# Comparative characteristics of ultradian rhythms of critical infrastructure employees under various conditions of professional activity

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**Abstract.** The article gives a comparative description of the ultradian rhythms of workers in critical infrastructures in various conditions of professional activity. In connection with the need to conduct repair and adjustment work, workers in critical infrastructures carry out their labor activities, often migrating to areas remote from their permanent place of residence. The study of the relevance to the health and functional capabilities of the body of workers in critical infrastructures according to ultradian rhythms has not been sufficiently studied. The study used the software-statistical complexes “Varicard” and “HolterLive” in the statistical processing “ISCIM6.0”. The HRV indicators were studied in a group of ground service workers in the usual natural and climatic production conditions and in a group of landing on the Arctic islands to perform repair and adjustment work. Studies have established that both groups experienced an energy-deficient state, which reduces resistance and causes an overstrain of the adaptation mechanisms of the autonomic nervous system in controlling the regulation of the heart rhythm. The results of the study showed that intense workload in extreme conditions of extreme professional activity negatively affects the state of health characteristic of maladaptation.

## 1 Introduction

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In recent years, it has drawn the attention of researchers to the study of the health of workers in critical infrastructures. Critical infrastructures are multi-compact systems (energy, transport, gas, electricity, water supply, construction, telecommunications, credit and financial, etc.), the stability of which ensures the functioning of the life and economy of any country [1]. They have a multi-level structure. This is because of the peculiarities of the operation of its facilities: 1) technical (machinery, technical equipment, hardware, apparatus); 2) social (staff); 3) organizational (interaction of operating services); 4) managerial (regulatory, controlling, etc.). Literature notes that the complexity of critical infrastructures makes it difficult to create an effective protection system aimed at their techno genie safety [2].

The labour and professional activities of technical personnel are determined by various conditions for its implementation and the level of labour intensity. It has not studied the health and functionality of the body of workers in critical infrastructure facilities enough. This is because of their professional activities, workers of critical infrastructures from the conditions of groundwork, and moving to extreme natural and climatic conditions, for example, the Arctic, Antarctic, tropics, mountainous terrain, etc. Specialists working in extreme conditions and situations experience different levels of labour intensity that affect systemic risks and diseases [3-6].

The intensity of professional work reflects the load on the central nervous system, sensory organs, and the emotional state of workers. It conducted the rationing of labour intensity according to the loads [7, 8]. However, the standards do not consider the individual characteristics and reactions of the human body to the load under various stress factors.

The complex and varied working conditions of workers in critical infrastructures, including arctic conditions, make it difficult to use invasive techniques. However, the use of non-invasive research methods is being updated. A striking example of such a method is heart rate variability, which has a significant range of mathematical and statistical indicators that characterize the dynamics of the autonomic nervous system in regulating heart rate control.

Researchers note that patterns of heart rate variability (HRV) reflect the changing effect of sympathetic and parasympathetic modulation of the autonomic nervous system [9, 10]. While the method for analyzing 24-hour heart rate (HR) and heart rate variability (HRV) is being actively studied, it does not explore well the method for analyzing ultradian rhythms. According to some reports, each HR/HRV parameter has its own rhythm and individual differences [11].

Some researchers in the analysis of HRV arrays of circadian and ultradian rhythms use a logarithmically scaled power spectrum analysis [12]. For example, it has found that the power of the high-frequency range reduced in people with vegetative insufficiency, and as a result, a metabolic need arises.

This study searches for the ultradian rhythms in workers of critical infrastructures in various conditions of professional activity.

## 2 Methods

The study used the software-statistical complexes “Varicard” and “HolterLive” in the statistical processing “ISCIM6.0”. Processing was done in a four-hour array. Studied such indicators of HRV: HR–heart rate; SDNN - total effect of autonomic regulation of blood circulation; RMSSD – activity of the parasympathetic link of autonomic regulation; MxDMn is the maximum amplitude of regulatory influences; power of spectral characteristics in log-normal distribution (lg: HF, LF, VLF, ULF); VLF/HF is the ratio between ergotropic and trophotropic processes, characterized by energy supply [13, 14].

