Model Based Processing of CardioVascular Variability Applied to Bed-Rest Case Studies

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Abstract

The cardio-vascular (CV) deconditioning observed in CV diseases or in weightlessness conditions can be reproduced by experimental maneuvers such as head down tilt bed rest (HDTBR) study. This maneuver can elicit CV regulation and control mechanisms.

Three healthy subjects were studied during an exercise session before and after a sustained bed rest study. The CV, baroreflex response, and identification of the components of diastolic arterial pressure (DAP) and sources of variability were studied.

Tachycardia and hypotension were observed after HDTBR. Changes were noticed in the baroreflex control of heart rate (HR) after HDTBR, whereas no clear difference in the diastolic time constant was found. Spectral power of DAP and of its tachogram-dependent component were lower after HDTBR..

The present work suggested the feasibility of the multiparametric analysis and gave preliminary indications of reflex mechanisms reset.

1. Introduction

The cardiovascular (CV) adaptation is of particular importance during postural changes, exercise, or gravity. Many reflexes such as the baroreflex, cardio-pulmonary reflexes among others are involved in the short-term control and regulation of the CV system (CVS). However, the causal effects of those reflexes and their exact role during CV deconditioning are not fully understood.

CV deconditioning is observed in CV diseases, and in weightlessness conditions. The effects of CV deconditioning can be reproduced by bed rest study, which might enhance or blunt the effects of regulatory CV mechanisms. The ability to interpret the effect of bed rest and exercise together and in parallel could add new knowledge on the alterations of regulatory mechanisms impinging on ABP through arterial baroreflex responses, sympathetic vasomotor tone control, auto-regulation responses in peripheral districts and organs.

The study of the baroreflex, CV, cardio-respiratory responses, with the identification of arterial blood pressure (ABP) components and their sources of variability can shed new light on mechanisms of regulation and control.

2. Methods

Three healthy subjects (24 years ± 3.5; 78 kg ± 7.7; 182 cm ± 5.6) were investigated before and after 14 days head down tilt (-6°) bed rest (HDTBR). The experiment consisted of two epochs of exercise on a cycle ergometer (Monark) at 50 W (Exe1) and 100 W (Exe2), each of them followed by a period of recovery at rest (respectively Rec1, Rec2). A baseline period of rest before the exercise session was also included in the present study (Rest).

During the exercise session, arterial blood pressure (Portapress; TPD Biomedical Instrumentation, Amsterdam, The Netherlands), EKG (BioPac systems Inc., Santa Barbara, CA) and the respiration (TUBA; Neltec AG, Kilchberg, Switzerland) were continuously recorded. All signals were sampled at a frequency of 100 Hz.

Artifact free, stationary segments of 3 minutes for Rest, 5 minutes for all other epochs of the protocol, were selected and beat-by-beat series of RR intervals, systolic arterial pressure (SAP), diastolic arterial pressure (DAP), respiration, were obtained.

The baroreflex response were assessed by estimating the baroreflex gain (BRG, ms/mmHg)) using the

sequence method (sequences of three or more consecutive beats with a minimum change of 1 mmHg in SAP and 4 ms in RR were identified.)[1]. The diastolic decay (τ, s) was also parameterized by means of a deconvolution procedure [2].

A multivariate parametric model (Fig. 1) [3] for the investigation of CV dynamics was applied to data. The parameters included in this multivariate analysis are respiration, heart period (HP), SAP, DAP, pulse pressure (PP). The model belongs to the ARXAR class. Causal blocks are all-zero FIR filters, which opening the loops represent the exogenous (X) part; residuals are autoregressive (AR) uncorrelated processes.

