Heart Rate Variability During Gravity Transitions

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Abstract

During parabolic flight short periods of microgravity and hypergravity are created. During standing position time domain analysis showed higher vagal modulation of the autonomic nervous system in microgravity compared to hypergravity. We hypothesised that this behaviour could better be unravelled by analysis of frequency domain heart rate variability (HRV) techniques. During parabolic flights a subject is exposed to 20-25 sec periods of microgravity (at the top of the parabola), preceded and followed by 20 sec duration episodes of hypergravity.

No significant differences were found in the frequency parameters in supine position for each of the phases. In standing position higher values for Total Power, high frequency (HF), low frequency (LF), LF/HF and HF% in 0 g phase were found in comparison with the 3 other phases. LF% was significant lower in standing position at 0g compared with 1.8g.

These results show that despite the time window limitations, frequency analysis is still possible on ultra short data segments.

1. Introduction

Changes in gravity have profound cardiovascular effects [1],[2]. Experiments on earth to simulate real microgravity are head down bedrest (HDBR) and head out of water immersion (HOI) [3,4]. Real microgravity accessible to humans on earth however, can only be reached at the apex of parabolic flights, which lasts about 20 to 25 seconds [5]. This is the only way to study human cardiovascular responses to real microgravity conditions except for space flight. Body fluid hydrostatic pressure gradients will occur at transitions from hyper- to microgravity and will result in different distributions according to the body position during hypergravity [2,6].

Heart rate variability (HRV), as obtained from ECG recordings, is a unique non-invasive tool to obtain insight into the control and modulation of cardiovascular function trough the autonomic nervous system [7].

The three successive phases of the parabola (hypergravity, zero gravity and again hypergravity) last only 20 to 25 sec (fig 1.). Due to this short period problems arises for frequency analysis. There is a conflict between the frequency resolution and duration: the windows needed to have a good frequency resolution are to wide and this will cause overlapping of the different phases.

Therefore all studies that analysed HRV were restricted to time domain parameters [8]. Altough time domain analysis can provide some information about the activity of the autonomic nervous system it has some important limitations[9]. To overcome the Heisenberg theorem (good frequency resolution or good time resolution but not both), we used zero padding: adding the mean before and after the RR time series untill the new time serie is long enough for frequency analysis. This technique, also used for Wavelet analysis [10], wil not add or remove any other frequency to the origanal time serie.

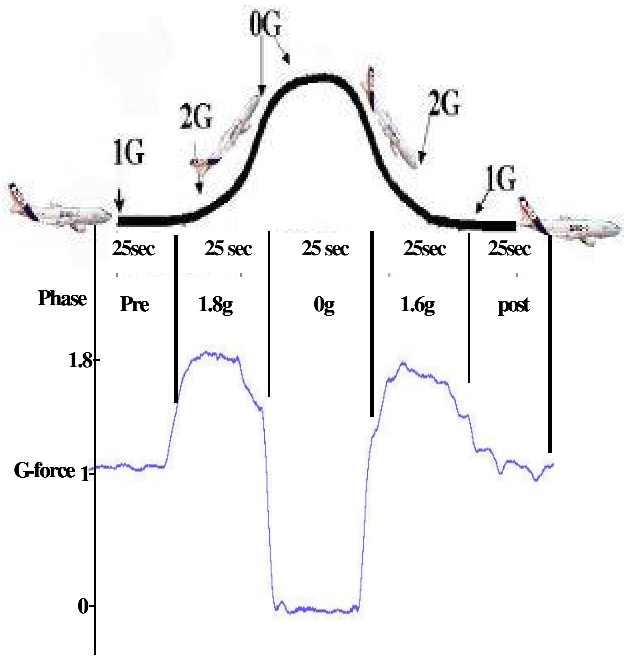

Fig 1. Parababolic flight profile

2. Methods

2.1. Study population

Seven male volunteers, aged between 22 and 57 year (35± 12 yrs), free of any cardiac pathology, were monitored during parabolic flight. Special flight medico-physical examination was performed at "the Medical center of the Belgian Airforce, Brussels" one month before the flight campaign in order to pass FAAIII tests. Informed consent to participate in the study was obtained from all subjects. To eliminate the effects of pharmacological agents altering the cardiovascular parameters being measured neither general medications nor medications for the control of motion sickness were taken before or during flights. Subjects experiencing motion sickness during one flight where excluded for further analysis of that flight. The experimental protocol was approved by the local ethical comittie

