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AGE DYNAMICS OF INDICATORS OF THE MICROCIRCULATION SYSTEM IN STUDENTS ACCORDING TO LASER DOPLER FLOWMETRY

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The article is devoted to the problem of studying blood microcirculation in healthy individuals at different stages of ontogenesis.
The aim *of the study was to investigate the peculiarities of the skin blood flow in students aged 17–21.*
Materials and ways of the research*. In order to study the functional state of blood microcirculation the method of laser Doppler flowmetry (LDF) was used.*
Results. *Determination of the age dynamics of the tissue blood flow in subjects aged 17–21 years showed that the parameter of microcirculation in the subjects increased from minimal values at 17 years to maximal values at 21 years. In the female subjects, the value of the microcirculation parameter was higher at 17 years than in the male subjects, while the maximum perfusion value for girls was at 19 years and at 20 years in the male subjects. Assessment of the regulatory devices showed that the amplitude value of low-frequency oscillations in females fell at the age of 19 years and in males at 20 years. The maximal amplitude index of vasomotor oscillations was registered at the age of 19 years both for boys and girls. The amplitude of vasomotor oscillations in the high-frequency range varied in both girls and boys. Three types of LDF-grams were identified among the young adolescents: aperiodic LDF-grams, which correspond to normoemic type of microcirculation, monotonous low amplitude LDF-grams, which correspond to hypooemic type of microcirculation, sinusoidal LDF-grams, which correspond to hyperemic type of microcirculation.*
Conclusions. *As many studies have shown, the heterochronicity of values of blood microcirculation indices is preserved in male and female subjects: in one age section the indices are higher in females, in the other one – in adolescents. This fact reflects the general biological regularity of different maturation of male and female organisms*
Keywords: *microcirculation of blood, laser Doppler flowmetry, age periods of ontogenesis*

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1. Introduction

The state of health of the population is of paramount importance at the stage of development of each country. Today, the survey of the health of student youth remains an urgent problem, as their age is important for the realization of reproductive function [1, 2]. At the same time, during this period there are morpho-functional disorders of the main body systems, which are associated with new loads: requirements for higher education, changes in lifestyle and living conditions, bad habits, increased neuropsychological activity [2, 3].

The skin has a dense network of blood vessels. The autonomic nervous system controls the expansion or contraction of the lumen of blood vessels, regulates the temperature of a particular area of skin and the whole body. Nerve connections between the skin and the internal organs occur through viscero-skin reflexes. When the sensitivity of resistant areas of the skin is disturbed, trophic, vascular, and secretory reactions are also disturbed. At internal pathology there are various vascular and trophic effects. Therefore, the importance of studying the processes occurring in human skin is becoming broader [4, 5]. Indicators of cutaneous blood flow to some extent reflect the processes occurring in the internal organs [6, 7].

The question of the peculiarities of cutaneous blood flow in healthy individuals is not as obvious as the clinical diagnosis [7, 8]. Therefore, the problem of studying blood microcirculation in healthy individuals at different stages of ontogenesis remains relevant.

Thus, **the aim of the study** was to investigate the individual-typological features of cutaneous blood flow in students 17–21 years.

2. Materials and methods

The study was performed in the Research Laboratory of Physiological Research of the Department of Human and Animal Anatomy and Physiology of Bohdan Khmelnytsky Melitopol State Pedagogical University within the complex research theme of the Department “Psychosomatic features of student health” (registration number 0120U101436) in 2021–2022 academic year.

The study examined 50 healthy young men and women aged 17–21, volunteer students studying at the

Bohdan Khmelnytsky Melitopol State Pedagogical University. The paper adheres to ethical principles for people who are subjects of research, taking into account the main provisions of the Guidelines for Good Clinical Practice (GCP) dictated by the International Conference on Harmonization (ICH) and the Helsinki Declaration of the World Medical Association for Biomedical Research, in which people are their object (World Medical Association Declaration of Helsinki, 1964, 2000, 2008), the Council of Europe Convention on Human Rights and Biomedicine (2007), the relevant laws of Ukraine.

Before enrolling, students took a questionnaire in which they answered their general health and permission to use the personal data obtained in the study. The results of compliance with biotic norms were considered in the protocol of the Department of Human and Animal Anatomy and Physiology of Bohdan Khmelnytsky Melitopol State Pedagogical University No. 10 from 01.03.2022.

In order to study the functional state of blood microcirculation, the method of laser Doppler flowmetry (LDF) was used, which allowed to assess the state of cutaneous blood flow [9, 10]. The LDF method is based on non-invasive optical detection of tissues by a monochromatic signal (usually in the red region of the spectrum) and analysis of the frequency spectrum of the signal reflected from motile erythrocytes [11, 12]. The study used a highly informative computer laser Doppler flowmeter LAKK-0.1 with a laser radiation source at a wavelength of 0.63 μm. The curve of real-time LDF-gram records was displayed on the computer monitor screen. In the study of blood microcirculation in humans, the sensor head of the device was fixed on the palmar surface of the distal phalanx of the fourth finger. The duration of the standard recording was 4 minutes.

The computer program for processing LDF-gram allowed to determine the following characteristics of blood microcirculation: microcirculation parameter (MP); standard deviation (SD) of the recorded Doppler signals; coefficient of variation (Kv). Indicators were measured in conventional units – perfusion units (perf. Units).

