher than in girls (26% versus 10%). In a study of representatives of 31 types of sports, it was revealed [54] that in 1,577 women, the pNN50% value was statistically significantly higher (29.3%) than in 3,199 men (24.6%). So, the literature data do not allow us to draw an unambiguous conclusion regarding the dependence of the pNN50% value on gender, including in athletes and non-athletes.

The Value of pNN50% Depending on the Period of the Annual Cycle (preparatory, competitive, transitional)

Bonaduce D, et al. [33] in a study of 15 elite cyclists (age 21) found that during the period of intensive training, i.e. in the preparatory period, the value of pNN50% was 43%, and during the rest period, i.e. in the transition period – 38%. Liao L, Li J [55] in the study of elite female volleyball players, it was shown that during the preparatory period, as well as at the beginning and end of the competitive period; the values of pNN50% were, respectively, 20.0%; 21.9% and 22.6%, i.e. gradually increased. Raczak G, et al. [56], examining 22 stayer runners (24 years old), they found that in the preparatory period the value of pNN50% was 48.0%, in the competitive period - 38.0%. Kalabin OV, Mikhailov MM [46], found that in the professional volleyball player of the Olympic champion M.M. Mikhailov, in the competitive period, the pNN50% values had great variability (from 7.4% to 80.8%), but on average they amounted to 38.7%. According to [42], athletes who train for endurance (8 orienteers and one track and field athlete) had a pNN50% value of 56.0% during the preparatory period. It is customary for ski racers to distinguish preparatory, competitive and transitional periods [6,57]. Examining 16 ski racers (18-25 years old; MS), [43] showed that before the start of the training camps (TC), the pNN50% value was 70.3%, and after their completion 72.0%, i.e. it remained consistently high. We could not find any other information about the value of pNN50% depending on the periods of the annual cycle for ski racers.

We have carried out the registration of cardiointervalogram (CIG) from 8 ski racers - members of the national team of the Republic of Tatarstan (MS, MSMK) in cross–country skiing, including the master of sports (MS) K.D. (the first author of the article) throughout the annual cycle, including the preparatory, competitive (team, including the athlete K.D.) and during the transition period (athlete K.D) . As reported in our publications [6,7,11-13,23], CIG -registration with the athlete K.D. and all other members of the Tatarstan national team were held for 5 minutes in a lying position after a night's sleep (before breakfast) in comfortable conditions using the VNS-Micro system (Neurosoft, Ivanovo), and the Poly-Spectrum program (Neurosoft) was used in the analysis of CIG. All generally accepted indicators were evaluated, including the value of pNN50%. The athlete K.D. has completed a total of 217 self–registrations of CIG, of which 84 in the preparatory period, 74 -in the competitive period and 59 - in the transitional period. The values of HRV indicator, as well as the volume (Vmin, Vkm,) and power (Nwp ; N1+2+3 heart rate

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zones, N4+5 heart rate zones) of training loads in an athlete K.D. were calculated for each month and in general for each of the three periods (preparatory, competitive and transitional) of the annual cycles, expressing them as medians, 25 and 75 centiles [58]. The remaining 7 members of the RT national team had 106 CIG -registrations (62 in the preparatory period and 44 in the competitive period). The assessment and calculation of pNN50% values were carried out by analogy as in the athlete K.D.; but the volume and intensity of training loads were not recorded for them. In all cases, the Mann-Whitney criterion was used to assess differences, considering them statistically significant at p<0,05 [58]. For calculations, including Spearman's correlation coefficient [58], the program BioStat2009 Professional. 5.9.8. (the company Analyst Soft) was used.

It was found that the median pNN50% for an athlete K.D. during a sports season varied from 63.9% to 72.9%. But in general, the athlete K.D. had a median pNN50% in the preparatory period of 70.5% (25 and 75 centiles - 66% and 73%), in the competitive period - 68.8% (centiles 62% and 71%), and in the transition period – 68.9% (centiles 65% and 72%). This means that the median pNN50% remained at 68.8-70.5%. The differences between the preparatory period (70.5%) and the competitive period (68.8%) were statistically significant (p<0.05); the differences between the preparatory period (70.5%) and the transition period (68.9%), as well as the differences between the competitive (68.8%) and transitional (68.9%) periods were insignificant. Indirectly, this means that at athlete K.D. in the preparatory period has an increase in the median pNN50%, which statistically significantly decreased in the competitive period and remained at the same level during the transition period. We also showed, that 8 members of the Tatarstan national ski racing team (6 MS and 2 MSMC) had similar dynamics during the preparatory and competitive periods of the median pNN50% - in the preparatory period, the median pNN50% was statistically significantly higher than in the competitive period (68.8% vs. 65.1%, respectively; p<0.05)); this indicates that all members of the Tatarstan national team, including skier K.D., have decreased PD of ANS activity during the competition period, judging by the registration of CIG in clinostasis (as a manifestation of anxiety). Thus, the literature data [33,56] and the results of our research allow us to conclude that during the annual cycle of athletes, including elite ski racers, the values of pNN50% in the preparatory period reach their maximum values, after which they slightly but statistically significantly decrease in the competitive period and remain at this level in the transition period.

