Blood pressure variability as a sensitive parameter for assessment of physiological effects of hypogravity on the cardiovascular system

Anton Cherepov[1], Daria Pozdeeva[2], Elena Arkhipova[1,2], Aleksandr Kotov[1], and Mikhail Baranov[1]

[1] Research Institute for Space Medicine, Federal Research Clinical Center, FMBA of Russia, Moscow, Russia
[2]Institute of General Pathology and Pathophysiology, Moscow, Russia

ICI meeting 2015
December 13-15, 2015
Tel-Aviv, Israel

INTRODUCTION

Processes of adaptation to hypogravity and hypokinesia occur during space flights and under conditions of their terrestrial modeling. The most obvious effect of hypogravity on the human body is displacement of liquid media to the upper part of the body, which triggers the mechanisms providing long-term adaptation to the new conditions. These changes primarily affect the function of the cardiovascular system (CVS) and respiratory system (RS), which necessitates their continuous monitoring under conditions of hypogravity. For evaluation of the adaptation processes in CVS and RS, parameters of the autonomic balance is responsible for adaptation to environmental changes, in particular, to weightlessness.

Changes in cardiovascular system (CVS) under conditions of hypogravity simulated using 21-day ortho- and antiorthostatic hypokinesia at different angles were studied. The aim of the experiment was selection of informative CVS parameters most sensitive to these conditions.

METHODS

Individual functional sufficiency of the cardiorespiratory system was evaluated using a Spiroarteriocardiorhythmograph instrument complex (SACR, Intox, Russia) (Fig. 1) that can simultaneously and continuously record respiration, electrocardiogram, and blood pressure.

The method makes it possible to calculate the relative contribution of sympathetic and parasympathetic autonomic nervous system (ANS) into heart rate (HR) and blood pressure (BP) regulation, integrated values of cardiogram intervals, parameters of lung ventilation, baroreflex parameters, etc.

Fig. 1. SACR recording.

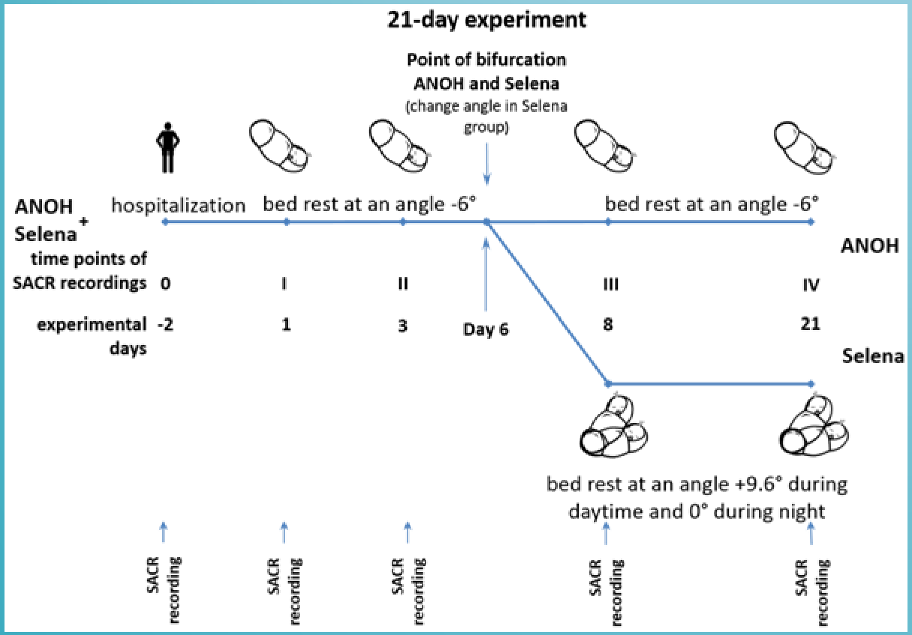


Fig. 2. Design of the experiment.

