MODELING THE RECOVERY OF THE SYMPATHETIC AND PARASYMPATHETIC MODULATION IN ASTRONAUTS AFTER SHORT AND LONG DURATION SPACE MISSIONS

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ABSTRACT

The influence of microgravity on cardiovascular control was confirmed in this study. Therefore, linear HRV parameters were clustered in groups according to their physiological meaning. At early post flight, parts of the autonomic modulation of heart rate were significantly influenced, different for day and night periods, but the recovery was already complete 30 days after return.

1. INTRODUCTION

Does weightlessness in space disturb the human cardiovascular control system in astronauts? This question was already examined multiple times in literature, but the answer is still not clear. The clinical hallmark post-spaceflight orthostatic intolerance with postural tachycardia suggests that the autonomic nervous system (ANS) might be involved. The ANS affects heart rate by a continuous interaction between the sympathetic and parasympathetic branch. The sympathetic pathways speed up the firing rate of the sino-atrial (SA) node and consequently the heart rate while the parasympathetic or vagal pathways lower the heart rhythm [1]. The main interest of measuring cardiac sympathetic and vagal activity lies in its prognostic value in cardiovascular risk [2, 3].

Heart rate variability (HRV) is used as a noninvasive marker to investigate the autonomic modulation of heart rate. Low HRV levels and slow HR recovery are two important indications of impaired vagal activity. The aim of this study is to investigate how the several aspects of autonomic nervous system are influenced by microgravity when astronauts return on Earth. Also the recovery afterwards is examined. Therefore, different HRV parameters relating to the same aspect of autonomic modulation will be grouped in one model. In addition, day and night periods will be investigated separately.

2. METHODOLOGY

2.1 Data acquisition

24h Holter recordings from 8 astronauts were used. 5 went to the International Space Station (ISS) for a long term mission of several months while the other 3 have only been in space a short time. Each astronaut was measured at three different time moments, namely pre flight (L-30), early post flight (R+5) and late post flight (R+30)

2.2 Linear HRV analysis

After preprocessing the RR interval time series, all linear parameters described by the Task Force of the European Society of Cardiology and the North American Society of Pacing and Electrophysiology [1] were calculated. In the time domain, HRV Index and TINN are used as geometric measures while mean RR, SDNN, SDANN, SDSD, SDNN-Index, RMSSD and pNN50 are the statistical parameters. After resampling the tachogram at 2 Hz, the power spectral density (PSD) was computed by using the Welch method. In the frequency domain, very low frequency power (VLF: 0.003 – 0.04 Hz)), low frequency power (LF: 0.04 – 0.15 Hz), high frequency power (HF: 0.16 – 0.40 Hz) and total power (0.01 – 1.00 Hz), as well as the ratio of low over high frequency power (LF/HF), were calculated. In addition, the power can be expressed in absolute values (ms^2) or in normalized units (n.u.).

To evaluate all aspects of cardiovascular control by ANS, HRV parameters were combined. SDNN and total power (TP) are both measures for the total variability in heart rate, while rMSSD, pNN50 and HF power represent vagal modulation. LF power is mainly, but not only, influenced by sympathetic influence. LF/HF and LF (n.u.) reflect typically the sympathovagal balance.

2.3 Statistical analysis

Combining multiple parameters in one model is only possible by using z-scores. Then, different parameters could be considered as repeated measure of the same physiological phenomenon. Repeated Measures Multivariate ANOVA offers a solid testing method to determine whether the weightlessness had a significant influence on a certain group of parameters and therefore on a specific part of the ANS. The P value was obtained by the Wilks' Lambda test statistic. $P < 0.05$ was considered statistically significant.

3. RESULTS

The differences between day and night were as expected for most parameters, with higher values during the night for all statistical time domain measures except for SDANN. Also TP, VLF and LF increased during the night as did the HF due to the respiratory sinus arrhythmia (RSA).

