The NASA Digital Astronaut Project: Computational Modeling of Space Physiology

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Abstract

The Digital Astronaut Project (DAP), within NASA's Human Research Program, develops and utilizes computational modeling in the mitigation of human health and performance risks associated with long-duration spaceflight. Applied computational modeling supplements space physiology research by informing experimental design and elucidating important factors associated with space flight induced physiological phenomenon. They become an especially critical tool in areas where data are lacking. DAP also tailors computational models to inform design and to predict efficacy of proposed spaceflight countermeasures devices. These technologies include exercise devices to reduce physical deconditioning and additionally, lower body negative pressure, blood flow occlusion and artificial gravity simulating devices as countermeasures to spaceflight-induced fluid shifts.

Objectives of the specific DAP computational models and simulation analyses include supporting the development of compact exercise devices that will be flown on NASA's new exploration crew vehicles. Biomechanical modeling informs design requirements to ensure that properly performed exercises fit within the volume allocated for exercise and to determine whether the limited mass, volume and power requirements of the devices affect biomechanical outcomes. Models that involve muscle atrophy and bone loss predict device efficacy for protecting musculoskeletal health during long-duration missions. A lumped-parameter whole-body model relates the shift in the blood of the cardiovascular system, the cerebral spinal fluid, interstitial fluid and lymphatic system fluid due to gravitational changes to corresponding pressure and volume allocations. These models simulate low-gravity fluid shift effects and are coupled to models predicting the associated changes in tissue strain in areas of physiological interest to aid in predicting countermeasure effectiveness. Collectively, this broad suite of models is used to aid human space exploration risk reduction.