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The indicators of HRV in workers of critical infrastructures in various conditions of extreme professional activity studied. It has identified two small groups: 1) the first one - conducted ground repair and change work at production and test sites (in the text designated it as a ground group); 2) the second - performed a trans-latitudinal flight with subsequent landing to the Arctic latitudes to solve non-standard professional tasks (in the text - landing group).

Group working on the ground (age: 28.4±0.3; ±σ=3.3) performed professional activities in the usual production conditions: repair of high-voltage installations, bridges, roads, communications equipment, industrial damage, petrochemical, chemical and other industries.

The landing group (age: 35.3±6.3; ±σ=1.8 years) comprised specialists of various professions, whose activities related to working under a complex of stress factors of various nature: changing natural and climatic conditions, trans-latitudinal flight, high-altitude landing on a limited island platform, low temperatures, ocean winds at different heights, high arctic pressure, and others.

The indicators recorded in the production process. It made 120 measurements (the first group - 60, the second group - 60 measurements) of ultradian rhythms in conditions of physical activity during the working day from 6 to 19 hours.

The data processed mathematically (M±m; ±σ) and statistically (Student's t-test). The calculated correlation according to Pearson (r) using the program Statistica10. It made the figures in Microsoft Excel.

## 3 Discussion

Comparative analysis of the study indicated that HR ($t=2.85$; $P<0.05$), SDNN ($t=5.58$; $P<0.001$), RMSSD ($t=2.88$; $P<0.05$) in analyzed groups observed above the norm, however, in the ground group it noted higher than in the landing group. The landing group showed a significantly higher MxDMn value ($t=4.11$; $P<0.001$) and a moderate predominance of the parasympathetic nervous system compared to the ground group, which was characterized by a balance of the sympathetic and parasympathetic divisions of the autonomic nervous system.

In the group performing a trans-latitudinal flight to the Arctic latitudes, the power of the high-frequency range (Hflg) observed to be low, and the power of the low-frequency range (lg: LF, VLF, ULF) was high. The power of HFlg ($t=10.33$; $P<0.001$) found to be significantly lower than in the ground group of specialists. In the landing group, the metabolic requirement also significantly increased (VLF/HF $t=2.58$; $P<0.05$), which indicates autonomic failure (Figure 1).

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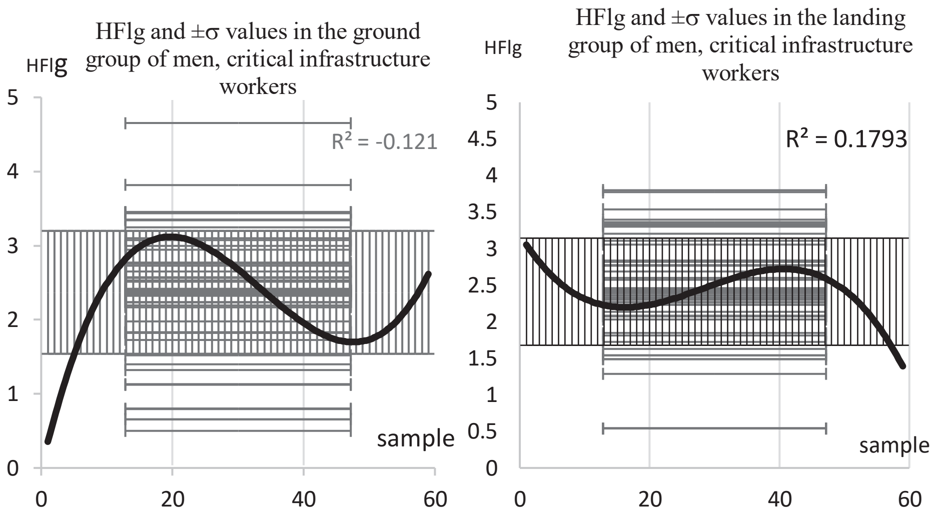


**Fig. 1.** The values of HFlg and ±σ of the ultradian rhythm in the production group and the landing group in the Arctic latitudes in the polynomial's approximation of the 3rd degree.