At early post flight (R+5) the geometric parameters did not change in comparison with the pre flight (L-30) condition. All statistical measures showed a significant or nearly significant decrease at R+5 during the day and night except SDNN, SDANN and SDNN-Index at night. On the contrary, mean RR showed no evolution at all. All effects seemed to be disappeared 30 days after return (R+30).

Fig. 1 shows the time evolution for several HRV parameters, averaged over the complete population and clustered in three groups. All parameters belonging to the same group indicate a similar evolution. Microgravity caused a fall in the total variability (TP, SDNN) although only significant during day (p=0.007). While the vagal modulation decreased significantly (day: p=0.004, night: p=0.011) at early post flight, the sympathovagal balance decreased slightly during daytime (p=0.328), but increased strongly (p=0.010) at night short after returning to Earth.

4. DISCUSSION

All HRV parameter values obtained pre flight are in the range expected for healthy male test subjects as found by Ramaekers et al. [4], except for SDNN due to different signal lengths in both studies. LF and HF differed as well due to a different way of calculating the PSD although the normalized parameters corresponded.

With respect to the influence of microgravity on the autonomous control of HRV, evolutions during day and night should be discussed separately. Some days after returning, a general decrease in modulation of the heart rate by the ANS was found during the day, as vagal influence dropped significantly and the sympathovagal balance did not change, which indicates that also sympathetic influence dropped. After 30 days, there seems to be an almost complete recovery. At nighttime, the sympathovagal balance increased early post flight, probably mainly caused by a fall in vagal modulation. This means that the sympathetic modulation of heart rate during the night increased relatively in comparison with the values pre flight. All parameters seemed to be restored after 30 days.

5. CONCLUSION

The influence of microgravity on cardiovascular control was confirmed in this study. During daytime a general decrease in modulation of heart rate was found early post flight compared to pre flight while at night an increase in sympathovagal balance was observed indicating that microgravity caused a relatively higher sympathetic influence in the autonomic modulation. All effects seemed to be disappeared 30 days after return.

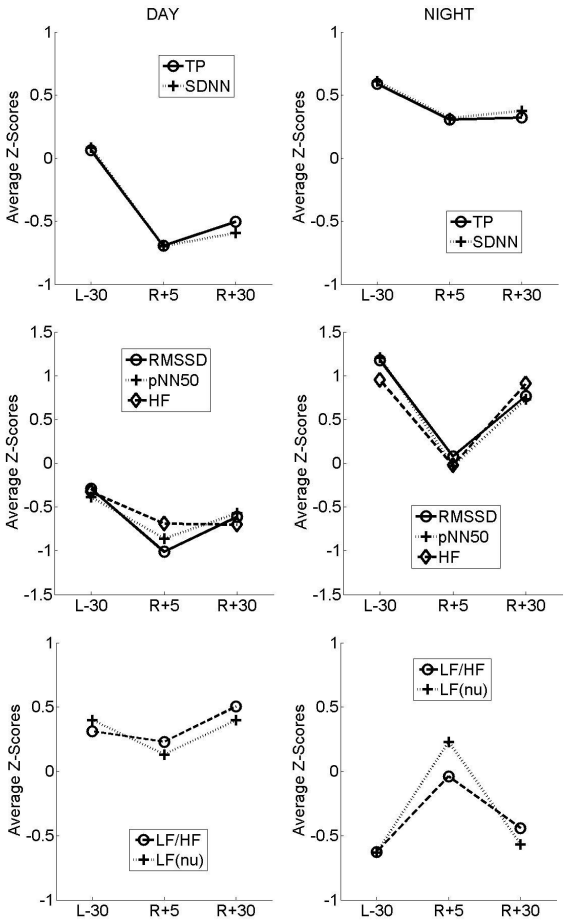

Fig. 1. Average z-scores over pre (L-30), early post (R+5) and late post (R+30) flight for the individual HRV parameters related to total variability (top), vagal modulation (middle) and sympathovagal balance (bottom) during day (left) and night periods (right).

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