The Value of pNN50% in the Structure of the Mesocycle (training camp, TC)

In the training of ski racers, it is customary to allocate separate mesocycles or TC [57,59]. The average duration of the mesocycle is one month. The following types of mesocycles are distinguished:

a) Retractive - for the beginning of the preparatory period.

b) Basic - the main type in the preparatory period.

c) Control and preparatory - the transition phase from the basic to the competitive mesocycle.

d) Pre-competitive, aimed at preparing for the competitive period or the main start.

e) Competitive, i.e. performance at competitions.

f) Restorative or transitional - after performances at competitions. Thus, the content of the mesocycle is determined by the goals and objectives of the training process [57].

There is a single piece of information in the literature regarding the dynamics of pNN50% values throughout the TC. In particular, Litvin FB, et al [43] in a study of 16 ski racers (18-25 years old; 1 adult, CMC, MS) showed that before the start of training camps (TC) before the competition period, the pNN50% value for 1st graders was 32.5%, and after their completion – 58.3%, for CMS -66.9% and 70.5%, respectively, for MS – 70.3% and 72.0%. Although the authors did not indicate the statistical significance of the differences, these results suggest that the values of pNN50% may change during even one TC. The Tatarstan national ski racing team, including athlete K.D., held 11 ski competitions during the 2019-2020 ski season [6,7,11], of which 7 in the preparatory period, including: P. Raubichi, Republic of Belarus; Izhevsk; Belmeken, Bulgaria; Tyumen; St. Petersburg; Ergaki, Krasnoyarsk Territory; Vershina Tei village, Republic of Khakassia. HRV registration was carried out at each TC, including at the athlete K.D. An analysis of the data obtained for the 7th TC of the preparatory period showed that for the athlete K.D. values of pNN50% at the beginning, middle and end of the TC were 71.1%, 72.9% and 69.1% respectively (statistically significant differences were found only between the middle of the TC and its completion, p<0.05). These data allow us to conclude that in the structure of one mesocycle (TC), the values of pNN50% may increase [43], or have wave-like dynamics, as shown in our study.

The value of pNN50% depending on the volume / intensity of training loads

Our data obtained during the registration of CIG from a ski racer, a master of sports (MS) athlete K.D. allowed us to estimate the dependence of the median pNN50% on the volume and intensity of training loads during the season. The methodology of these studies is described in detail in our articles [6,7,11,12,23]. Here we explain that for ski racers, the volume of training loads can be expressed in terms of training duration (minutes/day; hours/day; hours/year) [60-63], or the total volume of cyclic load, i.e. km/per workout/day/month/year [59]. The power of loads

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is usually estimated by the value of the "working pulse" [61,63]. Currently, based on the value of the working pulse, it is proposed to allocate five zones of intensity of training load [64,65]. It is believed [64-66] that the intensity of the first three zones is the intensity of the load, at which the working pulse is within 50-80% of the maximum heart rate for this athlete (HRMAX); these are the so–called low intensity zones in which the athlete is in an aerobic energy supply mode, and zones 4 and 5 (working pulse above 80% HRMAX) are high intensity zones in which training work is performed in an anaerobic energy supply mode. In the literature, we could not find data on the dependence of pNN50% on the intensity/power of training loads in ski racers.

Registering the heart rate with the POLAR 430 heart rate monitor equipped with a POLAR GPS sensor (Finland), we found that the intensity of the training load, judging by the values of the working pulse (WP), was relatively constant in all periods of the annual cycle of the athlete K.D. - the median of heart rate in the preparatory, competitive and transitional periods was 121 (centiles -112 and 130), 121 (111 and 130) and 120 (112 and 126) beats/min. And taking into account the allocation of 5 zones of intensity of loads [65], the athlete K.D. completed 41.4% of training in zone 1 (97-116 beats/min); 37.0% – in zone 2 (117-135 beats/min), 15.1% – in zone 3 (136-154 beats/min), 4.8% - in zone 4 (155-174 beats/min) and 1.7% - in zone 5 (175 beats/min), thereby making the load 1- 3 zones in the preparatory period (168 min/day) It is statistically significantly higher ($p<0.05$), than in the competitive (125 min/day) and transitional (101.5 min/day) periods, and in the competitive period it is statistically significantly higher than in the transitional period. The load in zones 4 and 5 in the preparatory (4 min/day) and competitive (1.5 min/day) periods was higher($p<0.05$), than in the transition period (0 min/day).