Amplitude-frequency analysis (AFA) of hemodynamic rhythms was also performed, which was based on the spectral cleavage of the LDF -gram. Among them, very low-frequency VLF (metabolic oscillations), low-frequency LF (vasomotor oscillations), high-frequency HF (respiratory oscillations) and pulse flaxmotions of CF oscillations are physiologically significant [10, 12].

The obtained data were subjected to mathematical and statistical processing using Biostat 5.0. The Shapiro-Wilk test was used to test the normality of the data distribution. The standard Microsoft Excel software product was used to prepare tables and calculations.

3. Research results

During individual development, the system of blood microcirculation continues to undergo functional changes, which in turn is associated with changes in the mechanisms of regulation of both local and central [13, 14]. According to the results of the study, the value of perfusion in the subjects gradually increased from 17 years to a maximum of 20–21 years (Table 1).

Table 1

Age dynamics of microcirculation indicators according to LDF data in students aged 17–21 years

Microcirculation parameter	17	18	19	20	21
MP, perf. units					
girls	7.8±0.5	8.2±0.7	9.0±0.8	8.3±0.6	7.9±0.6
boys	6.7±0.4	7.6±0.6	8.0±0.7	8.9±0.7	8.2±0.7
SD, perf. units					
girls	0.92±0.15	0.9±0.16	1.07±0.17	1.18±0.18	1.20±0.16
boys	0.85±0.12	0.96±0.14	0.90±0.15	1.13±0.16	1.22±0.17
Kv, c. u.					
girls	1.7±0.15	1.64±0.12	1.72±0.13	1.68±0.13	1.73±0.14
boys	1.61±0.14	1.65±0.12	1.7±0.14	1.66±0.11	1.75±0.15

The value of blood microcirculation (MP) in girls (Fig. 1) varied in the studied interval of ontogenesis in waves. The lowest values were recorded at the age of 17 years – 7.8±0.5 perf. units, maximum at 19 years – 9.0±0.8 perf. units, with a gradual decrease to 7.9±0.6 perf. units up to 21 years. The value of SD increased from a minimum value of 0.92±0.15 perf. units at 17 years to 1.20±0.16 at 21 years.

In 17-year-old boys (Fig. 2) the rate of tissue blood flow was minimal – 6.7±0.4 perf. units and gradually increased over the age period to 1.22±0.17 at 21 years.

In 18-year-old boys, the MP value continues to increase to 7.6±0.6 perf. units or 12 % (compared to 17-year-olds). During this time, the SD rate increases by 13 % . In the group of 18-year-old girls, the increase is less significant and is 8.2±0.7 perf. units for MP and 0.99±0.16 perf. units for SD. In absolute terms, 18-year-old girls are ahead of boys.

At the age of 19, the growth rate of indicators in the group of young men decreases to 8.0±0.7 perf. units for MP and 0.90±0.15 perf. units for SD, while among girls of this age MP increases by 10 % to 9.0±0.8 perf. units and SD (1.07±0.17 perf. units) increases by 8 % .

The MP rate of 20-year-old boys increased by 11 % (8.9±0.7 perf. units) compared to that of girls, and SD (1.13±0.16 perf. units) – by 26 % . In addition, in girls of 20 years age, the value of MP decreased to 8.3±0.6 perf. units, and SD increased to 1.18±0.18 perf. units.

At the age of 21, there are almost no changes in MP and SD. Thus, in young men MP was equal to 8.2±0.7 perf. units, in girls – 7.9±0.6 perf. units. While the magnitude of blood flow modulation continued to increase slightly to 1.22±0.17 perf. units in young men and 1.20±0.16 perf. units in girls.

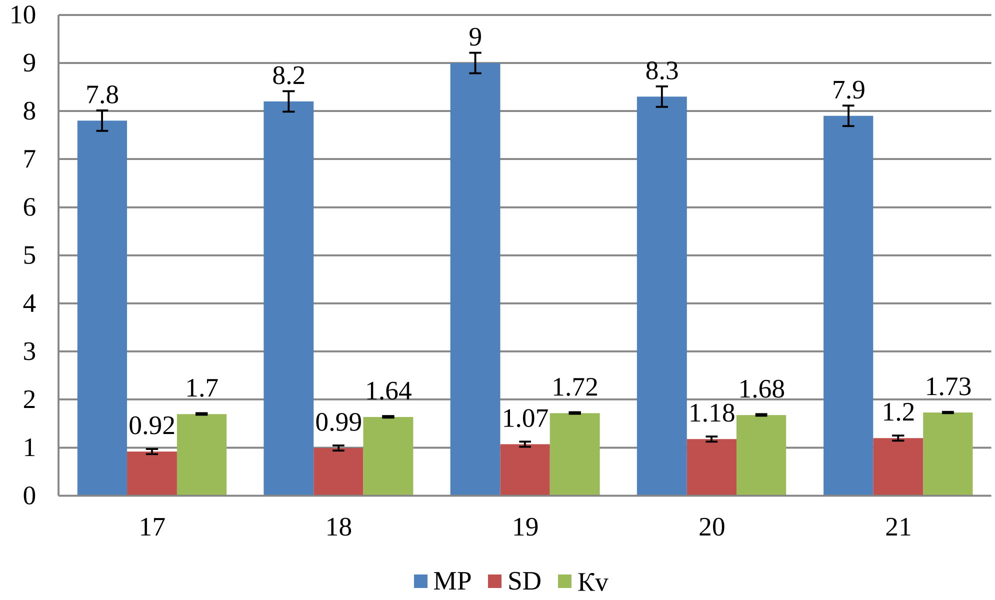

Fig. 1. Age dynamics of microcirculation indicators according to LDF data in female subjects 17–21 years

