Application of a biomedical hardware-software complex for the study of ultradian rhythms by heart rate variability

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Abstract. The article presents the results of the study of ultradian rhythms by amplitudes (A) and periods (T) of spectral characteristics (HF, LF, VLF, ULF) of the heart rate variability method using the HOLTERLIVE software package in ISCIM6.0 statistical processing in men, participants in a trans latitudinal flight and landing on the Arctic islands. The analysis of THF and TLF of the shows the symmetry and stability of adaptive reactions, while the range of ultra-slow (TVLF) and ultra-slow (TULF) waves shows the asymmetry and instability of the adaptive processes of the body of participants in a trans-latitude flight and landing on the Arctic islands. The transitions of the amplitude (A) and periods (T) of the power of harmonics from symmetry to asymmetry revealed in the examined people characterize the transitional states in the regulation's control of the heart rhythm.

1 Introduction

At present, it will pay much attention to the study of rhythmic processes in various scientific fields and spheres of society. The human body is subject to the influence of exogenous and endogenous factors, responding to their effects with adaptive and adaptive reactions. Circadian rhythms are the most studied. Since the main activity of a person falls in the daytime, the body experiences various influences of external factors from a flight from one time zone to another, to various stress factors in which it finds itself for several reasons. Ultradian rhythms are the most unexplored in chronobiology and are relevant in studies of human rhythmic processes, especially in various social conditions.

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Moving further north in search of new resources, a person creates an infrastructure around himself. It related the problem of the development of the Arctic latitudes to the fact that the created infrastructure has a negative impact on the unstable Arctic ecosystem with a small amount of phytomass [1-6]. It related another problem to the fact that a person is under the influence of a complex of specific conditions of high latitudes that affect his health [7-11]. In the Arctic latitudes, a person falls under the influence of various seasonal stress factors: low temperatures, arctic cyclones and anticyclones that cause pressure distribution, winds, clouds, snowstorms. First, the harsh natural and climatic conditions of the Arctic affect the adaptive reactions of the cardiorespiratory system.

In the literature, it paid special attention to the study of the reaction of the human body to low temperatures. Prolonged exposure to cold leads to a decrease in temperature in peripheral tissues. There is a low temperature of the fingers and toes, but inside the body the temperature does not change, and paradoxical cold vasodilation [12] occurs. It is believed that this mechanism protects the body from cold injuries [13-15]. Research has established that the stability of the physiological state of the human body in extreme environmental conditions depends on the stability of intersystem connections [16]. An analysis of the literature data indicates significant changes in immunological parameters associated with the peculiarities of rhythmic processes depending on the duration of stay in polar conditions [17]. It noted that the longer the period of residence in the Arctic, the more often there is an increase in the number of chronic allergic, cardiorespiratory diseases, latent cardiovascular insufficiency, endocrine changes and other pathological phenomena [18-20]. There is acute hypoxia, cold allergy, body resistance and minimal physiological stress, as well as a decrease in cognitive activity during a long stay in the Arctic latitudes, according to some researchers [21-24].

It is important to note that infrastructures that are built at high latitudes require maintenance. In the event of an emergency, there is a need for urgent delivery of specialists to the liquidation areas. Here, specialists experience urgent adaptation to the extreme natural and climatic conditions of the Arctic. The Arctic infrastructure needs specialists who ensure its technical safety and repair and adjustment work. Their delivery occurs both by sea transport and by air. If the sea conducted the movement, then there is a gradual adaptation of specialists to the natural and climatic features of high latitudes. But if air transport is employed, then the human body drops under the influence of the Arctic complex of stress factors. Researchers have not sufficiently studied the influence of such conditions on the physiological and mental state of a person [25], his adaptive reactions and behavior.

It has actively introduced new medical technologies into the practice of doctors, physiologists, and pathophysiologist in the last decade [26]. The emergence of modern methods of diagnostics in cardiology, such as magnetic resonance imaging of the heart (MRI), computed tomographic angiography (CTA), contributed to the development of new medical technologies in modeling unclear cardiac pathologies, which makes it possible to treat methods each individually [27-28].

