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# Absolute and Relative Power of LF Waves of Cardiointervalogram in Athletes (Literature Review)

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**Abstract**

The review systematizes information about the average values or medians of such indicators of heart rate variability (HRV) as the total power of the spectrum (TP), absolute (AMLF) and relative (LF%) power of low-frequency waves (LF-waves) of the cardiointervalogram recorded in the prone position. It has been established that the values of TP and AMLF increase with high motor activity, with an increase in the fitness of the athlete (experience in sports), with aerobic training, i.e., they depend on the sports specialization, as well as on the volume and intensity of training loads, which was revealed in relation to the values of TP. For cross-country skiers, the variability of the values of TP and AMLF during each of the three periods of the annual cycle is characteristic, but in general, there is an increase in their preparatory period, the preservation of high values in the competitive period and a decrease in the transition period. The idea is confirmed that TP reflects the influence of the parasympathetic department, and AMLF - the sympathetic department of the autonomic nervous system. Information regarding the value of LF% of athletes are few in number. Judging by the results of the study of the elite athlete K.D. (the first author of the article) and 7 members of the national team of the Republic of Tatarstan in cross-country skiing, this indicator increases significantly in the competitive period and decreases in the transition period. This is regarded as a reflection of the formation of emotional stress in the competitive period and, probably, the formation of the anti-apoptic myocardial system in the preparatory period.

**Keywords:** Athletes; Heart rate variability; Total spectrum power; Absolute and relative power of LF-waves; Training cycle periods; Pre-Start Emotional State

**Abbreviations:** HRV: Heart Rate Variability; ECG: Electrocardiogram; ANS: Autonomic Nervous System

## Introduction

Analysis of heart rate variability (HRV) is mainly used to evaluate patients with various diseases, including cardiovascular diseases [1]. The use of HRV analysis in athletes, including endurance athletes, is only gaining popularity [2]. HRV analysis, i.e. the variability of the duration of intervals R-R of the electrocardiogram (ECG) provides an assessment of the autonomic control of cardiac activity, including the effect on the activity of the heart of the sympathetic (SO) and parasympathetic (PO) divisions of the autonomic nervous system (ANS), as well as a number of biologically active substances [3]. A working group of the European Society of Cardiology and the North American Society for Stimulation and Electrophysiology ( EKO and NASPLE ) recommended the use of a range of temporal and spectral measures [4]. Among the latter is the power of the three main types of the CIG spectrum: 1) high-frequency (or HF-waves), for which the limits of the ranges are 0.15-0.40 Hz; 2) low-frequency (or LF-waves) with boundaries of 0.04-0.15 Hz; 3) very low-frequency (or VLF-waves) with boundaries of 0.003-0.04 Hz. In this case, the sum of all powers of the spectrum in the range from 0.003 to 0.5 Hz, i.e. HF + LF + VLF , is defined as the power of the total oscillation spectrum, or TP [4].

Earlier in our reviews, attention was paid to such indicators of the HRV of athletes, including cross-country skiers as TP, the absolute and relative power of VLF waves [5], and the absolute and relative power of HF waves [6], and their dependence on a number of factors. At the same time, it was found that the values of TP, the absolute power of VLF and HF-waves, and especially the relative power of VLF-waves, i.e. VLF% reflect the degree of influence of ANS software on the heart, and VLF% probably reflects the intensity of synthesis of non-neuronal acetylcholine by cardiomyocytes, and the values of the relative power of HF-waves, i.e. HF% reflect the formation of a state of anxiety. Also, in general, for the annual cycle, a direct dependence of the median TP on the volume of training loads, V km (the higher the volume, the higher the median TP), and a direct dependence of the median of the absolute power of VLF waves on the volume (V km) and intensity (N hrs) loads [7].

This review reflects the literature and our own data on the absolute and relative power of slow (LF) waves.

It was previously believed that slow or LF waves (0.04-0.15 Hz) mainly reflect the activity of baroreceptors at rest [8], i.e. implementation of the baroreceptor reflex [2,9]. Then it was postulated that LF waves reflect the state of the SO of the ANS [4,10,11], or the state of both parts of the ANS, i.e. SO and software. However, the interpretation of LF-waves as an indicator of sympathetic control of cardiac activity is questioned [12]. A number of authors associate the power of LF-waves with changes in blood pressure [13], or with the formation of psychological stress, since its presence increases the power of LF waves [14,15]. We proceeded from the idea that the power of LF waves mainly reflects the influence of SO ANS on the activity of the heart.

An analysis of the literature shows that information about the dynamics of the absolute power of LF-waves (AMLF) and relative (i.e. expressed as a percentage of TP) power of LF-waves (LF%) in athletes, including depending on the volume and intensity training loads are few. In connection with the need to optimize the training process, the purpose of this review is to systematize the data of the literature and our own research on the values of the absolute and relative power of LF waves, characteristic of athletes, including those training for endurance. We add that in many works cited below, as a rule, the values of LF% were absent, and therefore we calculated them on the condition that the values of TP and AMLF were indicated in the cited work and marked with the symbol*.