2.2. Data acquisition

This study was conducted during the 29th ESA parabolic flight campaign performed in November 2001. The flights were organized by ESA and NOVESPACE at the Société Girondine d'Equipments, de Réparation, et de Maintenance Aéronautique (SOGERMA) center in Bordeaux, France. The AIRBUS A300 ZERO-G aircraft was used to perform the parabolic flight profiles. Flights were scheduled on three consecutive days. Each flight incorporated 31 parabolas and lasted 2.5 to 3h.

A g_z accelerometer was used to measure instantaneous gravity continuously. The hypergravity vector is perpendicular to the floor of the plane. Five consecutive phases were considered: (figure 1): Phase 1, normogravity (1 g) 20 sec before each parabola; Phase 2, pre-hypergravity (1.7-1.8 g) on the ascending leg of the parabola; Phase 3, microgravity (0g) at the top of the parabola; Phase 4, post-hypergravity (1.6-1.8g) on the descending leg of the parabola; Phase 5, normogravity during the first 20 sec after each parabola. (fig 1.)

ECG electrodes were applied to the chest wall of the subjects prior to the flight. ECG was monitored with a lead II derivation. Leads were connected to an ECG amplifier. The analogue output was connected to an external A/D convertor, and sampled at 1000 Hz per channel and stored in a laptop computer. Control measurements (1g) were obtained in the airplane one day before the first flight, at the same hour as take off.

Four subjects were measured during each flight session. Each subject was involved in at least 2 flights. The same subjects were monitored supine and standing during the same flight. After 15 parabolas positions were changed in order to obtain a maximum of 15 parabolas in each situation. To prevent free floating during microgravity subjects were attached with a belt around the chest in supine position and around the feet in standing subjects.

2.3. Data analysis

After peak detection [11], which uses a derivative/threshold criterion, visual inspection was performed for artefacts and ectopic beats. All phases with artefacts were eliminated for further analysis. Each phase was separated manually based on the g forces. Start and end of each phase was defined as follows: >1.6g for pre hypergravity, < 0.1g for microgravity and >1.5g for post hypergravity. From these signals mean heart rate was calculated.

To obtain high frequency resolution, zero padding was performed: first the signal was divided by meanRR followed by adding equal number of zero's before and after the signal to obtain 256 data points. For FFT analysis we used a window of 256 points and a sample frequency of 0.5 sec, which led to a frequency resolution of 0.0078 Hz. Fig. 2 ilustrates the effect of mean padding for a sinus and for a short (20s) tachogram.

For each position results of all parabolas were pooled for all subjects. Therefore mean values correspond to 90±4 parabola's.

For joint time-frequency analysis Wigner-Ville distribution (WVD) was computed. In order to suppress cross-terms in the power spectrum the 'Smoothed Wigner-Ville distribution' (SWVD) was used. The

