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HEART KINETIC ENERGY DECONDITIONING AFTER THE 60-DAYS ESA-RSL HEAD-DOWN BED-REST: WEARABLE MONITORING AND MACHINE LEARNING

Abstract

Introduction - Head-down tilt bed-rest (HDBR) simulates cardiac deconditioning that occurs during long duration space flight. The effects of 60-days HDBR were assessed by a novel non-invasive wearable heart kinetic (HK) cardiac monitoring method based on Seismocardiography (SCG) and 6-dimensions Ballistocardiography (BCG) using Cardiovector, a cardiac monitoring system on board ISS. Results were compared to phase-contrast (PC) MRI-derived stroke volume (SV).

Methods - HK was measured in a controlled breathing (CB) protocol performed before (PRE) and after 58 days (HDT58) of bed-rest on 23 healthy males (age 28±6) separated in 2 groups, 11 control (CTRL) and 12 Reactive Jump Counter-measure (JUMP). Aortic PC-MRI was performed, and blood velocities were integrated over the aortic lumen area to compute SV. During CB, we recorded ECG, respiration, SCG, and 3-dimensional linear (lin) and angular (rot) BCG. Newton's equations of kinematics were used to compute the energy transferred to the body by each cardiac contraction (HKtot = HKlin + HKrot). Feedforward Artificial Neural Networks (ANN) were used to classify the records (decomposed according to the respiration phases) in 2 categories: PRE vs HDT58, or CTRL vs JUMP. 72 parameters based on heart kinetics energies and ECG analysis + height and weight were used as inputs of the model. It was cross-validated using a Leave-One-Out strategy on the subjects. The overall performance was evaluated by summing the confusion matrices.

Results - Comparison between CTRL PRE and CTRL HDT58 showed a significant ($p<.05$, paired t-test) decrease in SV (22%) and a decrease in HKtot (27%) and HKrot (30%) but not in HKlin. The ANN trained with the computed HK energies showed high capability on discriminating the records of two heart conditions (PRE vs HDT58), with better results in the JUMP group (Positive Predictive Value, PPV=87%) than in the CTRL group (PPV=83%). However, the ANN method was not able to discriminate the 2 groups after 58 days.

Conclusion - This is the first study using HK cardiac monitoring together with PC-MRI and showing a decreased cardiac contractility and SV after HDBR deconditioning. As HKrot was the main parameter

decreased during the experiment, the twist of the heart seems to be the first parameter affected by the deconditioning. The large PPV showed the high potential of the method to distinguish two heart conditions and suggests that the method has a potential to identify cardiac diseases such as heart failure.