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ADAPTIVE CHANGES IN HEART RATE VARIABILITY AND CARDIAC FUNCTION DURING LONG-TERM SPACEFLIGHT: INSIGHTS FROM WEARABLE DEVICES

Abstract

Exposure to microgravity during spaceflight significantly affects the human body, including alterations of the autonomic nervous system, changes in heart rate variability (HRV), and redistribution of blood flow in the chest area. The objective of this study was to use a wearable device to investigate the changes in the cardiovascular system of cosmonauts during their mission on the International Space Station (ISS). Data was collected from eight cosmonauts (one female) using a device measuring electrocardiography (ECG) and impedance cardiography (ICG). The subjects were asked to perform controlled 5-second breathing cycles, and recordings were made before (-66 ± 19 days), during (7 ± 5, 37 ± 4, and 158 ± 5 days), and after ($+3 \pm 1$ days) spaceflight. The measurements on Earth were done in sitting position, while in space they were done in free-floating. HRV features included root mean square of successive differences between normal heartbeats (RMSSD) and the ratio of power in the low and high frequency ranges (LF/HF). In addition, stroke volume (SV) normalized by baseline value, pre-ejection period (PEP), left ventricular ejection time corrected for heart rate and gender (LVETi), and their ratio (PEP/LVETi) were computed for each beat using the ECG and ICG signals. They were then averaged over the whole record. We consider $p<0.05$ as statistically significant. Data is expressed as median and interquartile range.
From baseline to the first week in space, we observed an increase in RMSSD from 0.018 [0.013; 0.022] to

0.030 [0.024; 0.037] s, and SV by 35% [6%; 48%], and a decrease in LF/HF from 1.28 [1.04; 2.78] to 0.63 [0.30; 1.10], PEP from 68.11 [56.16; 72.79] to 55.94 [50.46; 60.65] ms, and PEP/LVETi from 0.15 [0.13; 0.16] to 0.12 [0.11; 0.13]. Besides, within 6 months in space all parameters tended to return to baseline levels.

In space, astronauts experience a microgravity-induced head-ward fluid shift. This shift causes hemodynamic and autonomic changes. An increase in cardiac preload and a sympathetic withdrawal causing a reduction in systemic vascular resistance ipso facto produce an increase in SV, a reduction in PEP and a tendency to increase LVETi, as compared to sitting position on Earth. These changes happen early during the flight, but afterwards these features tend to come back to baseline levels. The findings of this study confirm that the cardiovascular system can adjust to the microgravity environment within a few months, at least with the countermeasures used onboard the ISS.