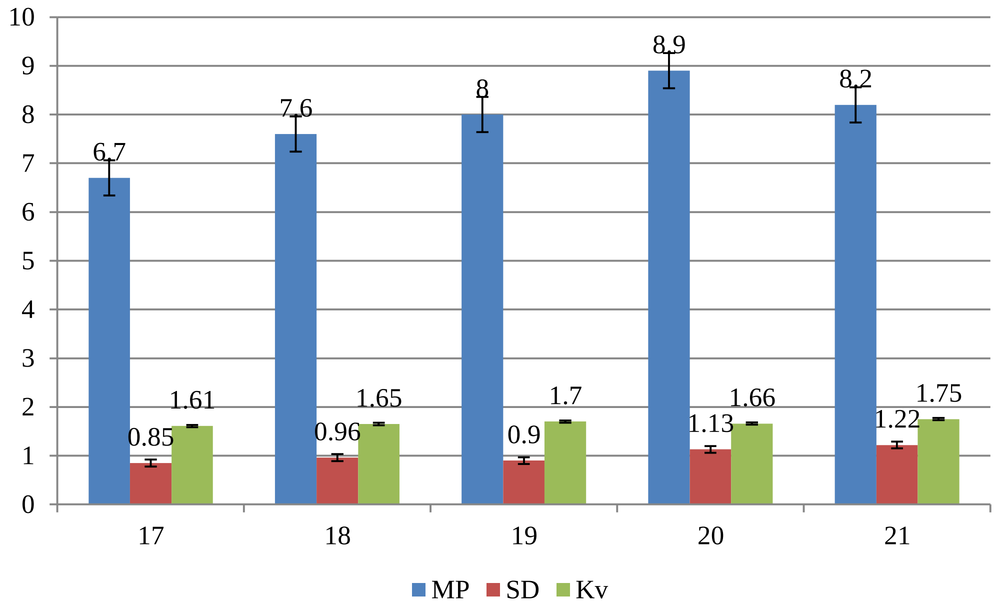

Fig. 2. Age dynamics of microcirculation according to LDF data in the studied 17–21 years of male sex

Thus, as studies have shown, in males and females there is a heterochrony of the values of MP and SD: at one age higher than the values of the studied females, and at another – in young men. This fact reflects the general biological pattern of different maturation of the male and female body [14, 15]. Thus, the values of MP from 17 to 19 years were higher in girls, in 20 years boys were ahead of this indicator, and at the age of 21 their values were almost the same. According to the SD, girls were ahead of boys in all ages.

When studying the age dynamics of harmonics of the frequency-amplitude spectrum, it was found that in 17-year-old boys the amplitude of VLF-oscillations was 1.66±0.43 perf. units (Table 2). The jump in the amplitude of VLF oscillations was recorded from 18 years (1.90±0.58 perf. units) and begins to increase up to 20 years (2.02±0.53 perf. units).

Similar results were observed during the analysis of the age dynamics of the amplitude of VLF-oscillations in females (Table 3). At 17 years, the value of the amplitude of very low-frequency oscillations was 1.77±0.55 perf. units with a further increase to 1.94±0.58 at 18 years, and a maximum value (2.18±0.64 perf. units) at 19 years. By the age of 20, the amplitude of the above oscillations decreases to 1.90±0.49 perf. units and up to 1.79±0.48 perf. units in 21 years.

Table 2

Age dynamics of frequency-amplitude spectrum in male subjects

Age, years n=23	Amplitude of oscillations, perf. units			
	VLF	LF	HF	CF
17	1.66±0.43	0.98±0.15	0.24±0.01	0.02±0.003
18	1.90±0.58	1.32±0.17	0.31±0.03	0.03±0.01
19	1.95±0.46	1.38±0.24	0.26±0.02	0.02±0.002
20	2.02±0.55	1.26±0.31	0.24±0.02	0.02±0.003
21	1.85±0.53	1.00±0.24	0.29±0.03	0.03±0.01

Table 3

Age dynamics of frequency-amplitude spectrum in female subjects

Age, years n=27	Amplitude of oscillations, perf. units			
	VLF	LF	HF	CF
17	1.77±0.55	0.96±0.17	0.28±0.03	0.03±0.01
18	1.94±0.58	1.25±0.20	0.30±0.03	0.04±0.01
19	2.18±0.64	1.44±0.22	0.28±0.02	0.04±0.01
20	1.90±0.49	1.19±0.29	0.22±0.02	0.03±0.01
21	1.79±0.48	1.07±0.25	0.25±0.03	0.03±0.01

The age characteristics of the dynamics of LF-oscillations in boys include an increase in the amplitude from 0.98±0.15 perf. units at 17 years to 1.38±0.24 perf. units at the age of 19. Subsequently, by the age of 21, its value decreased markedly and amounted to 1.00±0.24 perf. units. When estimating the age dynamics of the amplitude of low-frequency oscillations in girls, a gradual increase in the amplitude from 0.96±0.17 perf. units at 17 years to the maximum amplitude of LF-oscillations at 19 years – 1.44±0.22 perf. units and a gradual decrease in this indicator to 21 years (1.07±0.25 perf. units).