**LF and LF% values depending on the level of motor activity (athletes, non-athletes)**

Examining 65 teenage hockey players (mean age-14.7 years; "experience" of training-8.7 years) and 30 healthy adolescents not involved in sports, G.N. Shangareeva [16] found that the values of AMLF and LF% in hockey players were higher (1877 $ms^2$ and 35.1%, respectively) than in non-athletes (1164 $ms^2$ and 29.3%, respectively). In a study of 22 volleyball players (18-21 years old), members of the men's youth team of KhMAO-Yugra, and 22 healthy non-athletes (students of a medical university), it was found [17] that AMLF values in volleyball players were statistically significantly higher than in students (respectively, 1193 $ms_2$ versus 657 $ms_2$) , while the value of LF%, on the contrary, is lower (27% versus 35.3%). In the study of athletes and healthy people comparable in age, [18] came to the conclusion that in athletes, AMLF was statistically significantly higher than in non-athletes.

Thus, literature data indicate that AMLF values are higher in those involved in sports than in non-athletes [16-18]; indirectly, this indicates a more pronounced effect of SO ANS on the activity of the heart (at rest) compared to non-athletes. Information about the value of LF% is ambiguous - according to some data, it is higher in athletes [16], and according to others, on the contrary, it is lower [17].

## The values of AMLF and LF% depending on the "experience" (training) of the athlete and his sportsmanship

V.M. Mikhailov [19] studied two groups of football players - under the age of 21 and over 32 years old. He found that the AMLF was 2345 $ms^2$ and 1235 $ms^2$, respectively. This allows us to state that with an increase in the experience of sports training, i.e. AMLF may decrease with age. However, other authors [20], who studied swimmers from 8 to 14 years old, believe that with the training and age of the athlete, the value of AMLF increases , i.e. the influence of SO ANS on the activity of the heart at rest increases (information on the values of LF% is not given in this work). During the study of 16 skiers (18-25 years old) of different levels of sportsmanship (1st category, CMS and MS) during the training camp, it was found [21] that the median AMLF was 1544 $ms^2$, 1089 $ms^2$ and 3772 $ms^2$, respectively, and the median LF% 27.3%*, 14.4%*, 33.5%*, respectively. These data indicate that in athletes, including cross-country skiers, the AMLF value recorded under clinostasis conditions is higher than in non-athletes, while with an increase in sportsmanship it can change, including increase. This suggests that athletes in conditions of clinostasis have a higher effect of SO ANS on the activity of the heart than non-athletes. Regarding the LF% indicator, information is scarce and ambiguous.

**LF and LF% values for overtraining**

According to T N Solomka [22], 1-3 weeks before the decrease in sports results, the relative power of LF waves increases, i.e. LF%, and the relative power of fast (HF) waves decreases, which is estimated as excessive activation of SO ANS. E A Gavrilova [23] believes that a decrease in AMLF and LF% against the background of an increase in the absolute power of HF waves indicates an increase in the functional state of an athlete (this allows predicting an increase in the level of training of an athlete), while an increase in AMLF and LF% indicates a decrease in the functional state athlete and his overtraining. The literature also


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reports that a decrease in AMLF may indicate an athlete's fatigue [24-26], and his overtraining [27]. Thus, literature data on this issue are ambiguous.

## LF and LF% values depending on the type of sports specialization

In a study of 29 adolescents aged 11-14 years old involved in cross-country skiing and 40 of their peers involved in sports tourism, it was found [28] that skiers had higher AMLF values than tourists (the authors do not give specific values of LF% of the indicator). In a study of 18-19-year-old swimmers, hockey players, and weightlifters, it was found [29] that AMLF values were the highest in hockey players (2308 $ms^2$), lower in swimmers (1380 $ms^2$), and even lower in weightlifters (810 $ms^2$); but LF% in swimmers were higher - 30.3% than in hockey players (26.6%) and swimmers (28.2%). These data indicate that the values of AMLF and LF% depend on sports specialization. In a study of 18-23-years-old athletes (66 skiers, 20 swimmers, 33 Greco-Roman wrestlers), it was found [30] that the AMLF values were maximum in skiers - 2137 $ms^2$, significantly less in wrestlers - 1330 $ms^2$, and even less in swimmers - 1102 $ms^2$; and the values of LF% were maximum in swimmers - 33.3%, less in wrestlers - 28.5%, and even less in skiers - 22%. A postgraduate student of our laboratory, a doctor of functional diagnostics (V.V. Kishkina 2017, unpublished data), conducting daily ECG monitoring of 40 adolescents aged 15-16 years, found that in 20 of them involved in swimming or athletics, the average daily median AMLF was 4040 $ms^2$, and for 20 adolescents involved in football or basketball-3900 $ms^2$, i.e. it was not possible to reveal the influence of sports specialization in adolescents in the conditions of their examination in a hospital. In a study of 1005 men aged 16 to 40 years, of which 305 were engaged in cyclic sports, 200 in complex coordination sports, 150 in team sports and 350 in martial arts, it was found [31] that the values of LF% depend little on sports specialization (they were 29.1%, 30.8%, 27.6% and 30.2%, respectively, and the differences between them were statistically insignificant (p>0.05) Commenting on these data, E. A. Rul & O. N. Kudrya [32] believe that AMLF and LF% values do not depend on sports specialization, but are determined by the type of regulation of cardiac activity, which is discussed in more detail below.

Since the opinions of the authors differ, we considered it necessary to summarize the literature data on the values of AMLF and LF% of athletes, taking into account their sports specialization.