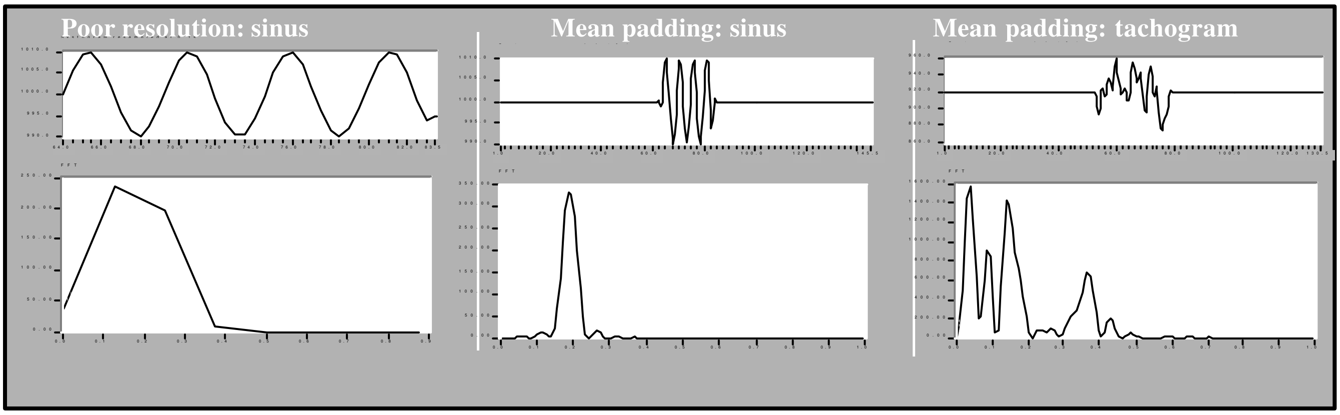

Fig 2. Illustration of mean padding: Leftt: sinus without mean padding, Middle: sinus with mean padding, Right. real tachogram

Frequency domain		TotPwr (ms^2)	LF (ms^2)	LF% (%)	HF (ms^2)	HF% (%)	LF/HF
Supine	Basal	1196.8±836.4	620.2±538.4	47.7±12.7	367.6±310.4	32.2±13.2	2.3±1.2
	Pre	1354.6±1523.9	547.9±373.0	49.9±12.8	495.6±951.0	28.1±15.8	3.7±2.1
	1.8 g	637.4±514.8	295.1±136.2	53.1±14.5	256.5±422.5	30.8±17.8	3.2±1.6
	0 g	1136.4±619.7	599.4±280.1	52.8±9.0	247.2±247.8	21.0±9.1	4.5±2.5
	1.6 g	1890.1576.8	962.6±795.1	52.6±8.8	335.5±315.0	23.2±11.5	4.9±2.5
	Post	1531.7±1221.1	705.0±492.6	46.7±12.8	393.4±639.1	38.7±15.2	4.7±3.3
Standing	Basal	809.9±1059.1	547.3±734.9	63.4±10.6	105.6±174.9	12.7±6.1	7.8±3.3
	Pre	774.8±408.3	537.8±289.0	66.0±7.5	102.9±91.9	14.8±6.6	8.3±3.4
	1.8 g	443.9±281.2	303.8±208.3	64.3±5.8	49.0±31.6	13.5±3.4	6.7±1.3
	0 g	4169.0±2977.3*	1539.1±782.2*	45.7±13.2*	1467.7±1649.1*	26.4±15.6*	3.4±2.6*
	1.6 g	761.7±610.6	468.1±396.1	59.7±6.1	83.8±76.6	15.1±4.8	6.5±2.6
	Post	1495.4±1226.0	918.5±751.2	62.3±7.0	231.1±231.7	17.7±5.9	6.7±2.1

Table 1:Frequency domain parameters during different phases of parabolic flight

SWVD provides an instantaneous power spectrum and computes the instantaneous center frequency beat to beat. All software was in house developed and implemented in LABVIEW, which is a graphical language.

3. Results

MeanRR significantly increased during microgravity in standing position (779±89 vs. 876±158). In supine position no difference could been observed for meanRR

Table 1 shows all frequency domain parameters. In supine position none of the parameters significantly changed during microgravity. In standing position TotalPwr, HF, LF and HF% were significantly higher during microgravity. LF% and LF/HF were significantly lower during microgravity.

4. Discussion

Methodological

This was the first study to use spectral analysis on the short data sets of HRV during parabolic flights. By using mean padding, we were able to use FFT without loosing important frequency resolutions. SWVD on the other hand can serve as illustrative technique for these short signals. But due to the large window, which overlaps different phases, absolute value can not be used.

Despite the time window limitations, frequency analysis is still possible on ultra short data segments.