When analyzing the data on the dynamics of the amplitude of HF-oscillations should be noted fluctuating changes in the amplitude of high-frequency oscillations in boys and girls from 17 years of age. So, if at young men at 17 years the amplitude of high-frequency fluctuations is equal 0,24±0,01 perf. units, then further determined its abrupt changes: at the age of 18 it increased to a maximum of 0.31±0.03 perf. units and gradually decreased to 0.24±0.02 perf. units in 20 years, up to 21 years again noted its increase to 0.29±0.03 perf. units. In females aged 17 to 21 years, the amplitude of high-frequency oscillations varied from 0.28±0.03 perf. units at 17 years, at 18 years there was an increase to 0.30±0.03 perf. units. From the age of 19 there was a decrease in the amplitude of high-frequency oscillations to 0.28±0.02 perf. units and the next minimum in 20 years – 0.22±0.02. At the age of 21 there was an increase in amplitude to 0.25±0.03 perf. units.

The age characteristics of the amplitude of CF-oscillations include a relatively stable value of the indicator in subjects of both sexes. At the age range from 17 to 21 years in young men, the amplitude of CF-oscillations ranged from 0.02±0.003 perf. units at 17, 19 and 20 years and up to 0.03±0.01 perf. units at 18 and 21 years old. Amplitudes close in value were also registered among females at this stage of ontogenesis.

Thus, among the amplitude characteristics of cutaneous blood flow, the amplitude of low-frequency oscillations in girls was at the age of 19 years, and in boys at 20 years. The maximum amplitude of vasomotor oscillations was recorded at 19 years in both boys and girls. The amplitude of oscillations in the high-frequency range changed in waves in both girls and boys. Increases in heart rate were recorded in male subjects at 18 and 21 years, in females – 18–19 years.

Based on the qualitative analysis of dopplergrams, three types were identified that differ significantly in their parameters: aperiodic LDF-gram (type I), monotonic low-amplitude LDF-gram (type II), sinusoidal LDF-gram (type III).

Of the total sample, the most common, in 55 % of cases, is type I (Fig. 3). Aperiodic LDF-grams are characterized by relatively high values of MP 8.8±0.4 perf. units and well-defined aperiodic fluctuations in blood flow SD – 1.02±0.09 perf. units. Temporary variability in blood flow is an objective characteristic of the level of tissue activity and acts as a superposition of “active” and “passive” modulations of flaxmotions.

In the frequency-amplitude spectrum of LDF - grams type I were dominated by very low-frequency (VLF-oscillations) and low-frequency (LF-oscillations) oscillations. The average amplitude of VLF oscillations is 2.05±0.17 perf. units, and the contribution of low-frequency oscillations in the total spectral power is 58±2 % (Table 4).

The amplitude of vasomotor oscillations is significantly lower – 1.48±0.16 perf. units compared to VLF oscillations.