### Ski Racers

In a study of 18-25-year-old elite ski racers (masters of sports, MS) it was revealed [21] that even at one training camp, the median AMLF for these skiers varied from 3334 to 3772 $ms^2$, and the median LF% varied from 26% to 33.5%. In a study of 34 cross-country skiers aged 17-22 years, it was noted [32] that, due to the presence of different types of regulation of the activity of the heart, they are characterized by a high variation in AMLF values - from 334 to 12231 $ms^2$ (LF% values are not given). It was shown [33] that in 20-22-year-old skiers, the TP values at one training camp (TC) varied from 3320 to 3399 $ms^2$, the AMLF values varied from 1196 to 1222 $ms^2$, and the LF% values varied from 35.9% to 36.7%. According to our data [7], which are described in more detail below, the elite skier-racer master of sports K.D. during the annual season, the medians TP, AMLF and LF% varied from 5754 to 11099 $ms^2$, from 1107 to 2912 $ms^2$, and from 16.2 to 25.8%, respectively. R. Hedelin et al. [34], who studied cross-country skiers aged 16-19, found that the values of AMLF and LF% change throughout the entire ski season. In particular, after the preparatory and competitive periods, i.e. during the transitional period, the AMLF values decreased, and the LF% values increased only in the competitive period, which is regarded as a reflection of the growth of SO activity, especially in the competitive period.

So, ski racers have high values of TP and AMLF, as well as a high variability of AMLF and LF% throughout the entire annual training cycle [5-7,21,32-34], which probably reflects undulating activity SO ANS depending on the volume and intensity of the training load.

### Biathletes

In a study of 25 biathletes (CCM, MS at the age of 21.5 years) in July (the beginning of the preparatory period), in November (the end of the preparatory period) and in March (the end of the competitive period), it was found [35] that the values of TP, AMLF and LF% varied respectively from 5228 $ms^2$ to 7059 $ms^2$, from 1343 $ms^2$ to 1614 $ms^2$, and from 22.8%* to 25.6%*. In 46 biathletes (CMS, MS) aged 18-25 years, the values of TP, AMLF and LF% depended on the type of regulation of cardiac activity [36] in 21 athletes with a central type of regulation, the values of TP, AMLF and LF% amounted to 2681, respectively $ms^2$, 1830 $ms^2$ and 68.2%*, and 25 in athletes with an autonomous type of regulation- 5735 $ms^2$, 1290 $ms^2$ and 22.4%*, respectively.

### Swimmers

In 8-9-year-old swimmers, the values of TP, AMLF, and LF% were 3226 $ms^2$, 1437 $ms^2$, and 44.5%*, respectively, and in 14-15-year-old swimmers, they were 4536 $ms^2$, 1503 $ms^2$, and 33.1%*, respectively [20]. This means that with an increase in the swimming experience, the value of TP increases and the value of LF% decreases. According to [29], in 18-19-year-old swimmers, the values of TP, AMLF, and LF% were 4546 $ms^2$, 1380 $ms^2$, and 30.3%*, respectively. It was established [30] that in 18-23-year-old swimmers, the values of TP, AMLF, and LF% were 3310 $ms^2$, 1102 $ms^2$, and 33.3%*, respectively. At the same time, F.B. Litvin et al. [37], studying 50 swimmers (15.5 years old), found that the values of TP, AMLF and LF% depend not on sportsmanship, but on the type of regulation of cardiac activity in sympathicotonics, the values of these indicators were respectively 1173 $ms^2$, 404 $ms^2$ and 34.4%*, in normotonics, respectively, 4234 $ms^2$, 1319 $ms^2$, and 31.1%*, and in vagotonics, 10370 $ms^2$, 4215 $ms^2$, and 40.6%*.


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## Team Sports (Hockey players, Volleyball players, Handball players, Football players, Basketball players)

In 22 male volleyball players (18-21 years old), the values of TP, AMLF and LF% were 4405 ms$^2$, 1193 ms$^2$ and 27%*, respectively [17]; in 14-15-year-old hockey players, the values of TP, AMLF and LF% were 5347 ms$^2$, 1877 ms$^2$ and 35.1%* [16]; in 18-year-old hockey players they were 8649 ms$^2$, 2308 ms$^2$, and 26.6%*, respectively [29]. According to N.V. Ivanova [31], in 150 men (16-40 years old) involved in team sports, the LF% values were 27.6%. HE. Kudrya [38], examining 22 male handball players (1 adult, CMS, MS), aged 20.3 years, experience 8-14 years) 6 times during the annual cycle: at the beginning and at the end of the preparatory period; at the beginning and at the end of the 1st round of games, as well as at the beginning and at the end of the 2nd round of games, found that the values of TP, AMLF and LF% varied from 2781 ms$^2$ to 8015 ms$^2$, respectively; from 904 ms$^2$ to 2271 ms$^2$ and from 28.3%* to 32.5%*.

## Martial arts (Greco-Roman Wrestlers, Taekwondo, Jiu-Jitsu)

In 18-23-year-old Greco-Roman wrestlers (n=33), the values of TP, AMLF and LF% were 4668 ms$^2$, 1330 ms$^2$ and 28.5%*, respectively [30]. In a study of 14 highly qualified taekwondo athletes (23.5 years old), members of the Russian national team, of which 7 are women, it was found [39] that in men the values of TP, AMLF and LF% varied, respectively, from 5506 to 20918 ms$^2$, from 1989 to 6928 ms$^2$ and from 33.1%* to 36.1%*, while in women these figures varied from 3035 to 16738 ms$^2$, respectively; from 1075 to 5229 ms$^2$ and from 31.2%* to 35.4%*. Thus, in both men and women, TP and AMLF values show high variability, while LF% values are relatively stable. In 25-year-old male athletes ( n=18), engaged in Brazilian jiu-jitsu, the values of TP, AMLF and LF% were 3283 ms$^2$, 1215 ms$^2$ and 37%*, respectively [40]. It was established [31] that in 350 men (16 to 40 years old) engaged in martial arts, the values of LF% were 30.2%.