Significantly lower values were noted in the landing group compared to the ground group in terms of LFlg (t=4.2; P<0.001), VLFlg (t=2.72; P<0.05), which indicates an increase in individual adaptive processes, an increase in energy deficient state and desynchronization to high-altitude trans-latitudinal flight under desaturation conditions (Figures 2-3).

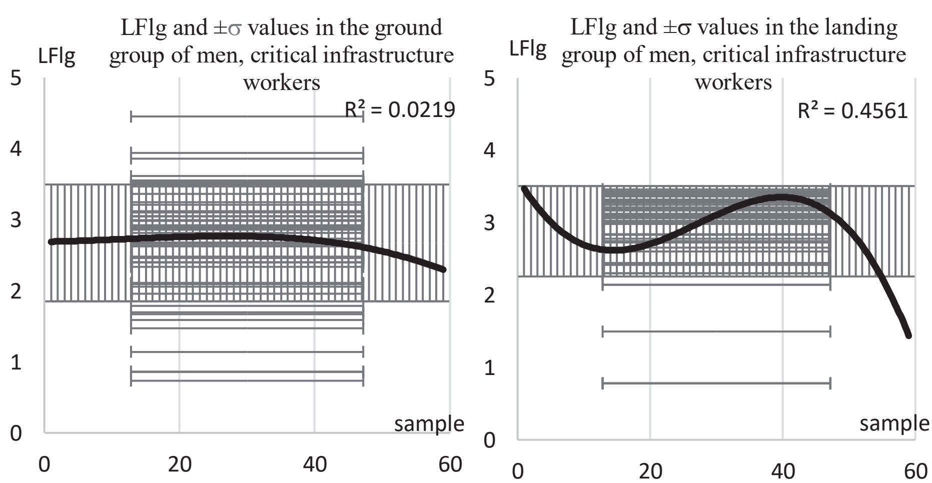


**Fig. 2.** The values of LFlg (±σ) of the ultradian rhythm in the production group and the landing group in the Arctic latitudes in the polynomial's approximation of the 3rd degree.

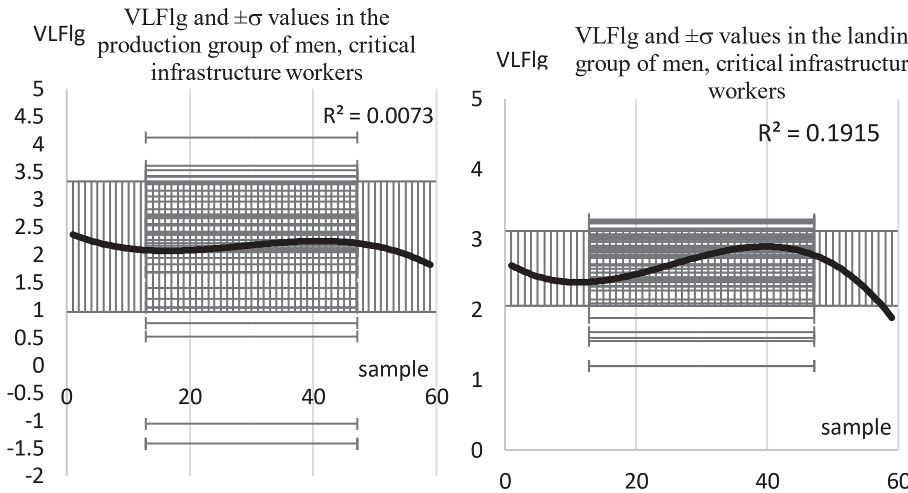


**Fig. 3.** Values of VLFlg (±σ) of the ultradian rhythm in the production group and the landing group in the Arctic latitudes in the polynomial's approximation of the 3rd degree.