The examination was carried out in the supine position (either horizontal or at the tilt prescribed by the experimental protocol; Fig. 2) and consisted of 3 continuous 2-min SACR recordings: 1) without respiratory masks and respiration recording (mask –); 2) with respiratory mask (functional test with increased "dead space (mask +); 3) functional test or controlled respiration at a frequency of 0.1 Hz with the use of respiratory mask and respiration recording (CR_6)

The experiment included 11 volunteers (19-39-year-old men) that also were distributed into 2 groups. The first group (5 volunteers) was subjected to 21-day tilt-down bed rest at an angle of -6˚ (ANOH group) (Fig. 2); these conditions simulated weightless space flight to the Moon with subsequent lunar orbiting. The second group (Selena; 6 volunteers) simulated space flight to the Moon with subsequent stay on the lunar surface. These volunteers were subjected to tilt-down bed rest (ANOH; -6˚) on days 1-5 of the experiment followed by alternation of daytime orthostatic bed rest at an angle of +9.6˚ (from 7 am to 11 pm) and nighttime horizontal bed rest (0˚; from 11 pm to 7 am) on days 6-21 of the experiment (Fig. 2).

The data were expressed as median with percentiles 25-75%. The nonparametric Mann-Whitney and Wilcoxon matched-pairs tests were used.

For all Figs. with data: — p<0,05, Mann-Whitney test (between groups); - - - — p<0,05, Wilcoxon matched-pair test (inside group)*

RESULTS

The most striking and significant between-group differences were found for BP and its autonomic regulation between ANOH and Selena groups.

Table 1. illustrates significant between-group differences in the dynamics of diastolic BP (DBP) and systolic BP (SBP) (ANOVA for repeated measures).

Table 1.

Compared groups	Time interval		
	Total observation period (days 1-21)	days 1-3	days 8-21
DBP_{ANOH} vs DBP_{Selena}	F(11, 99)=2,8460, p=0,00281*	F(5, 45)=0,12573, p=0,98568	F(5, 45)=4,8511, p=0,000124*
SBP_{ANOH} vs SBP_{Selena}	F(11, 99)=2,1070, p=0,02642*	F(5, 45)=0,45271, p=0,80908	F(5, 45)=1,2787, p=0,28977

Based on this result, we analyzed changes in autonomic regulation of BP by assessing DBP and SBP variability using spectral analysis of BP rhythms. Fig. 3 shows the dynamics of the total power of DBP and SBP spectra over the entire observation period.

The total power of DBP variability spectrum (TPD) significantly increased on day 21 of bed rest in the ANOH group exposed to invariable and more rigid conditions than Selena group. This increase in TPD was observed on day 21 during both mask-on and mask-off recording and especially during controlled respiration.

No significant differences in the total power of SBP spectra (TPS) were found.

Fig. 3.