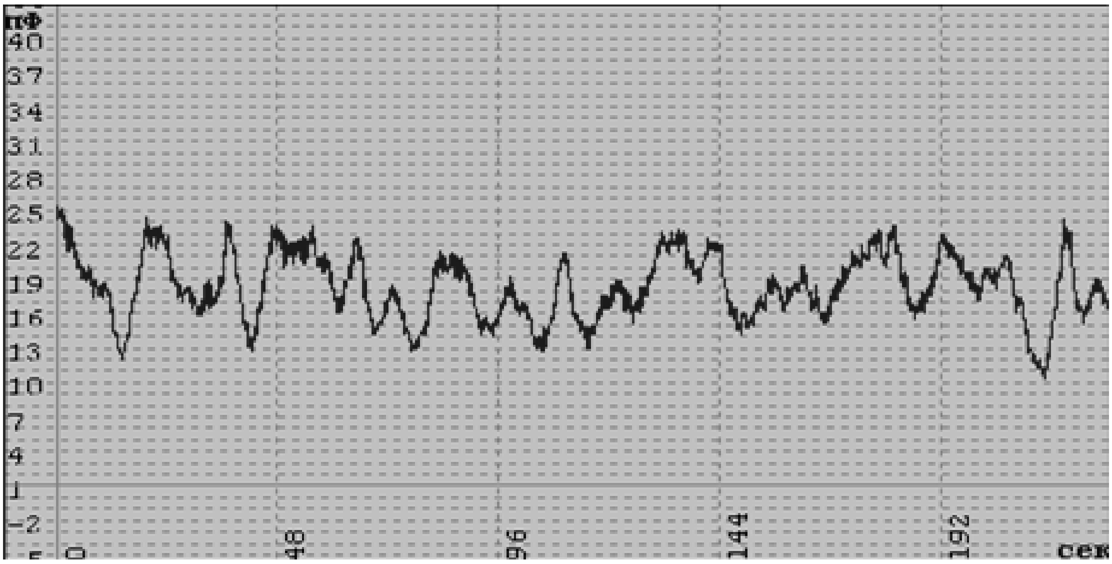

Fig. 3. Aperiodic LDF -gram in a 19-year-old girl

Table 4

Average parameters of LDF -gram of aperiodic type

Microcirculation parameters, M±m		
MP, perf. units		8.8±0.4
SD, perf. units		1.02±0.09
Kv		1.92±0.18
Frequency-amplitude spectrum of tissue blood flow		
	Amplitude of oscillations	The contribution of oscillations to spectral power
VLF-oscillations	Amplitude, perf. units	2.79±0.38
	Input, %	59±2.0
LF-oscillations	Amplitude, perf. units	1.48±0.16
	Input, %	33±1.0
HF-oscillations	Amplitude, perf. units	0.24±0.03
	Input, %	6.0±0.5
CF-oscillations	Amplitude, perf. units	0.04±0.003
	Input, %	2.0±0.2

Relatively high values of LF-oscillations indicate dilatation of microvessels [3, 11]. The increase in vasomotor activity is confirmed by the increase in the value of the contribution of the spectral power of low-frequency oscillations to the total power of the spectrum and is equal to 33±1 %. High-frequency waves of HF-oscillations are caused by the propagation of pressure drops in the venous part of the vascular bed into the microvessels from the outflow pathways of the blood. They are mainly associated with chest excursions. CF-oscillations are caused by changes in the speed of erythrocytes in microvessels caused by differences in systolic and diastolic pressure.

Type I dopplergrams differs in low values of amplitude and spectral power of high-frequency spectrum harmonics. Thus, the amplitude of oscillations of high-frequency HF-rhythm does not exceed 0.24±0.03 perf. units, the amplitude of CF-heart rate fluctuations is minimal – 0.04±0.003 perf. units. The contribution of the spectral power of high-frequency rhythms to the total power of the spectrum is several times less compared to low-frequency and does not exceed 6±0.5 % for high-frequency rhythm and 2±0.2 % for pulse oscillations. The predominance of the amplitude of low-frequency oscillations over high-frequency rhythms in the frequency-amplitude spectrum of LDF-grams of type I reflects the highest value of Kv – 1.92±0.18 c. u.

Thus, according to the characteristics of tissue blood flow and the balance of mechanisms of its active and passive regulation, the aperiodic type of LDF-grams corresponds to the normoemic type of blood microcirculation [10, 11].

The second type of LDF-grams occurred in 37 % of cases (Fig. 4). Monotonically low-amplitude LDF-grams are characterized by significantly low values of MP – 5.1±0.5 perf. units ($p < 0.01$) and SD – 0.60±0.12 perf. units ($p < 0.05$) (Table 5).

The decrease in MP is caused by an increase in the tone of smooth muscle cells that regulate the lumen of microcirculatory tract microvessels. In subjects with type II LDF-grams, the amplitude of vasomotor oscillations decreases to 0.85±0.19 perf. units.

The amplitude of VLF-oscillations in type II dopplergrams is reduced and does not exceed 1.58±0.14 perf. units. This, in turn, causes increased stiffness of the vascular wall and reduced tissue blood flow, which confirms the low value of MP.