Ordinary computer programs have certain rules for processing output signals. Automatic diagnosis by electrocardiogram is a typical example of clinical practice. Such devices in combination with software contribute to faster diagnosis and timely prevention of diseases [29].

This work identifies the symmetry and asymmetry of ultradian rhythms in terms of heart rate variability in participants of landing in the conditions of the Arctic latitudes to develop recommendations for the use of digital tools in medical and biological studies of ultradian rhythms (on the example of participants in a trans-latitudinal flight and landing in the conditions of the Arctic latitudes).

2 Methods

The study of the physiological state of a person in an airplane at various altitudes of a trans-latitudinal flight and subsequent landing on a limited area in the Arctic complicates the possibility of using invasive methods and techniques. Heart rate variability is a non-invasive method and allows you to monitor the state of the human body for a long time, for several hours, without interfering with active movements. To achieve the objective, a wireless hardware-software complex for 24-hour Holter monitoring "HOLTERLIVE" using with the possibility of remote analysis in statistical processing "ISCIM6.0".

The studying of the adaptive reactions of participants in the Arctic landing according to the variation of physiological parameters: amplitude (A) and periods (T) of spectral characteristics (HF – total activity level of the parasympathetic link; LF – total activity level of the vasomotor center; VLF – total activity level of the sympathetic regulation; ULF – the total level of activity of vegetative centers) for 10 hours. The amplitude (A) of the HRV spectra indicates the frequency of a set of vertical lines whose lengths are proportional on the horizontal axis. The period (T) indicates the spreading of the spectrum, where weak harmonics dissolve into stronger ones. Both indicators indicate adaptive reactions of the cardiovascular system of the body to the impact of endogenous factors.

The data processed mathematically ($M \pm m$; $\pm \sigma$) and statistically (r-Pearson correlation coefficient; R2 – coefficient of determination) in Microsoft Excel 2018 software. The chart indicates the distribution density of random variables, the median, the distribution of data by quartiles (lower and upper), maximum and minimum data values [30]. It can determine scatter (dispersion) and asymmetry of the data, and identify their outlier, by measuring the distance between the different parts of the box. We can see asymmetry both by the median shifted to either end of the box, and by the different lengths of whiskers emerging from the box. The chart characterizes a data set, its range in the sample, and used in publications to visualize statistical data.

Men conducted the trans-latitudinal flight and landing on the Arctic islands, specialists in various fields of infrastructure maintenance. It performed heart rate measurements from the moment of boarding the aircraft to landing at a height of 10 km, landing and subsequent inclusion in labor activity (n=8; age – 38.0; $\pm \sigma = 7.7$ years). The study did not consider the stages of adaptation to transmeridional flight, desaturation, and other conditions in which the participants were involved. It compiled an analysis of the indicators of heart rate variability to a complex of stress factors.

In this study, a priori, considered the amplitudes of the power spectra as the distribution of harmonics in the autonomic control of the heart rhythm, characterizing the general adaptive responses of the body to the impact of environmental factors. By observing the length of the period (T) demonstrates the length of the spreading of the spectrum, where weak harmonics dissolve into stronger ones, can assume that synchronization and symmetry in the control of heart rhythm regulation achieved because of the absorbing length of harmonics and characterizes the adaptive potential of the organism.

3 Results

The study of the amplitude (A) of the activity of the parasympathetic link in the regulation and control of the heart rhythm (HF) demonstrated a high level of dispersion of individual indicators (R2 = 0.08). In 15.4% of men, a pronounced, and in 46.1% – a moderate increase in the parasympathetic influence on the control of regulating the heart rhythm was revealed. The power amplitude of the harmonics of the vasomotor (LF) and sympathetic cardiovascular subcortical nerve centers (VLF) in 72% of the Arctic flight participants (R2 = 0,31 ÷ 0,27) indicated a pronounced and moderate increase in adaptive reactions.