## Other Sports

In 23 men (aged 17-28 years) involved in bullet shooting, the values of TP, AMLF and LF% were 4475 ms$^2$, 1634 ms$^2$ and 34.3%, respectively [41], and in 18-year-old weightlifters, respectively, 2871 ms$^2$, 810 ms$^2$ and 28.2%* [29].

### Section Summary

So, the analysis of the literature shows that the values of TP, AMLF in athletes of different specialties have a wide range and at the same time depend on sports specialization. The highest values were noted among taekwondo fighters [39], as well as among cross-country skiers [21]. At the same time, the variability of these indicators during the annual training cycle was noted, which is discussed in more detail below. In other sports, there is also a fairly wide range of TP and AMLF values [36-38,41]. It is most likely that the variability of the values of TP and AMLF depends on the degree of training and the stage of preparation. Regarding the values of LF%, the literature data are ambiguous.

## The values of TP, AMLF, LF% depending on the volume and intensity of training loads and on the period of the annual cycle

D. Plews et al. [42] indicate that in elite athletes training for endurance, SO activity correlates with high load intensity. The same conclusion is reached by V. Manzi et al. [10], pointing out that the AMLF values not only increase in response to a high load intensity, but also correlate with the athletic performance of amateur athletes in marathon running (the LF% indicator is not mentioned). It has been shown [2] that an increase in the total volume of load in elite endurance athletes reduces HRV, but the amount of training volume required to reduce HRV may depend on the population. For example, HRV was not affected by 60- and 120-minute loads, provided they were performed at low intensity (50 and 63% MIC max ). On the other hand, in a population of moderately active non-athletes, a 90-minute run (60% of VO2max ) reduced HRV, whereas 30- and 60-minute runs at the same intensity did not reduce HRV.

In the annual training cycle, in particular, it is customary for cross-country skiers to single out preparatory, competitive, and transitional periods [43]. Some authors note that the highest TP values in athletes are typical for the preparatory period, while in the competitive period the TP values may decrease, and the AMLF values increase [23,44]. The same conclusion is reached by Hedelin et al. [34], who studied cross-country skiers aged 16-19; the authors found that in the transitional period the value of AMLF is lower than in the preparatory and competitive periods; this, in their opinion, indicates a decrease in the activity of SO ANS in the transition period. In a study of 25 biathletes (CMS, MS, 21.5 years old) in July (the beginning of the preparatory period), in November (the end of the preparatory period and the beginning of the competitive period) and in March (the end of the competitive period), it was found [35] that the TP values were respectively 5868 ms$^2$, 5228 ms$^2$ and 7059 ms$^2$; the AMLF values are 1576 ms$^2$, 1344 ms$^2$, and 1614 ms$^2$, respectively, and the LF% values are 26.8%*, 25.7%*, and 22.8%*, respectively. It can be concluded that AMLF is relatively stable, while LF% decreases in the end of the competitive period. Studying 22 male handball players (1 adult, CMS, MS; average age -20.3 years, sports experience 8-14 years) with 6-fold registration of the CIG, including at the beginning and at the end of the preparatory period, at the beginning and in at the end of the 1st round of games, as well as at the beginning and end of the 2nd round of games, O.N. Kudrya [38] found that the TP values were 2781 ms$^2$, 4664 ms$^2$, 5275 ms$^2$, 8015 ms$^2$, 4431 ms$^2$, and 3926 ms$^2$, respectively; AMLF values are 1099 ms$^2$ , 1445 ms$^2$, 1579 ms$^2$, 2271 ms$^2$, 1307 ms$^2$, and 904 ms$^2$, and the values of LF% are respectively 39.5%*, 30.9%*, 29.9%*, 28.3%*, 29.4%*


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and 23%*. The author concludes that in the preparatory period and in the first half of the competitive period there is a significant increase in the values of TP and AM LF, and the value of LF% gradually decreases from the beginning of the preparatory period to the end of the competitive period.

We have found that the elite skier-racer athlete K.D. (the first author of the review), which is reported in more detail in our article [5], the values of TP, AMLF and LF% vary throughout the annual cycle. These data were obtained during the registration of CIG, carried out in the morning of the next day (i.e., after training or competition), before meals in the supine position using VNS-Micro by the Neurosoft company (Ivanovo) using the Poly- Spectrum" of the same company. At the same time, the CIG parameters were compared with the volume and intensity of the training loads of the athlete K.D. It was established (Figure 1) that the athlete K.D. median TP changed throughout the sports season (from 5754 to 11099 $ms^2$), including increased in the preparatory period (up to 9473 $ms^2$), remained high in the competition period (8047 $ms^2$) and statistically significantly ($p<0.05$) decreased in the transition period (6961 $ms^2$). At the same time, in the preparatory and transitional periods, the median TP fluctuated from month to month, while in the competitive period it was relatively stable (Figure 2). Calculation of the Spearman coefficient showed that the values of TP are directly dependent on the volume of the training load, expressed by the length of the running route for 1 training day (V km), as well as on the intensity of the training loads (N hrs), judging by the value of the "working" pulse (beats per minute) during exercise.