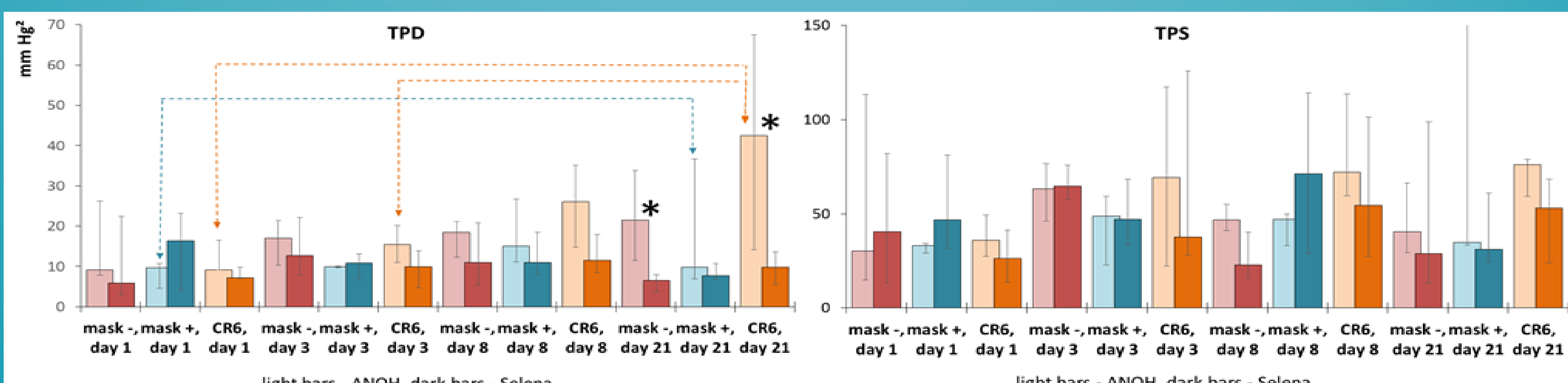
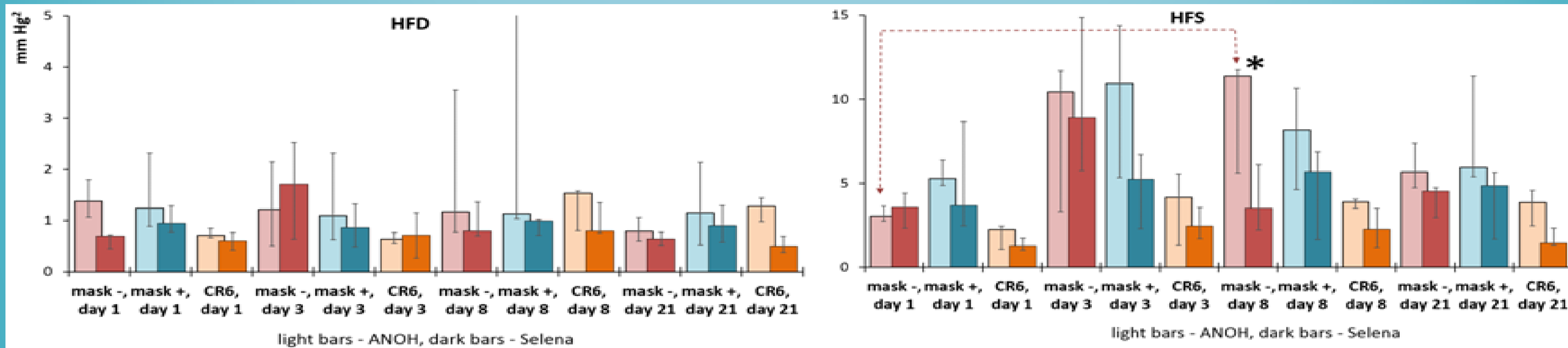


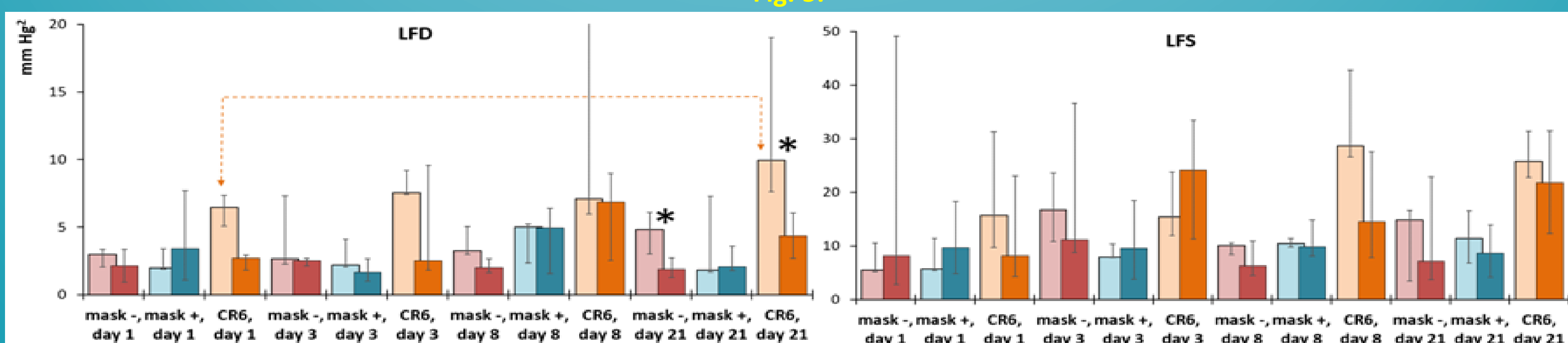
Fig. 4.