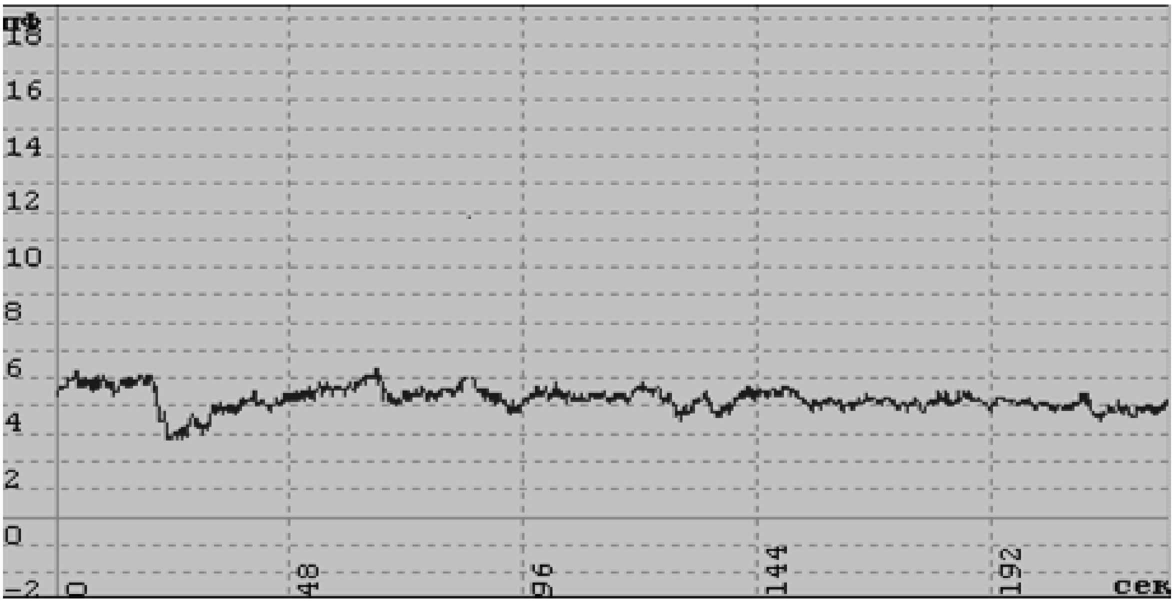

Fig. 4. Monotonously low-amplitude LDF-gram in a 21-year-old boy

Table 5

Average parameters of LDF-gram of monotone low-amplitude type

Microcirculation parameters, M±m		
MP, perf. units		5.1±0.5
SD, perf. units		0.60±0.12
Kv		1.33±0.09
Frequency-amplitude spectrum of tissue blood flow		
VLF-oscillations	Amplitude of oscillations	The contribution of oscillations to spectral power
	Amplitude, perf. units	1.58±0.14
	Input, %	57.0±3.0
LF-oscillations	Amplitude, perf. units	0.85±0.19
	Input, %	31.0±2.0
HF-oscillations	Amplitude, perf. units	0.22±0.02
	Input, %	8.0±1.0
CF-oscillations	Amplitude, perf. units	0.10±0. 004
	Input, %	4.0±0.5

At the same time in the range of high-frequency oscillations, in comparison with type I dopplergrams, decrease in amplitude is not observed, moreover, there is a weak tendency of its growth to the level of 0.22±0.02 perf. units among HF oscillations and 0.10±0.004 perf. units for CF oscillations.

The nature of the ratio of the contribution to the total spectral power of the studied oscillations is also changing. For LDF-grams of type II, against the background of a slight decrease in the spectral power of VLF-oscillations to 57±3 % and LF-oscillations to 31±2 % is characterized by a significant increase in the power of the spectrum of HF-oscillations to 8±1 % ($p<0.05$) and CF fluctuations up to 4±0.5 % ($p<0.05$).

The rapid decrease in the amplitude of the rhythms in the low-frequency region against the background of a constant value of high-frequency harmonics leads to a decrease in the value of Kv to 1.33±0.09 c. u.

The set of the received parameters convincingly testifies to formation of orientation on weakening of active at simultaneous strengthening of a role of passive mechanisms in modulation of a fabric blood-groove.

In general, the monotonically low-amplitude type of LDF-gram corresponds to the “hypoemic” type of microcirculation with reduced blood perfusion and increased vascular tone, resulting from increased sympathetic neurogenic effects on tissue circulation.

Less common is type III LDF -grams (in 8 % of cases) (Fig. 5). Subjects with sinusoidal LDF -grams differ from representatives of I and II types of dopplergrams with the highest values of MP – 9.2±0.9 perf. units and SD – 1.65±0.30 perf. units (Table 6).

Thus, for LDF-grams of type III is characterized by a decrease in the amplitude of very low-frequency oscillations to a minimum of 1.26±0.24 perf. units, which is 63 % less than among aperiodic LDF-grams and 25 % less than monotonically low-amplitude LDF-grams. In comparison with the aperiodic type of LDF-grams, low values of amplitude are registered in the range of vasomotor oscillations – 0.83±0.15 perf. units ($p<0.05$). Their amplitude is also lower than the amplitude of LF-oscillations of monotonically low-amplitude LDF-grams.