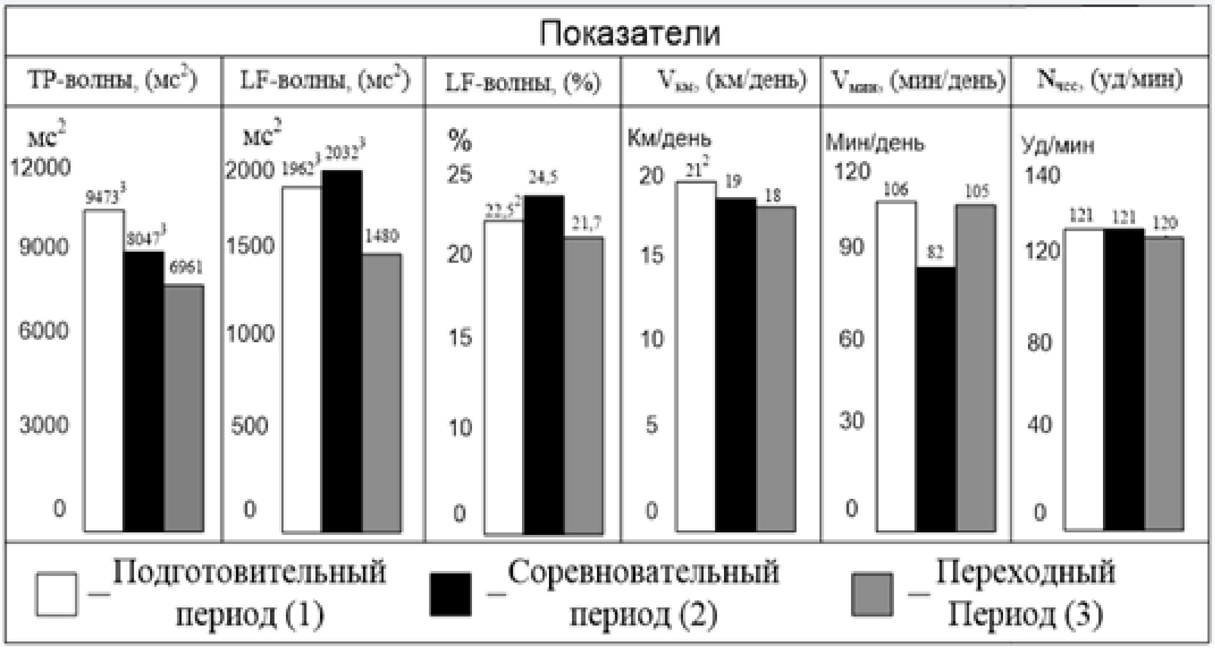


**Figure 1:** Dynamics of the values of the median total power TP (ms2), absolute TP values of LF waves (ms2) or AMLF, relative power of LF waves, ie LF%, as well as the volume of training loads, expressed in km of the way (Vkm) or the duration of training (Vmin), and its intensity, expressed by the value of the "working" pulse, beats/min (Nhr) in the preparatory (1), competitive (2) and transitional (3) periods (respectively- the 1st, 2nd and 3rd columns) for the athlete TP KD.

We found (Figure 3) that the median AMLF in athlete K.D. also changed during the annual season (from 1107 to 2912 $ms^2$), including increased in the preparatory period (1962 $ms^2$), remained high in the competition period (2032 $ms^2$), and decreased in the transition period (1480 $ms^2$) (Figure 1). At the same time, in all three periods, there were statistically significant differences between the individual months of the period. It was not possible to reveal the dependence of AMLF on the volume (V km, V min) and intensity (N hrs) of the load, including in general throughout the entire annual season, it was not possible.

Median LF% in athlete K.D. also changed during the sports season (from 16.2% to 25.8%) (Figure 4). In the preparatory period, it was 22.5%, statistically significant ($p<0.05$) increased during the competition period (24.5%) and tended to decrease during the transition period (21.7%) (Figure 1). It was not possible to reveal the dependence of the median LF% on the volume (V km, V min) and intensity (N hrs) of training loads, including, in general, for the annual cycle, it was not possible.



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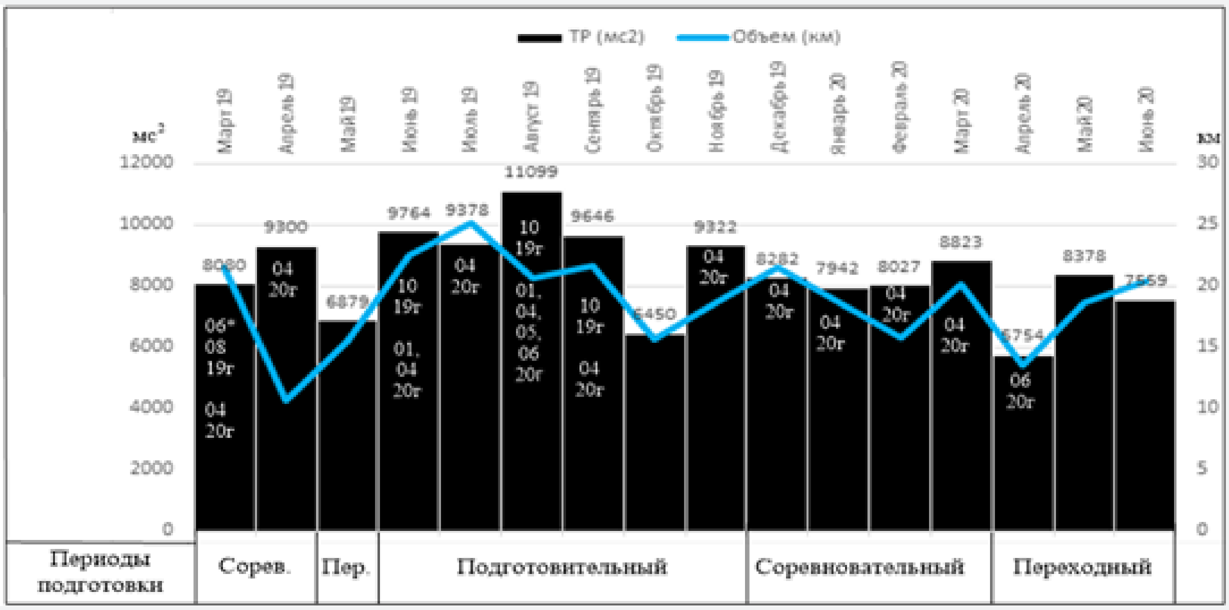