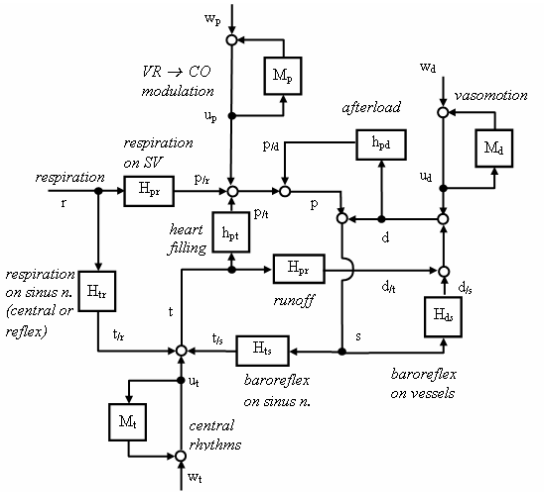

Figure 1: multivariate model of interactions between HP, DAP, PP, respiration.

Effects on DAP which were included are: diastolic runoff describing the decrease due to prolonged HP in the previous interval; baroreflex modulation of vascular resistances responding to previous SAP values. PP components include: respiration effects on stroke volume (SV); changes in heart filling related to previous HP; afterload related to DAP within the same beat.

In this study, we focused the attention of our decomposition analysis on the absolute power of DAP in the low frequency (LF, $0.04 < f < 0.15$ Hz) and high frequency (HF, $0.15 < f < 0.5$ Hz) bands before and after bed rest and on the power of its tachogram-dependent component (D/t) power in the same bands. Spectral power in the bands were computed after auto-regressive estimation of spectra of the signal and its component.

3. Results

Fig. 2 showed for each subject the CV, baroreflex, and the vascular response during the exercise session before and after the bed rest period (respectively RR Intervals (RRI), SAP, DAP, BRG, and τ). All subjects displayed tachycardia after BR for each epoch (decrease of RRI). Hypotension was observed after HDTBR in the first two subjects, whereas in subject 3 diastolic and systolic hypotension are much less marked. The BRG was decreased after HDTBR for each subject. The subject 2 showed similar BRG values during exercise and the following resting period after and before HDTBR. No clear difference was noticed in the diastolic time constant by the HDTBR maneuver.

The analysis of absolute powers in the LF band showed a marked decrease in the post-bed rest experiment for two of the three subjects. The trend in DAP power was remarkably different after bed rest: in pre-bed rest results, a slight increase during Exe1 was followed by a strong decrease during Rec1, while in post-bed results this trend was substantially lost. As to D/t, the response elicited by Exe1 and the following during Rec1 were opposite to the responses regarding DAP. In all cases, bed rest decreased the power of this DAP component with respect to pre-bed rest values.

As to the HF band, the trend observed in DAP power before and after bed rest was virtually comparable in two of the three subjects, with an increase during Exe1 followed by a decrease during Rec1, a strong increase during Exe2 and a subsequent decrease during Rec2. Bed rest lowered the values of the power in all epochs of the experiment. With respect to D/t, the effect of bed rest consisted of a strong lowering of the power in this band in all epochs of the experiment.

4. Discussion and conclusions

Changes which were observed in the CV and baroreflex indexes, although superimposed to individual differences, may suggest different sensitivity and timing in the adaptation to simulated micro-gravity. Results may also suggest a differentiation of both the cardiac and the vascular adaptation in response to exercise.

The mutual influence between cardiac responses and vascular responses was investigated from the point of view of the identification of the tachogram-dependent component of DAP. Their subsequent spectral analysis showed that HDTBR is able to alter the power of these signals both at rest and during exercise.

The present preliminary results show a common trend in a generalized reset of reflex mechanisms as evidenced by the changes in BRG and the influence of HP variability on DAP variability. Conversely, this finding is not paralleled by a reset in passive vascular parameters concurring to the τ time constant of the windkessel model.