It revealed asymmetry along the different lengths of the whiskers of the power of harmonics AHF, AVLF, AULF and peaks in amplitudes AHF, AULF, which shows instability and incompleteness of adaptive reactions. According to dispersion, it can be stated that it performed individually the process of adaptation of the cardiorespiratory system of the participants in the Arctic landing because of either the amplitude of fast (AHF) or infra slow waves (AULF) (Fig. 1).

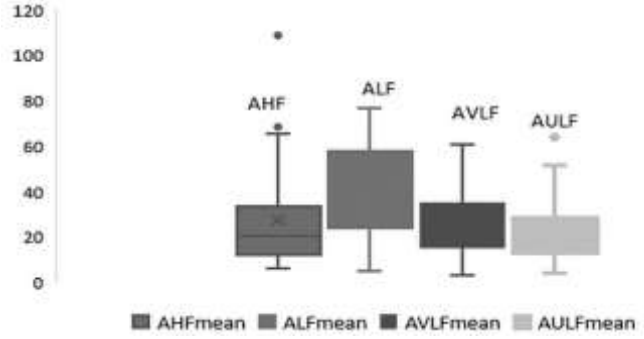

Fig. 1. Amplitude indices (A) of the power of the HRV spectra of participants in the Arctic flight.

Synchronization of the control of regulating the heart rhythm of the subjects was carried out by the amplitude of the power of infra slow waves (AULF). The amplitudes (A) of the spectral powers of the harmonics shifted to the ALF region, which is typical for the enhancement of adaptive responses. However, the frequency range of the power amplitude of the harmonics has a widespread and indicates an increase in the asymmetry of the rhythmic processes of the heart rhythm, as a transitional state to symmetry and characterizes the individual characteristics of adaptation to a complex of stress factors at high latitudes under conditions of an Arctic flight.

The obtained data on the amplitude of the power of harmonics allow us to conclude that in the participants of the Arctic landing, the amplitude of heart rate variability shifted symmetrically towards the activity of the vasomotor center (ALF), which is evidenced by the minimum and maximum values of the antennae. This indicates symmetry in the dispersion's distribution of this indicator and characterizes the transition to the stability of the body's adaptive processes to the negative impact of a complex of unfavorable Arctic factors.

Analysis of the periods (T) of the power of harmonics indicated a high level of frequency band density. Periods THF (R2 = 0.59), TLF (R2 = 0.62), TVLF (R2 = 0.67) in 78.4% of participants. This indicates a pronounced predominance of the parasympathetic influence on the control of regulating the heart rhythm. Under the conditions under study, it shifted the power periods of these spectra towards ultra-slow waves (TULF) and act as a synchronizer of the body's vegetative homeostasis. The data obtained considered as an asymmetry and a transitional state characterizing the pronounced stress of functional systems (Fig. 2).

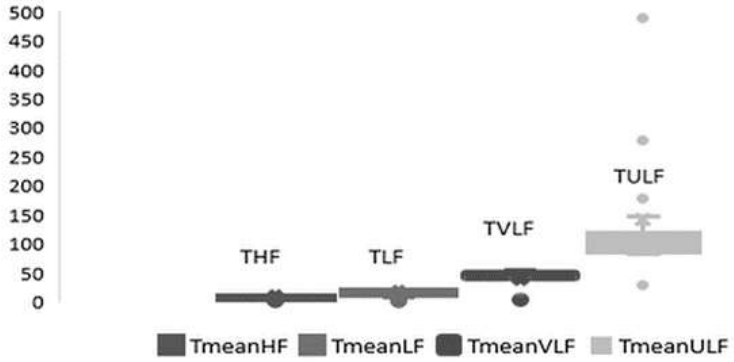

Fig. 2. Indicators of the period (T) of the power of the HRV spectra of participants in the Arctic flight.