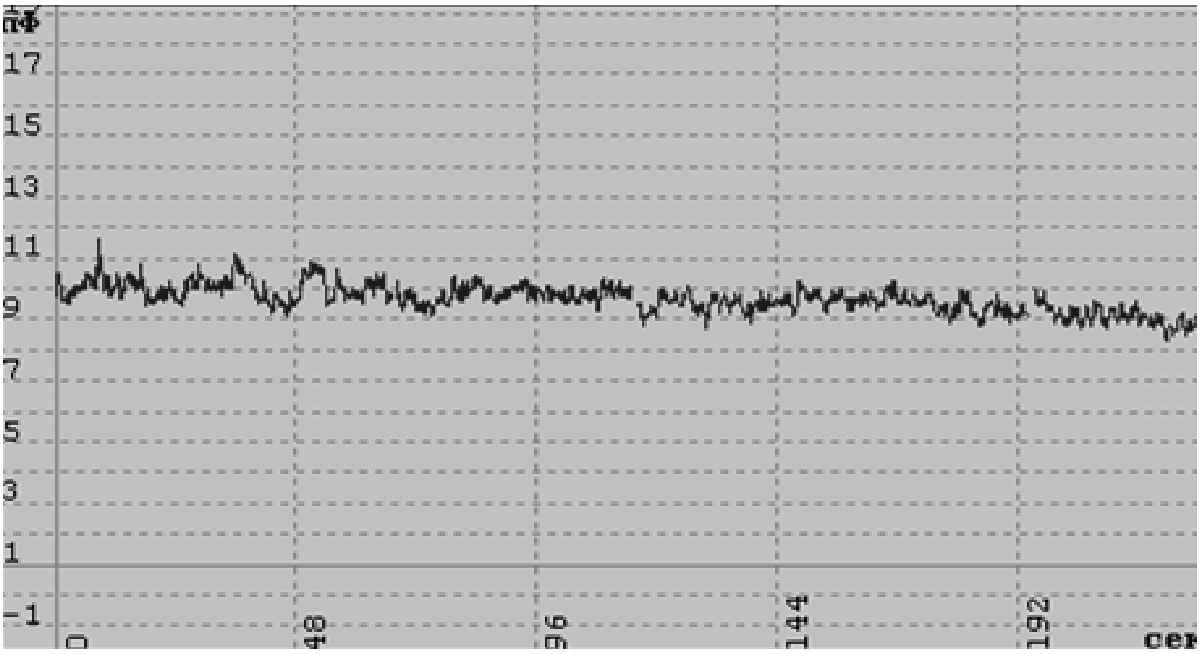

Fig. 5. Sinusoidal LDF-gram in the subject of 20 years

Table 6

Average parameters of LDF-gram of sinusoidal type

Microcirculation parameters, M±m		
MP, perf. units		9.2±0.9
SD, perf. units		1.65±0.30
Kv		1.25±0.07
Frequency-amplitude spectrum of tissue blood flow		
VLF-oscillations	Amplitude of oscillations	The contribution of oscillations to spectral power
	Amplitude, perf. units	1.26±0.24
	Input, %	48±3
LF-oscillations	Amplitude, perf. units	0.83±0.15
	Input, %	31±1
HF-oscillations	Amplitude, perf. units	0.31±0.07
	Input, %	11±1
CF-oscillations	Amplitude, perf. units	0.24±0.05
	Input, %	9±0.5

In general, low values of amplitude and spectral power of low-frequency harmonics indicate a decrease in vascular tone of arterioles due to reduced neurogenic activity (sympathetic component) and decreased myogenic tone of precapillaries. According to the results of the study, the average amplitude of CF-rhythm of sinusoidal LDF-grams is 3 times higher than among aperiodic LDF-grams and 2.5 times higher than the amplitude of CF-oscillations of monotonically low-amplitude type ($p<0.01$). As a result, the increase in blood flow is confirmed by the highest value of the microcirculation parameter among the three types of LDF-grams.

The dominance of passive mechanisms of control over modulations of tissue blood flow is manifested through an increase in the amplitude and power of the spectrum of HF oscillations. Thus, the amplitude of HF oscillations increases to 0.31±0.07 perf. units, which is 63 % higher compared to the aperiodic type of LDF - grams ($p<0.05$) and 41 % higher than monotonically low-amplitude LDF-grams ($p<0.05$).

The largest changes relate to oscillations in the cardiac arrhythmia, where the amplitude of CF oscillations increases to 0.24±0.05 perf. units with a simultaneous increase in the value of spectral power up to 9±0.5 %. Therefore, considering the data of the frequency-amplitude spectrum, the sinusoidal type of LDF-grams is not only increased inflow, but also weakens the outflow of blood from the microcirculatory tract, which, ultimately, can initiate the development of stagnant processes. Given the hyperemic nature of microcirculation, as well as reducing the contribution of vasomotor rhythm in the modulation of tissue blood flow sinusoidal LDF-grams correspond to the "hyperemic" type of blood microcirculation.

The results of the study indicate differences in the sex of LDF-grams of different types. The smallest differences between male and female subjects were found for LDF-grams of the aperiodic type. In terms of the intensity of microcirculation and the level of fluctuations in the flow of erythrocytes, the female body is inferior to the male. In particular, in girls with type I LDF-grams, the value of MP is 8.3±0.8 perf. units, and SD – 0.95±0.09 perf. units, which is 3 % and 15 % less compared to young men. For boys in the frequency-amplitude spectrum, the values of the amplitude of VLF-oscillations are higher (by 12 %), while in girls the amplitude of LF-oscillations is 10 % higher than in boys. In the high-frequency range, the amplitude of HF-oscillations in boys is 14 %, and CF-oscillations are 33 % higher than in girls. The slight predominance of the amplitude of vasomotor oscillations in the group of females leads to a higher value of Kv (7 %) compared with boys. Analysis of spectral characteristics showed that boys are ahead of girls in terms of the power of the spectrum of VLF-oscillations by 7 % and inferior to girls in terms of the power of the spectrum of LF-oscillations by 6 % and 32 % in HF-rhythm. No difference in the spectral power of the cardiac arrhythmia was detected.

In the group of individuals with monotonic low-amplitude LDF-grams increase the differences in the studied indicators, but they do not reach a statistically significant level. Girls are 21 % ahead of boys in terms of blood flow intensity and 11 % in terms of flaxmotion. In the frequency-amplitude spectrum in the studied females, compared with men, the amplitude of VLF is greater by 15 %, the amplitude of LF-oscillations by 22 %, HF-oscillations by 4 % and 5 % of CF-oscillations.

In the studied men with sinusoidal LDF-grams, the value of MP by 10 % and SD by 14 % higher than in females. Girls have a 6 % greater amplitude of VLF oscillations than men. At the same time decreases by 5 % the amplitude of LF-oscillations and 30 % of CF-oscillations. Among the values of spectral power in the studied females, higher HF-rhythm (26 %) and CF-rhythm (9 %) are registered, while in men the spectral power of low-frequency oscillations is 7 % higher.

Summing up the analysis of the existing differences in the indicators of LDF-metry in males and females, it is necessary to point out the lack of significant differences in the parameters, regardless of the type of LDF-grams. The contribution of myogenic factor in the regulation of capillary blood flow in the studied 17–21 years increases. The influence of the parasympathetic link of regulation, according to spectral power, is slightly enhanced in the transition from 17 to 21 years. In general, a definitive level of the ratio of active and passive mechanisms with the dominance of the active component of modulation of cutaneous blood flow is formed by adolescence. There are almost no age-related changes in the contribution to the total power of the spectrum of high-frequency rhythms in the subjects.