Taking into account the "working pulse", which varied between 120 and 121 beats/min, we showed that in all periods of the annual cycle (preparatory, competitive and transitional) and in the whole season, the median of pNN50% did not depend on the volume of training load expressed as Vkm (the values of the Spearman coefficient were respectively -0.00; -0.04; -0.01 and 0.02), or expressed as Vmin (the values of the Spearman coefficient were 0.00; 0.03; 0.07 and 0.02, respectively). At the same time, a comparison of the effect of the duration of the two types of loads, i.e. performed either within 1-3 zones, i.e. in aerobic mode, or performed in 4-5 zones, i.e. in anaerobic mode, by pNN50%, it was shown that with an increase in the duration of aerobic exercise, i.e. 1-3 zones, the median of pNN50% increases statistically significantly. However, this is typical for the preparatory period (Spearman's coefficient was 0.28; $p <0.05$), but such a dependence, judging by the value of the Spearman coefficient, did not manifest itself in the competitive (-0.02) and transitional (-0.20) periods, and in the whole season (0.09). It was not possible to identify the effect of the duration of anaerobic training loads (i.e., 4 and 5 zones) included in the training of an athlete K.D. on the median of pNN50% - Spearman's coefficient for the preparatory, competitive and transitional periods and for the season was 0.13; -0.08; -0.06 and 0.03, respectively). Figure 1 partially reflects these results.

The Value of pNN50% in Athletes, depending on the Type of Autonomic Regulation of Cardiac Activity

According to Shlyk NI et al [27] & Shlyk NI [28], in athletes, regardless of their sports specialization, age and other factors, HRV indicators mainly depend on the type of regulation of cardiac activity. However, we previously showed [23,24] that all 8 members of the Tatarstan national ski racing team, including the athlete K.D., according to the classification [27,28], have an autonomous type of regulation of cardiac activity, i.e., a clear dominance of the influence of PD of ANS on cardiac activity during registration of CIG in conditions of clinostasis. The high values of pNN50%, equal to 65.1%-72.9%, typical for the members of the RT team, including the athlete K.D., confirm our conclusion. In general, we believe that the innate features of the autonomic regulation of cardiac activity determine the choice of a sport and success in it.

Conclusion

Previously, we analyzed the spectral parameters (TP), the absolute power (ms^2) of HF-, LF- and VLF- waves and the relative (as a percentage of TP) power of these waves, i.e. HF%, LF% and VLF% [6,7,11-13] and time indicators: stress index (SI, conventional units) [23]; duration of normal R-R intervals (RRNN, ms) or heart rate (HR, beats/min) [24]. We confirmed that the values of TP, HF-, LF- and VLF- waves, as well as VLF% (in clinostasis conditions) reflect the effect of PD on the heart. At the same time, we assumed that the VLF% index probably reflects the intensity of synthesis of non-neuronal acetylcholine by cardiomyocytes [6, 7, 11], and LF% and HF% [6,12,13] and RRNN/HR [23] reflect the formation of a state of anxiety in connection with upcoming starts. Also in these studies, it was found that the median of TP increases with an increase in the volume (Vkm) and intensity (HRwp) of training loads of a ski racer [6]. The results presented in this review confirm the idea that the pNN50% value reflects PD of ANS activity - the higher the values of this indicator, the greater PD of ANS on heart activity [5,32-37,39,40]. This is especially typical for elite athletes who train for endurance [35,41-44], since with an increase in length of service and the level of sportsmanship, the values of pNN50% increase, which indirectly indicates an increase in PD of ANS activity. However, a review of the literature data indicates that the opposite trend is observed during strength training - with increasing skill and experience, the

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value of pNN50% decreases, which indicates an increase in the activity of SO of ANS when registering CIG in clinostasis [38,40]. A review of the literature data showed that the question of the influence of age and gender on the value of pNN50% remains open and requires further study.