**Figure 2:** Dynamics of median TP (columns) and volume (Vkm) of the training load (line graph) of the elite athlete KD.
Note: The numbers inside the columns reflect the months from which this month is statistically significant (according to the Mann-Whitney test, i.e. p<0.05) differs in TP values.

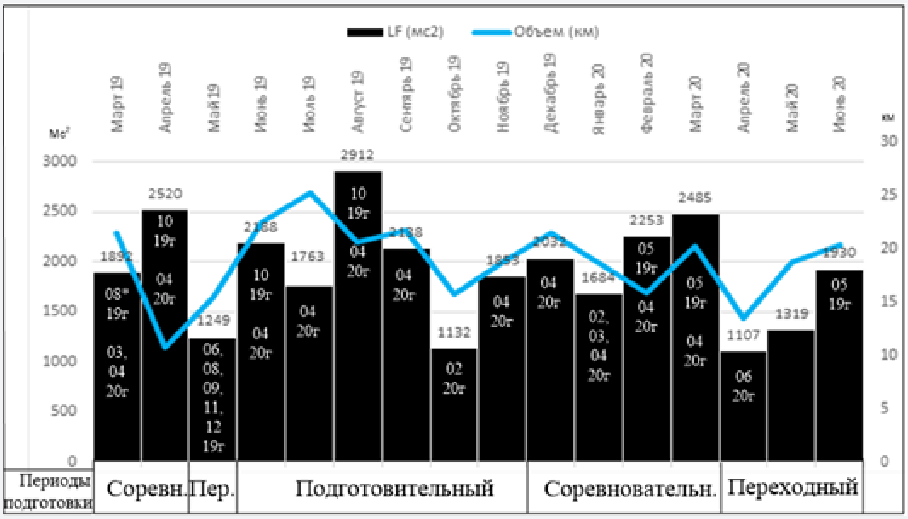


**Figure 3:** Dynamics of medians AMLF (bars) and volume ( Vkm ) of training load (line graph) of elite athlete KD.
Note: The numbers inside the columns reflect the months from which this month differs statistically significantly (according to the Mann-Whitney test, i.e. p<0.05) according to the AMLF values.

We have also shown (Figure 5) that for 8 members of the national team of Tatarstan in cross-country skiing (6 MS and 2 MSMK) during the preparatory and competitive periods, the median TP and LF% have similar dynamics, as in the athlete K.D. , and namely, in the preparatory period the median TP were significantly ($p<0.05$) higher than in the competitive period (respectively 9923 ms$^2$ versus 7864 ms$^2$), the median LF% in the preparatory period was lower than in the competitive period (respectively 19.9% versus 22.7 %). We explain the growth of LF% in the competitive period by the fact that this period, as is known [45], is characterized by the formation of a feeling of anxiety, which reflects the increased influence of the SO ANS on the work of the heart at rest. With regard to the AMLF dynamics , there are differences between the athletes of the Tatarstan team-


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in athletes of the Tatarstan team the AMLF values (2057 $ms^2$) in the preparatory period were higher than in the competition (1728 $ms^2$), but these differences were statistically insignificant (p>0.05).

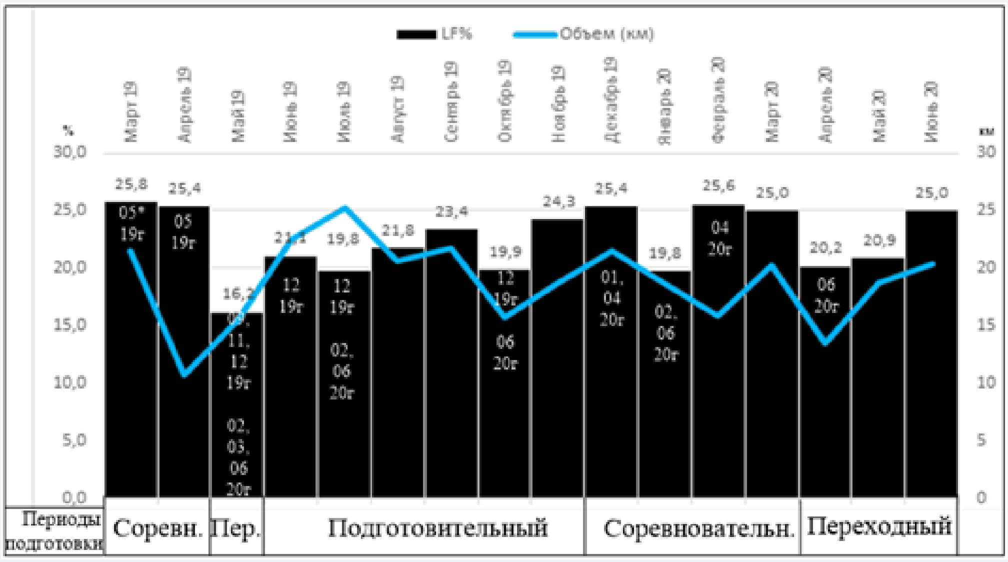


**Figure 4:** Dynamics of medians LF% (bars) and volume (Vkm) of the training load (line graph) of the elite athlete KD.
Note: The numbers inside the columns reflect the months from which this month differs statistically significantly (according to the Mann-Whitney test, i.e. p<0.05) in terms of LF% values.