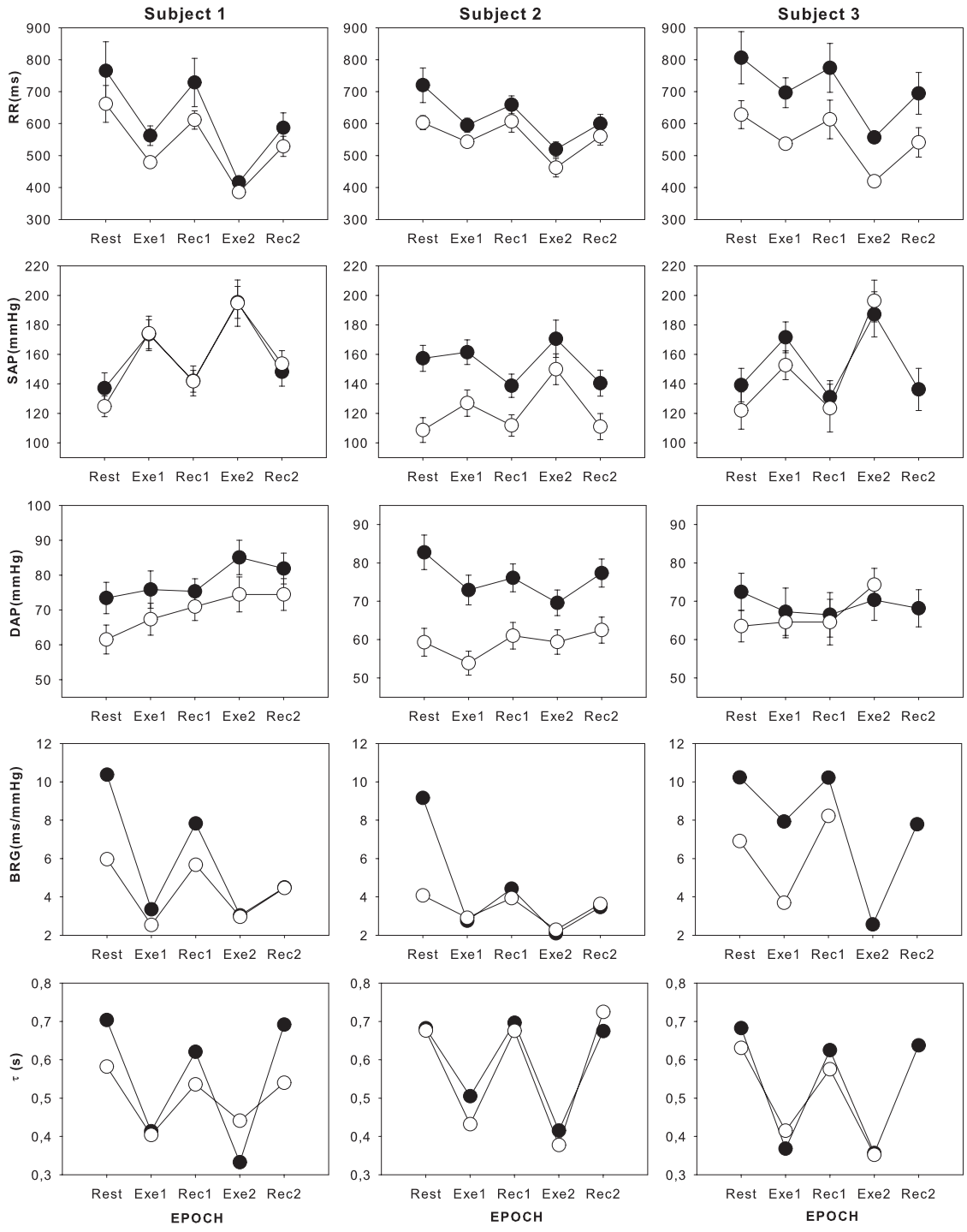

Figure 2: From the top to the bottom panels are shown respectively for each subject RR intervals (ms), Systolic Arterial Pressure (SAP, mmHg), Diastolic Arterial Pressure (DAP, mmHg), the baroreflex gain (BRG, ms/mmHg), and the diastolic time constant (τ, s) during Rest, Exe1, Rec1, Exe2, Rec2 period before (●) and after (○) the bed rest period.