According to the results of the study, it was found that all three types of LDF-grams are found in young subjects (Fig. 6). Normoemic type of microcirculation is most common in students aged 17–21 (55 % of cases), hypoemic in 37 % of cases and hyperemic type (8 %).

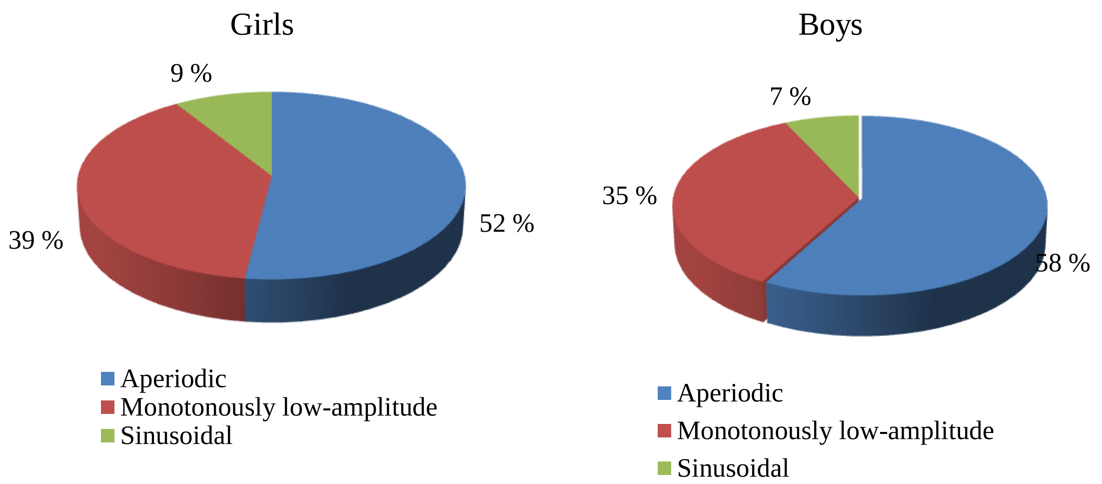

Fig. 6. Distribution of different types of LDF-grams among the subjects (%)

Thus, in girls 17–21 years of age less often (39 %) are monotonously low-amplitude LDF -grams and at the same time increasing (up to 9 %) the number of subjects with sinusoidal type. In the group of young men aged 17–21 years, the monotonically low-amplitude type is registered in 35 %, and sinusoidal – in 7 % of cases in the whole sample.

Our data suggest that the distribution of different microcirculatory types among females and males is approximately the same.

4. Discussion of research results

The obtained data on the peculiarities of the microcirculation process are of great theoretical and practical importance for understanding the mechanisms of regulation of cutaneous blood flow. The age-specific features of blood microcirculation parameters substantiated as a result of the study make it possible to detect functional changes in blood circulation using laser Doppler flowmetry (LDF-metry) and recommend this method for screening studies to identify risk groups for cardiovascular diseases.

Study limitations. It should be noted that, despite the widespread research of the human cardiovascular system in clinical practice and, especially, in the study of the microcirculatory system in persons with various pathologies [1, 3, 7, 8], there is an acute shortage and limitation of research in characterizing regulatory parameters of blood microcirculation in healthy people, especially taking into account age and sex differences in the body.

Prospects for further research. The obtained data on the detection of the functional state of the skin blood flow system in the body of adolescents open up prospects for further in-depth study of microcirculation at different ages and the detection of functional disorders and pathological processes.

5. Conclusions

Determining the age dynamics of tissue blood flow in people aged 17–21 showed that the MP in the subjects increased from a minimum of 17 years to a maximum of 21 years. In the female subjects, the value of MP at 17 years was higher than in boys, and the maximum value of perfusion in girls was 19 years and 20 years in male subjects.

Assessment of the state of regulatory mechanisms showed that the amplitude of low-frequency oscillations in girls is at the age of 19 years, in boys at 20 years. The maximum amplitude of vasomotor oscillations was recorded at 19 years in both boys and girls. The amplitude of oscillations in the high-frequency range changed in waves in both girls and boys.

Among young people, three types of LDF-grams were identified. Aperiodic LDF-grams, which corresponded to the normoemic type of microcirculation, were characterized by relatively high values of MP and well-defined aperiodic fluctuations in blood flow. Monotonous low-amplitude LDF-grams corresponding to the hypoemic type of microcirculation were characterized by significantly low values of MP and SD. The parameters of the frequency-amplitude spectrum indicated a weakening of active and simultaneous strengthening of the role of passive mechanisms in the modulation of tissue blood flow. Subjects with sinusoidal LDF-grams had the highest MP values. Low values of the amplitude in the spectral power of the harmonics of the low-frequency range indicated a decrease in vascular tone of the arterioles due to a decrease in neurogenic activity and a decrease in myogenic tone of the capillaries. Normoemic type of microcirculation was most common in students aged 17–21 (55 % of cases), hypoemic in 37 % of cases and hyperemic type (8 %). The distribution of different types was approximately the same in females and males.

Conflict of interests

The authors declare there is no conflict of interests.

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