HEART RATE VARIABILITY DURING CENTRIFUGATION IN ASTRONAUTS PRIOR TO AND AFTER LONG DURATION SPACEFLIGHT: PRELIMINARY DATA

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1. ABSTRACT

Spaceflight is known to induce vestibular and cardiovascular deconditioning. The current ESA SPIN project conducts research on vestibular and cardiovascular deconditioning after long duration spaceflight. Hereto, vestibular function and cardiovascular parameters are evaluated during centrifugation and during a tilt test in astronauts prior to and after spaceflight. The experiments are conducted using the 'Visual and Vestibular Investigation System'. During rotation, cardiovascular and breathing parameters are recorded by means of the 'Lifeshirt® system' (Vivonoetics). The current analysis focuses on the cardio-respiratory response during 2 consecutive centrifugation runs, a counter clockwise (CCW) and a clockwise (CW). The RR-interval recorded postflight during the second CW rotation decreased significantly compared to the preflight data. No significant effects were observed on the parameters (amplitude, marker of vagal activity, and phase) of the respiratory sinus arrhythmia (RSA). However, the time of respiration and the amplitude of the RSA were correlated.

Our preliminary results suggest a postflight recovery problem of the sympathetic nervous system after activation and show that the respiration has a large influence on the RSA amplitude.

2. INTRODUCTION

During spaceflight, the vestibular and the cardiovascular system need to adapt to microgravity. Consequently, astronauts often suffer from spatial disorientation and orthostatic intolerance when returning to normal gravity [1,2].

So far, intensive research has been carried out in order to elucidate this vestibular and cardiovascular deconditioning. Experiments on the application of artificial gravity, a possible countermeasure, on astronauts have been carried out during the 1998 Neurolab Spacelab mission. When returning to Earth, the astronauts that were subjected to centrifugation showed no symptoms of orthostatic intolerance or complaints of spatial disorientation. The function of the otolith-ocular reflex also seemed to be unaffected after the spaceflight [3].

The current ESA SPIN project focuses on the effects of long duration microgravity on the vestibular and cardiovascular system, without the astronauts being subjected to artificial gravity in space. Therefore, this project serves as a control experiment of the aforementioned part of the Neurolab mission. The present paper specifically focuses on the effects of long duration weightlessness on the cardio-respiratory response of astronauts during centrifugation.

3. METHOD

3.1 Subjects and protocols

The experiments were carried out in Star City (Moscow) on four male astronauts and cosmonauts (mean age: 42.3 yr [37 yr; 52 yr]) taking part to long duration (6 months) missions (increments 15, 16, 20-21) in the International Space Station (ISS). They were not subjected to artificial gravity in space. Preflight experiments were scheduled on three different days around L-45 (L=launch). Postflight experiments were executed on three fixed days: R+1, R+4 and R+9 (R = return day). The 'Visual and Vestibular Investigation System' (VVIS,) is an eccentric rotation chair (50 cm from the axis of rotation), used during the Neurolab mission, It was used to centrifuge the subjects. Tests were done in total darkness. The protocol started with a CCW rotation lasting 5 min and 30 sec and, after a few minutes of rest, was followed by a CW rotation. During both rotations, the vector sum of earth gravity and the centrifugal (horizontal) acceleration of 1g, called the Gravito Inertial Acceleration (GIA), tilts 45 degrees. This tilt is a particular stimulus for the vestibular and cardiovascular system. Protocols were approved by the IRB of the University of Antwerp and the ESA review board and all the subjects gave their written informed consent before the start of the experiments.

During the whole experiment the subjects were allowed to breath at their own pace while performing various visual and proprioceptive tasks. For medical reasons some of the postflight recordings could not be executed (see details in Table 1).

Table 1. Number of measurements

	PREFLIGHT			POSTFLIGHT		
	Baseline	CCW rot	CW rot	Baseline	CCW rot	CW rot
N	12	12	12	10	9	10

3.2 measurements and analysis

The 'Lifeshirt® System' (Vivonoetics) was used for the simultaneous and continuous recording of ECG (at 1kHz) and thoracic and abdominal respiratory movements (at 150 Hz).

Fixed intervals of 1 minute recordings were selected to define the following three conditions of the protocol: baseline (before the CCW rotation), CCW rotation and CW rotation. ECG, tidal volume (Vt) and time of respiration (Tresp) were extracted from the raw data and the following events were identified: timing of heart beats (QRS) to determine RR-intervals (RRI), and timings of onset of inspiration and expiration by means of the 'moving average curve' (MAC) method [4]. The amplitude (ρ), and phase (Θ) of the respiratory sinus arrhythmia (RSA) were then calculated using a time domain algorithm, the "polar representation of RSA" [5].

3.3 Statistics

Non-parametric Friedman and Wilcoxon tests were performed. The correlation between Tresp and ρ was determined by means of a Spearman correlation. A significance level of 0.05 was chosen.

4. RESULTS

4.1 RRI

Statistical analysis showed a significant ($p=0.043$) decrease of RRI during the CCW rotation measured preflight, compared to before rotation (see figure 1). Comparison of the preflight data with those measured postflight reveals a trend that is reoccurring during each postflight measurement (R+1, R+4 and R+9), i.e. a decrease of RRI during both rotations compared to the baseline recordings (see figure 1). The decrease was significant for data measured on R+9 ($p=0.039$).

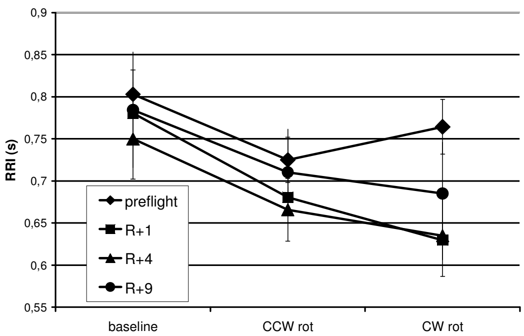

Figure 1. The mean RRI (±S.E.M.) of the 3 different conditions on the different data collection days. A significant decrease (p=0.043) of RRI recorded preflight is observed during the CCW rotation compared to pre-rotation baseline. The three conditions differed significantly (p=0.039) on R+9: a RRI decrease during both rotations can be observed. This trend also applies to the other post flight (R+1 and R+4) measurements.

4.2 RSA parameters

Statistical analysis revealed no significant effects for the phase of the RSA. A significant correlation between Tresp and the parameter ρ (amplitude) was observed ($p=0.001$). There were further no significant effects on the amplitude of the RSA.

5. DISCUSSION

The effects seen on the heart rate during the first CCW rotation could be explained by an 'anticipative' stress-effect of the subjects, causing an increase of sympathetic activation and thus increased heart rate. The subsequent heart rate decrease during the CW rotation could be attributed to a habituation of the subjects to the rotation. Interestingly, this effect was not observed during the testing days after their re-entry. On the contrary, the heart rate increased even more during the second rotation. This reflects a delayed or hampered recovery of the sympathetic nervous system after activation. It might be possible that spaceflight is at the base of this recovery problem because of a vestibular and a cardiovascular deconditioning.

As expected, the analysis revealed that the influence of Tresp is larger (and more significant) than the possible effect of microgravity on RSA amplitude. With the small number of subjects and the large inter-subject variability the statistical power is too low to permit a proper multifactorial statistical analysis for RSA. Imposing a particular breathing pattern to the subjects is not feasible during centrifugation. Therefore, more subjects are necessary to increase the power to elucidate possible effects.

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