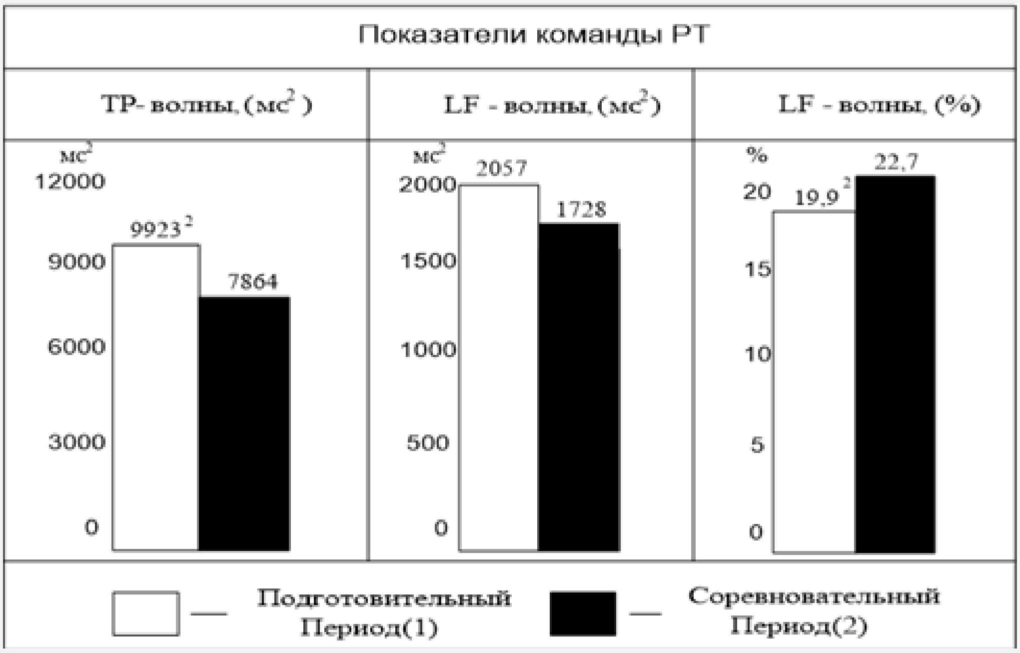


**Figure 5:** Dynamics of the median TP, AMLF and LF% in the preparatory (1) and competitive (2) periods (respectively - the 1st, 2nd columns) for 8 skiers-racers of the RT team.
Note: 2-means that the differences with the competitive (2) period are statistically significant according to the Mann-Whitney test, p <0.05.



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According to other authors, the values of TP, AMLF and LF% in skiers change throughout the annual training cycle and even during one training camp (TC). Thus, in a study of 18-25-years-old elite cross-country skiers (MS), it was found [21] that the median TP at the beginning of the TC was 11258 $ms^2$, and at the end it was 12779 $ms^2$, AMLF was 3772 $ms^2$ and 3334 $ms^2$, respectively , and LF%- 33.5%* and 26%*. In a study of 20 cross-country skiers (20–22 years old), it was found [33] that the TP values before and after the completion of the TC were 3399 $ms^2$ and 3320 $ms^2$, respectively, AMLF were 1196 $ms^2$ and 1222 $ms^2$, and LF% were 35.1%* and 36.8%*, i.e. did not change significantly. According to our data, the athlete K.D. even during one month of the next period, there are statistically significant wavy changes in the medians of TP, AMLF and LF% (Figure 2, 3, 4), which we explain by a change in the amount of training or competitive load.

## The Values of TP, AMLF and LF% in athletes depending on the type of autonomic regulation of Cardiac Activity

According to a number of authors whose works have already been cited above, the values of TP, AMLF and LF% significantly depend on the type of regulation of cardiac activity [32,36,37,46,47]. In particular, based on the values of the stress index (SI) and the absolute power of VLF waves (AM VLF ), it was proposed to distinguish four types (I, II, III, and IV) of the regulation of cardiac activity, which is determined by the severity of central and autonomic regulation [32,47]. I and II types of regulation are athletes, respectively, with moderate (SI>100; AM VLF>240 $ms^2$) the predominance of central regulation, and types III and IV, respectively, with moderate (SI-30-100; AMVL>240 ms2), or with pronounced (SI<30; LVLF>500 ms2) predominance of autonomous regulation. In fact, the central regulation, according to N.I. Shlyk [32,47] is the dominance of the effect of SO ANS on the heart under conditions of clinostasis, and autonomous regulation is the dominance of the effect of PO ANS under conditions of clinostasis. Thus, in a study of 46 biathletes (CMS, MS, 18–25 years old), it was found [36] that in 21 athletes with a central type of regulation, the values of TP, AMLF and LF% were respectively 2681 $ms^2$, 1830 $ms^2$, and 68.2%*, and in the autonomous type of regulation (n=25)-5735 $ms^2$, 1290 $ms^2$ and 22.4%*, respectively.

