Application of wearable multimodal devices to study microcirculatory-tissue systems under microgravity conditions

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Abstract — This paper presents the first results of the study of changes in microcirculatory-tissue systems functioning under spaceflight conditions.

Keywords— laser doppler flowmetry, fluorescence spectroscopy, wearable photonics, microgravity, microcirculatory-tissue system

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I. INTRODUCTION

Changes in the human cardiovascular system under the influence of microgravity conditions during space flight are one of the most important subjects in space medicine [1]. Over the years of missions to the International Space Station (ISS), various mechanisms of the influence of space flight conditions on hemodynamics changes have been studied. To date, however, this issue remains to be fully explored. This work aimed to study the dynamics of changes in blood microcirculation and metabolic processes of the human body during the acute period of adaptation to microgravity conditions during space flight using wearable multimodal photonics devices.

II. MATERIALS AND METHODS

The "LAZMA" experiment was carried out with a crew of astronauts (2 participated) during the ISS visiting expedition. The measurements were carried out in 3 stages: stage 1 – before spaceflight; stage 2 – during the stay of the crew on the ISS (December 8-20, 2021); stage 3 – after return from spaceflight. Each stage lasted at least 7 days with daily measurements of physiological parameters.

To study microcirculatory blood flow and oxidative metabolic parameters, the recently developed wireless wearable multimodal device "LAZMA-PF" (SPE "LAZMA" Ltd., Russia) [2], included laser Doppler flowmetry and fluorescence spectroscopy, were used. The analyzers were placed on the pads of the middle fingers and big toes, on the back of the wrists, and attached to the temples. Each measurement of one study area lasted 8 min during which the astronaut was in a state of complete physical and psychological rest.

The following parameters were recorded and analysed during the present study: index of microcirculation (I_m), amplitudes of endothelial (A_e), neurogenic (A_n), myogenic (A_m), respiratory (A_r), and pulse (A_p) oscillations, and the skin autofluorescence value when probing with 365 nm light (A_{365}), normalised to backscattered radiation.

III. RESULTS AND DISCUSSION

The study observed significant changes in microcirculatory function during the first 2-3 days of the astronauts stay on the ISS, with subsequent stabilization of parameters and their return to normal values in 2 days after landing. There was a decrease in the I_m in the temples due to an increase in the neurogenic and myogenic components of the precapillary arterioles tone. During measurements at the ISS, there was a decrease in the A_{365} parameter in the temples and an increase in this parameter in the legs, which is associated with changes in metabolic processes due to redistribution of blood flow under microgravity conditions. The present study is the first to develop a methodology for measuring the microcirculatory-tissue systems in the limbs of astronauts during acute adaptation to microgravity conditions and re-adaptation after the end of space flight. The developed technique was successfully tested in the mission of the crew of the "Soyuz MS-20" spacecraft.

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