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NUMERICAL SIMULATION OF CARDIOVASCULAR DECONDITIONING IN DEEP SPACE HUMAN MISSIONS.

Abstract

Deep space human missions involve important limitations regarding the health of the astronauts. Among them, the deconditioning of the cardiovascular system arises as a major potential hazard due to long-term microgravity exposure. Opportunities to experimentally study the degradation of cardiovascular health due to space travel are scarce and usually limited by low repetibility of data. We herein report results from intensive numerical simulations aimed at evaluate the risks involved in an extensive range of long-term mission scenarios. The simulation system NELME allows us to introduce dierent levels of exposure to micro or hypergravity, analyse the consequences on relevant gures of cardiovascular deconditioning, such as heart rate, mean stroke volume or vascular resistance; and assess the relative risk of putting a mission into jeopardy due to microgravity deconditioning eects.Thermical stress, aerobic or anaerobic exercise are also simulated to take into account a realistic long-term space mission including, for example, ExtraVehicular Activities or aerobic exercise as countermeasure. Gender dierences are also discussed. The model is based on previous works form Melchier et al. and Heldt et al. who described in analytical terms the process of orthostatic intolerance due to gravity alterations being applied on a healthy subject. We then incorporated these Runge-Kutta equations into a numerical model by using Matlab and Simulink software, to take into account the complex process of deconditioning of the cardiovascular system. Initial results from this model had been validated in parabolic ight. The simulation is based on an electrical-like control system model in which output variables of the body performance (vascular resistance,blood volume etc) are found while step-by-step changes of gravity and thermal stress were applied. Dierent micrograivity exposure scenarios, including Moon, Mars and also other deep space exploration missions are considered. Their potential risks thay may put in jeopardy the success of a crewed mission are quantied. We found that the vascular resistance deconditioning appears to be comparable for the reduced gravity at the level of the Moon until a level of 1/12th Earth's Gravity. This deconditioning could not be fully counteracted, according to the simulation, with aerobic exercise; which raises concerns for successful manned Mars mission scenarios and others beyond. This simulation tool may be of interest for designing future deep space crewed missions, and forecasting potential health hazards in long-term microgravity exposure scenarios.