To better illustrate the effect of gravity on the HF component we also used SWVD. In figure 3 we clearly

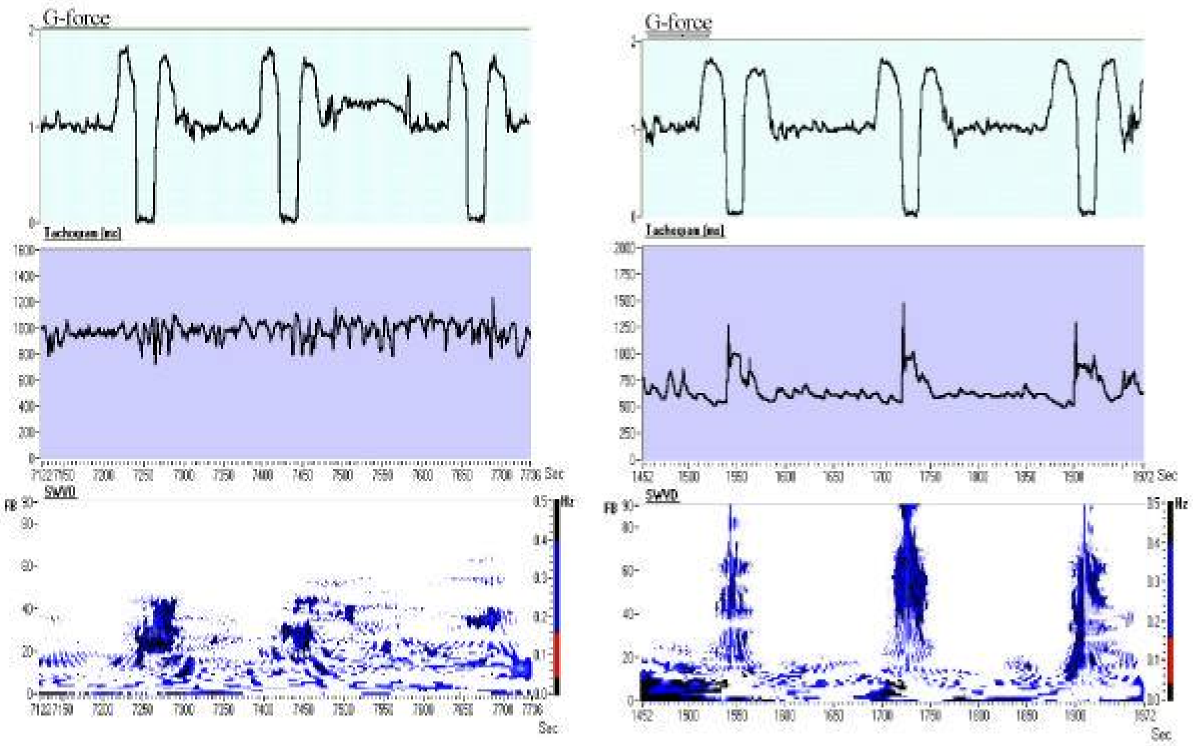

Fig 3. Left: supine subject, Right: standing subject. Upper: g force during 3 succesive parabolas, Middle: tachogram, Lower: SWVD for same subject

see the higher HF component during microgravity for a standing subject compared to a supine subject (fig 2b)

Physiological

The results we obtained with frequency analysis are in accordance to results of time domain analysis. In supine position the different gravity phases throughout a parabolic flight profile, have only limited influence on HRV indices. On the other hand in standing position higher vagal modulation is observable during microgravity. Also Capderou et al. [8] came to these conclusion, but in their study mean values during standing and supine were taken from the whole parabola and not differentiated for the different phases as in our study.

The higher LF component in the standing position suggest not only higher vagal tone, but also an increment in sympathetic tone. The sympathovagal balance will, decrease due to these changes of vagal activity. In microgravity no differences were found in autonomic activity between supine and standing position.

These results are in accordance with literature [12], which illustrates that even in short time series the activity of the autonomic nervous system can be determined. These results however were obtained by means of time domain parameters.

Acknowledgements

We thank the subjects who volunteered for this study. We acknowledge the support from the European Space Agency (ESA).

This study was supported by the Belgian Federal Office of Scientific Affairs (PRODEX program) and B.USOC (MC Limbourg, E. Haumont).

This study was supported by a grant of the Flemish Institute for the advancement of scientific and technologic research in the Industry (IWT).

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