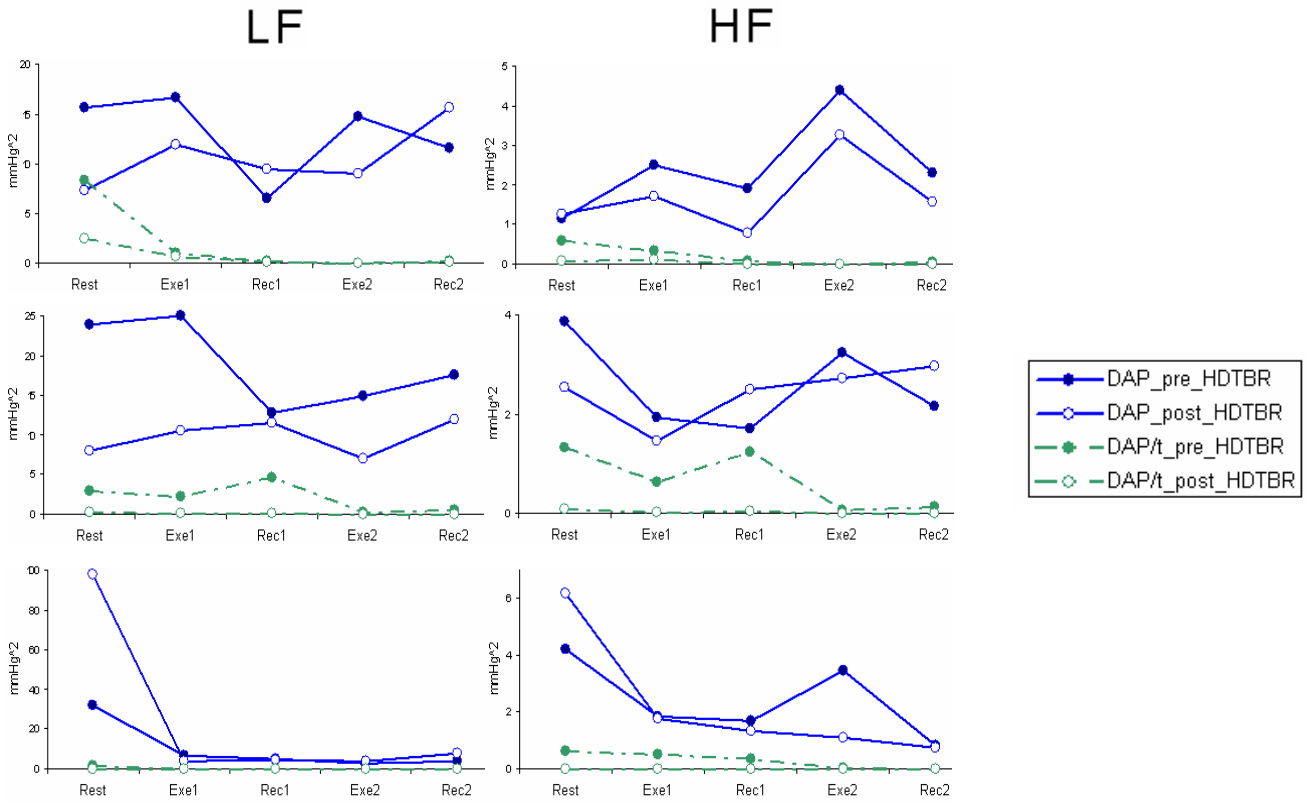

Figure 3: Power of DAP (blue) and tachogram-dependent component of DAP (green) before (●) and after (○) the14-day head-down tilt bed rest (HDTBR) for the three subjects.

In conclusion, our analysis simply represented a case study which was meant to be a preliminary test of a few modeling approaches to the investigation of CV deconditioning and alterations induced by bed rest. One of the advantages of this type of analysis is represented by the large number of parameters which can be taken into account and could provide information regarding a wide variety of phenomena concurring to CV control.

The joint use of a series of methods and models can prove instrumental in better interpreting the several indices that can be extracted by simple analysis of CV parameters under experimental conditions and could improve current knowledge on the effect of bed rest and exercise on CV alterations induced by weightlessness.

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References

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