Another option for classifying athletes is to divide them into sympathicotonic, vagotonic and normotonic [37,46]. The values of such HRV indicators as RRNN and SI [46], or the value of TP [37] were taken as the division criterion. Thus, in a study of 50 swimmers (age 15.5 years), it was found [37] that in sympathicotonic patients, the values of TP, AMLF and LF% were 1173 $ms^2$, 404 $ms^2$ and 34.4%*, respectively, in normotonics, respectively, 4234 $ms^2$, 1319 $ms^2$ and 31.1%*, while in vagotonics it was 10370 $ms^2$, 4215 $ms^2$ and 40.6%*, respectively. In a study of young cross-country skiers aged 10 and 11 years ( n=32), it was shown [46] that the values of TP, AMLF and LF% in sympathicotonic patients (n=6) were 1798 $ms^2$, 608 $ms^2$ and 33.8%, respectively, in normotonic (n=14) - 5621 $ms^2$, 1503 $ms^2$ and 26.7%*, respectively, and in vagotonics ( n =12) - 19028 $ms^2$, 4313 $ms^2$ and 22.6%*, respectively. We believe that the question of the dependence of TP, AMLF and LF% on the type of regulation of cardiac activity, raised in a number of works [32,36,37,46,47], requires additional evidence, including in experiments with animals.

## Conclusion

It is believed that the AMLF values reflect the state of the SO of the ANS [4,10,11], or the state of both parts of the ANS, i.e. SO and PO, or realization of the baroreceptor reflex [2,9]. However, some authors question the interpretation of LF waves as an indicator of sympathetic control of the activity of the heart [12]. Some authors associate the index of LF waves with changes in blood pressure [13], or with the formation of psychological stress, which increases the power of LF waves [14,15].

A review of the literature allows us to state that with high motor activity, i.e. when practicing many sports, the degree of influence of SO ANS on the activity of the heart increases, which is reflected in an increase in the average values or median of TP [16,17] and AMLF [18]. However, in relation to LF%, the information is ambiguous - according to some data, it is higher in athletes than in non-athletes [16], and according to others, on the contrary, it is lower [17].

With an increase in the growth of sportsmanship, the value of AMLF increases [20,21], which indicates an increase in the influence of SO ANS on the activity of the heart during CIG registration under clinostasis. It should be noted that athletes of different sports specializations have a wide range of variability of TP and AMLF [5, 21, 36-39, 41]. The values of TP, AMLF and LF% and their variability depend on the period of sports training [7,23,34,44], on the volume of the athlete's training load [2, 5, 7, 10, 42]. In particular, it has been shown that elite athletes during the preparatory period have a wave-like change in the values of TP, AMLF, LF%, namely, in the competitive period, the values of TP can decrease, while AMLF and LF% increase [5,7,23,44], and during the transitional period, AMLF values decrease [7,34].

LF value , and especially the LF% value in the competitive period and the decrease in these values in the transitional period , established by us [7] during the registration of CIG in conditions of clinostasis, can be regarded as a consequence of the formation of emotional stress in the competitive period caused by an anxiety state in connection with the upcoming participation in competitive starts. It is important that this dynamic is also characteristic of elite skiers. Other authors [48,49], who found an increase in AMLF in an athlete on the eve of the competition, also speak about the presence of such a condition in athletes. It is important to note that, according to clinicians, anxiety in patients with Parkinson's disease [50] or depression [51], judging by the decrease in HRV, increases the influence of SO ANS, which is reflected in the registration of CIG under clinostasis. Yes, M.


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Suzuki et al. [50], recording CIG during the day using POLAR chest sensors V800 and POLAR H10 in 27 patients with Parkinson's disease revealed a general decrease in HRV. In the study by S. Koch et al. [51], carried out on 2250 patients suffering from depression (1982 - healthy people), on the basis of temporal and spectral parameters, a decrease in HRV in patients with a depressive state was also revealed.

It can be assumed that a significant increase in LF% observed during the competitive period may be a consequence of the formation in the preparatory period of the so-called anti-apoptotic system of the myocardium, due to which the viability of cardiomyocytes is maintained under conditions of excessive physical exertion during sports endurance training and, at the same time, the efficiency of activation of myocardial adrenoreceptors increases. An analysis of literature data shows that this system may include endogenous antioxidants, including antioxidant enzymes such as superoxide dismutase [52-56], endogenous sensitizers of beta-adrenergic receptors, or ESBAR, including histidine, tryptophan, and tyrosine [57-60], as well as dopamine [61,62], serotonin [63], prostaglandins [64,65], nitric oxide [66-68], non-neuronal acetylcholine [5,7,69], and other hormones and mediators that exhibit the properties of antioxidants and anti-apoptotic factors, such as melatonin [53,70].

Undoubtedly, our hypothesis about the presence of an anti-apoptotic myocardial system requires careful proof. But the identification of its components and formation mechanisms deserves great attention, given the high percentage of heart disease in people leading a sedentary lifestyle under stressful conditions. Particular attention should be paid to the question of the dependence of the values of TP, AMLF and LF% on the type of regulation of the cardiac activity of an athlete, including a cross-country skier [32,36,37,46,47]. We believe that this question requires additional evidence, including in experiments on animals. We do not rule out that the type of regulation of cardiac activity depends on the components of the myocardial anti-apoptotic system, the composition of which can be largely individual. At the same time, we believe that the general patterns of dependence of the values of TP, AMLF and LF% on the type of sports specialization, the level of sportsmanship, on the periods of the training macrocycle, on the volume and intensity of the training session, will be characteristic of an athlete, regardless of the type of regulation of cardiac activity.

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