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Infradian cardiovascular rhythms during a 520-day simulated journey to Mars (Mars500 project)

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Background

• The Mars 500 project , organized by the European Space Agency (ESA) and the Institute for Biomedical Problems (IBMP) in Moscow, was designed to simulate a 520 d mission to Mars in duration, composition of the crew, activities, full life support and communication facilities with a Mission Control.

• Although physiological infradian rhythms have been described in humans, no evidence was found about their occurrence under strict controlled situations.

• Taking advantage of the Mars 500 study, we sought to explore infradian systolic and diastolic blood pressure (SBP, DBP) and heart rate (HR) rhythms.

Methods

Subjects & design

• Six healthy male subjects were selected to participate in the 520-d confinement study.

• Subjects were involved in 105 different scientific protocols that assessed physiological, psychological, social, ecological, and technological aspects of confinement.

• Their schedules were organized in 8-h periods of work, leisure, and sleep. No night shifts were programmed.

• The simulated timeline included entering into different successive orbits toward Mars, an egress on a simulated Martian Surface, and entering into different successive orbits toward Earth.

• Facilities comprised four (550 m^3) hermetically sealed interconnected modules resembling a spacecraft (medical & research, habitat, storage, lander), and a Martian surface simulator (Figure 1).

• Ambient conditions were 24°C, relative humidity of 35 – 45%, and artificial lightening of 50 – 300 lux.

Analysis

• For this protocol, SBP, DBP, and HR were assessed each morning and evening, on a daily basis.

• A Lomb-periodogram was applied to each signal to identify the main peaks that denote significant infradian rhythms.

• A three- harmonic cosinor model with a fundamental period of 520 day was fit to the data to obtain curve parameters for further exploratory analyses.

Results

• Significant infradian rhythms were found for all variables, but with different periods in most of the cases.

• The exception was a similar evening HR rhythm found in all subjects, with a (mean ± SD) period of 198 ± 10 days, and an amplitude of 31 ± 11 bpm^2/Hz ($p < 0.001$) (Figures 2-4).

• The rhythms seemed to be phase synchronized during the second third of the journey (Figure 5).

• Further analyses are being performed to exclude leakage effects in peak determination.

Figure 1: Mars-500 project facilities

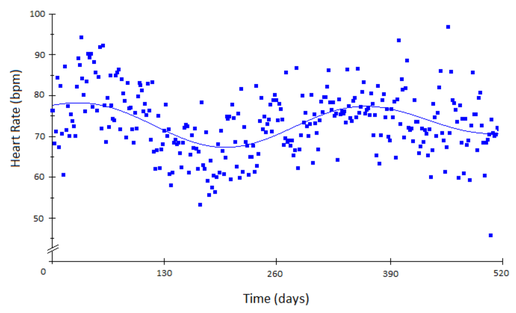

Figure 2: Evening heart rate of a selected crew-member. Dots denote heart rate values, while solid line shows cosinor fit.

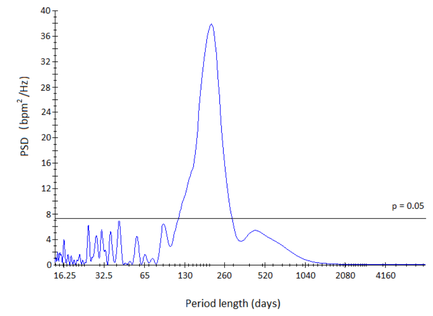

Figure 3: Lomb periodogram of the same subject of figure 2. The main peak denotes a period length of around 170 days.

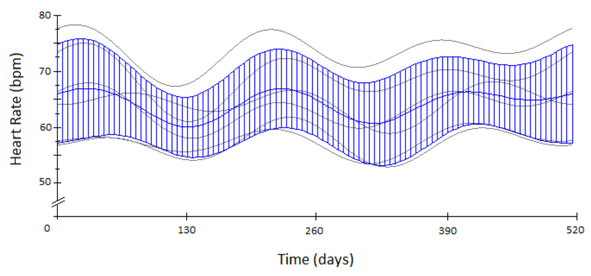

Figure 4: Cosinor fit for evening heart rate of all crewmembers (grey lines), with mean and CI 95% (blue lines).

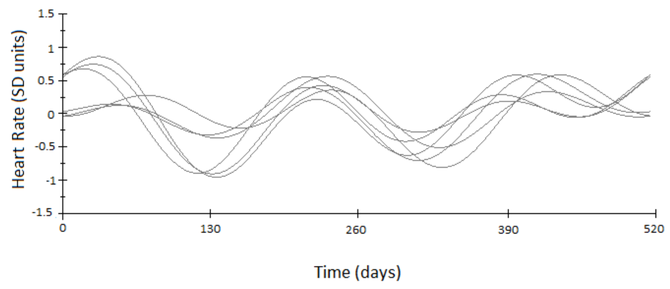

Figure 5: Cosinor fit for standardized evening heart rate of all crewmembers .

Discussion

• Several factors may account for our results, including seasonal changes in mood, physical activity, nutrition or sleep along confinement.

• The existence of endogenous free-running monthly cycles is difficult to prove.

• The suprachiasmatic nuclei are believed to be responsible for determining circannual biological rhythms.

• Seasonality is characterized by changes in sleep, mood and behavior and circannual rhythms had been described for autonomic variables.

• Studying human infradian rhythms may be relevant for understanding adaptation to slow changing environmental variables in health and disease.

Selected References

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