It was found that ULFlg (t=3.38; P<0.001) was significantly higher in the landing group compared to the ground group. This indicates the integration of the dynamics of the heart rate by waves of higher order (Figure 4).

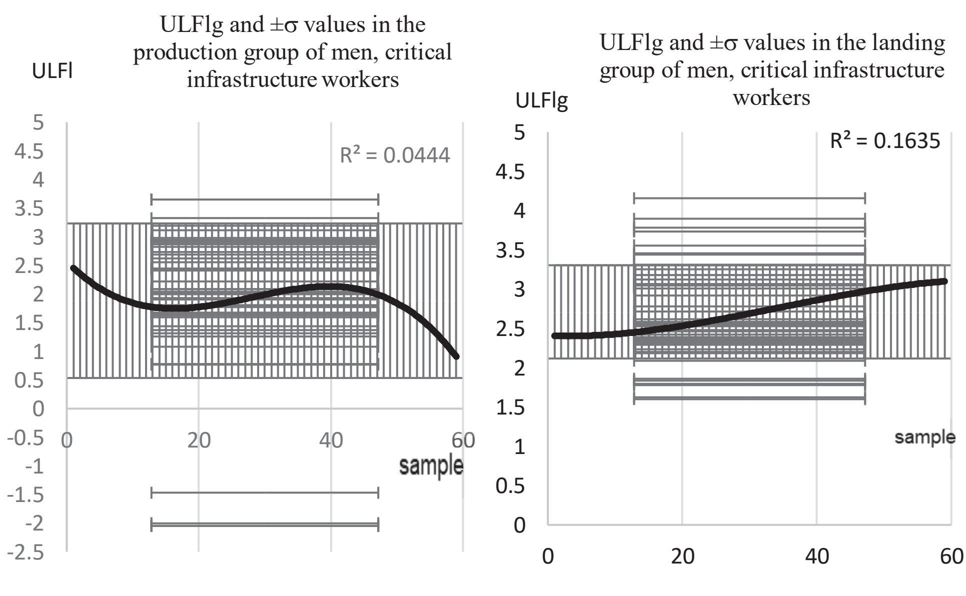


**Fig. 4.** Values ULFlg (±σ) of the ultradian rhythm in the production group and the landing group in the Arctic latitudes in the polynomial's approximation of the 3rd degree.

Thus, energy-deficient states reduce resistance and cause an overstrain of the mechanisms of adaptation of the autonomic nervous system in controlling the regulation of the heart rhythm. Certainly that the energy balance is maintained by respiratory and cardiovascular regulation, which ensures the supply of $O_2$ to the cells of metabolizing tissues [15, 16]. The results of the landing group show that workers have periodic breathing and breathing of the Cheyne-Stokes type. This is explained because the group landed in conditions of low temperatures and high-altitude Hyperoxic-Hypoxic. The ground group showed psycho-emotional stress. Autonomic failure modulates the slope of the HRV logarithmic scale.

## 4 Discussion

The data got allow us to assert that the intensity of the workload in an emergency among workers of the landing group to the Arctic islands to perform repair and change work of critical infrastructures characterizes vegetative insufficiency. Intense load negatively affects the state of health, characteristic of maladaptation. The lower the level of the high-frequency component and the higher the low-frequency ones, the higher the level of metabolism necessary for the formation of a balance between the sympathetic and parasympathetic divisions of the nervous system. Data received suggest that power spectra on a logarithmic scale can be useful for the overall integration of the heart rate dynamics generated by the central nervous system. The non-invasive HRV method in log-normal distribution can recommended for early diagnosis of autonomic dysregulation in heart rate control. The obtained data confirmed the literature sources that it can effectively use the slope of the HRV logarithmic scale in the analysis of ultradian rhythms in workers under conditions of different labour intensity.

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