Further, we present the results of the analysis of intra- and intergroup differences in the frequency components of BP variability (HFD/S, LFD/S, VLFD/S). BP variability power in different frequency bands determined using Fourier-transform analysis characterizes autonomic nervous system (ANS) activity and the function of mechanisms of BP regulation. Three frequency bands can be distinguished in the spectra: very low frequency (VLFS/D, 0-0.04 Hz), low frequency (LFS/D, 0.04-0.15 Hz), and high frequency (HFS/D, 0.15-0.4 Hz).

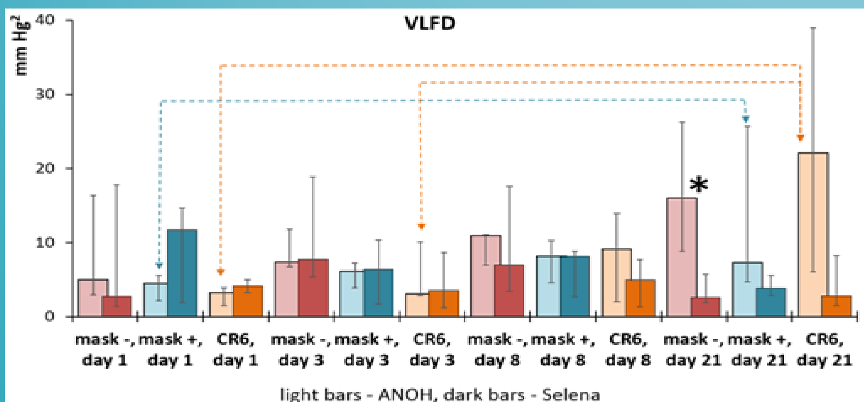
Analysis of the HF component of SBP and DBP variability (HFS/D) revealed significant intra- and intergroup differences in HFS (Fig. 4). In the ANOH group, the HF component of SBP variability (HFS) significantly increased by day 8 in comparison with the results of examination day 1 (time point 1) and in comparison with

Fig. 5.



the corresponding value in Selena group. These differences were more pronounced during mask-off recording (mask-) (Fig. 4).
Analysis of the LF component of SBP and DBP variability (LFS/D) revealed significant intra- (ANOH–ANOH) and intergroup (ANOH–Selena) differences only for LFD (Fig. 5).
In the ANOH group, the LF component of DBP variability (LFD) significantly increased by experimental day 21 in comparison with both day 1 (time point I) and corresponding value in the Selena group. This increase was most pronounced during functional test with controlled respiration (CR6).

Fig. 6.



In the range of very low frequencies (VLFD/S) (Fig. 6), a significant increase was observed for VLF component of DBP (VLFD) by day 21 of the experiment in the ANOH group in comparison with day 1 in the same group and in comparison with Selena group; these differences reached the level of statistical significance in the mask-off measurement. Considerable contribution of VLFD into total DBP variability most likely attests to appreciable role of local mechanisms (not related to autonomic regulation of the heart rhythm) in adaptation to chronic orthostasis.

CONCLUSIONS

- Under conditions of hypogravity, additional mechanisms of cardiovascular system regulation are activated, which affects variability of peripheral BP, especially diastolic BP variability.
- Regulatory mechanisms affecting SBP and DBP under conditions of hypogravity simulation are different, at least partially. Autonomic regulation of SBP was changed earlier (by 7-8 days) and primarily affected HFS, but this imbalance was leveled by day 21(in contrast to LFS).
- Our findings clearly show that variability of DBP depends on the severity and duration of hypogravity.

It can be concluded that DBP variability indexes are the most sensitive parameters for ortostasis evaluation.

a.cherepov@nphys.ru