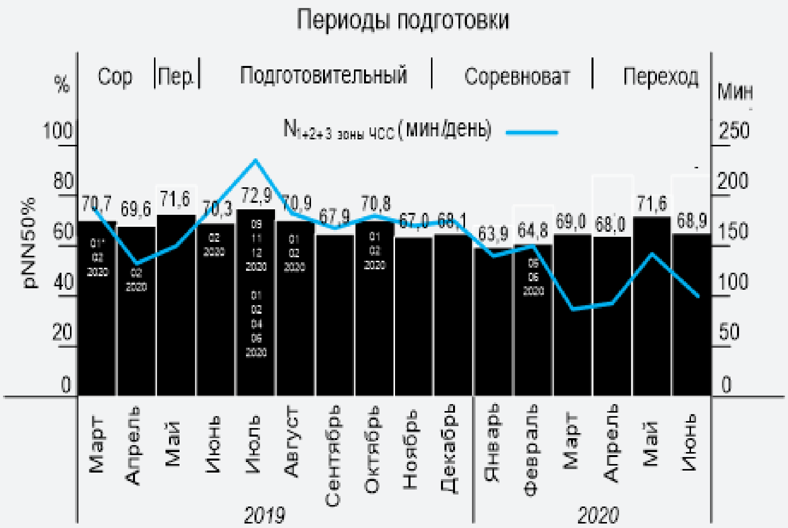

Figure 1: The medians of pNN50% (columns, %) and medians of the duration (minutes) of the training load carried out with an intensity of 1-3 zones, ie in the aerobic mode (line graph) of the elite skier K.D.
Note: above in Russian, the specified periods (preparatory, competitive and transitional); below – months of the year; scale on the left – pNN50% values, scale on the right - duration of training load (min).

Currently, it is widely believed that the values of HRV indicators in athletes do not depend on age, gender, length of service in sports, level of sportsmanship and other factors, but are determined by the innate type of regulation of cardiac activity [27,28,67,68]. However, our data on pNN50% values confirm our earlier conclusion that all members of the Tatarstan national ski racing team, including skier K.D., have an "autonomous" (according to the NI Shlyk classification [27,28]) the type of regulation of cardiac activity, which probably contributed to their athletic achievements in skiing due to their genetically programmed ability to synthesize non-neuronal acetylcholine in the myocardium. We have shown for the first time that the maximum values of the median of pNN50% are observed in the preparatory period for the elite ski racer K.D., and in the competitive period they decrease slightly, but statistically significantly and remain at this level in the transition period. Similar dynamics (for the preparatory and competitive periods) are typical for the entire team of skiers of Tatarstan team. This data confirms our assumption that anxiety increases in the competitive period, and therefore the activity of SD, which is also manifested when registering a cardiointervalogram (CIG) in clinostasis conditions.

We have shown the relative stability of the pNN50% value for elite skiers in the conditions of training camps (TC). So, for skier K.D., the median of pNN50% was initially 71.1%, in the middle of the TC – 72.9%, and at the end of the TC - 69.1%. We have shown for the first time that in the preparatory period, with an increase in the duration of the training load for a ski racer performed in 1-3 heart rate zones, the value of pNN50% increases, and, consequently, the activity of PD. However, for the competitive and transitional periods, as well as for the season, this dependence could not be identified. The review confirms our previous observations and conclusions based on the dynamics of spectral [6,7,11-13] and temporal [23,24] HRV indicators that they, including pNN50%, reflect an increased effect of PD on heart activity during many sports, especially those that develop endurance. Our data on the value of pNN50% confirm the assumption that in the process of adaptation of the body to high volume and intensity loads, an anti-apoptic system is formed that prevents damage to the heart, which inevitably occurs under the influence of oxidative stress

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and activation of beta$_1$-adrenergic receptors.

One of the important components of this mechanism is probably the so-called non-neuronal acetylcholine (Ach), which, under the influence of endurance training, cardiomyocytes begin to produce. As is known, Ach is a powerful antioxidant [69-71]. Previously, we showed [6,7] that the process of non- neuronal Ach-synthesis reflects such an indicator of clinostatic CIG as the relative power of VLF- waves (VLF%). The pNN50% index probably also reflects the formation of non- neuronal synthesis of Ach. This is indicated by the fact that for elite skiers throughout the entire annual cycle, its values are kept at a high level (65%-72%), while it decreases slightly during the transition period, but nevertheless, increases again, albeit slightly, in the preparatory period of the new ski season under the influence of training. Indirectly, this means that the synthesis of non- neuronal Ach persists for a long time, even with a decrease in the volume and intensity of training loads. It is also obvious that in the process of training and competitive loads aimed at increasing endurance, the activity SD of the ANS increases, as can be seen from the data of the remote heart rate registration of the skier-racer K.D., conducted using the POLAR H10 chest sensor (Figure 2). It is the SD of ANS that is the mechanism that prevents the excessive influence of non-neuronal Ach on the heart, and thereby prevents the formation of "sinus node weakness" at rest. We assume that the decrease in pNN50%, which can occur in an elite skier at the end of his sports career, will probably serve as one of the indirect evidence for the presence of non-neuronal synthesis of Ach by cardiomyocytes.

Figure 2: The heart rate (beats /min, upper panel) and speed (km/h, middle panel) of an athlete K.D., during the warm-up and competitive 15 km speed skating race at the "Continental Cup of Eastern Europe" in Syktyvkar, as well as the terrain of the ski slope (degrees, bottom panel) - according to the data of remote heart rate registration using the POLAR H10 chest sensor.

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