The analysis of THF and TLF of the subjects indicates the symmetry and stability of adaptive reactions. Whereas the range of ultra-slow (TVLF) and ultra-slow (TULF) waves indicates asymmetry and instability of the adaptive processes of the body of participants in a trans-latitudinal flight and landing on the Arctic islands. A maximally noted scatter of indicators increases with the TULF indicator. The density of the range of attractors and a significant number of random variables are characteristic of entropy. The data of the periods (T) of the power of the spectra considered as an overstrain of functional systems and limited adaptive capabilities of the participants in the Arctic flight.

4 Conclusion

The amplitude of the spectral analysis indicators (AHF, ALF, AVLF, AULF) of heart rate variability shifted symmetrically towards the activity of slower waves and gradually transitioned to asymmetry. Spectral analysis periods characterize the mechanism of adaptive responses from fast (THF) to an increase in the influence of ultra-slow (TULF) waves on regulating heart rhythm control.

Analysis of the obtained data suggests that the amplitude (A) of the frequency ranges indicates the individual capabilities of the adaptive process of the body, while the period (T) characterizes the adaptive responses that are evolutionarily formed to a complex of negative stress factors. Based on the assessment of the periods (T) of the spectrum power, the participants of the Arctic flight indicated desynchronization in the regulation's control of the heart rhythm, which is a manifestation of the general adaptation syndrome. According to researchers, prolonged exposure to adverse factors can lead to desynchronosis and lead to the development of pathological manifestations of [31].

The data obtained turned out to be contradictory. Both in the amplitude (A) and in the period (T) of the power of the harmonics, a transition from symmetry to asymmetry observed. The amplitude (A) indicates the stock of adaptation resources, and the period (T) shows their limitation of adaptation reserves. Infra slow waves (TULF) achieve synchronization of regulating heart rate control. Mathematical modeling of ultradian rhythms on HRV indicators under the action of stressors that causes prolonged stress [32], the onset of stress erased, hidden, but with deep mobilization of adaptive reserves [33-34].

An analysis of the professional activities of the participants in the Arctic flight to high latitudes and their observation during the training period suggests that all the subjects already had symptoms of the influence of previous stressors. And in this case, observed the inclusion of adaptation and readaptation processes. However, landing at high latitudes is the most powerful stressor, new and under new conditions, enhanced by psychological experiences,

which caused the mobilization of deep adaptive reserves at the TULF level. Individual adaptation to new conditions noted in the example of the ALF indicator. TULF data indicates readaptation to a complex of stressors known to the body, previously tested by it. It can stated that the signs of symmetry and asymmetry of the biorhythmological parameters of the cardiovascular system of participants in a trans-latitudinal flight and landing in the conditions of the Arctic latitudes indicate both individual and group physiological mechanisms of adaptive and adaptive reactions of the body to the impact of stress factors of various nature.

The transitions of the amplitude (A) and periods (T) of the power of harmonics from symmetry to asymmetry revealed in the examined people characterize the transitional states in the regulation's control of the heart rhythm. This is due to the urgent reaction of the adaptation of the organism of the examined to the complex of harsh conditions of the Arctic archipelago. The results of the study allow us to state that the amplitude (A) and period (T) of the power of the frequency ranges (HF, LF, VLF, ULF) of heart rate variability are markers of the physiological state of a person. The results obtained confirm the data that the impact of adverse factors can lead to asymmetry, and, to desynchronosis and lead to the development of pathological processes, since the body has a high probability of transition to the stage of exhaustion.

Thus, based on the identified transition from symmetry to asymmetry of ultradian rhythms in terms of heart rate variability in participants of landing in the conditions of the Arctic latitudes, a computer program was developed as a recommendation for the use of digital tools in medical and biological studies of ultradian rhythms. This program allows you to include any parameters aimed at ensuring the safety of both individual health and the analysis of the synchronization of labor activity in the prevention of man-made disasters.

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