

UNDERSTANDING THE EFFECTS OF LONG-DURATION SPACE FLIGHT ON ASTRONAUT FUNCTIONAL TASK PERFORMANCE

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Abstract

Space flight is known to cause alterations in multiple physiological systems including changes in sensorimotor, cardiovascular, and neuromuscular systems. These physiological changes cause balance, gait and visual disturbances, cardiovascular deconditioning, and loss of muscle mass and strength. These changes may affect a crewmember's ability to perform critical mission tasks immediately after landing on a planetary surface. To understand how changes in physiological function affect functional performance, an interdisciplinary pre- and postflight testing regimen, Functional Task Test (FTT), was developed to systematically evaluate both astronaut functional performance and related physiological changes. Ultimately this information will be used to assess performance risks and inform the design of countermeasures for exploration class missions. We are currently conducting the FTT study on International Space Station (ISS) crewmembers before and after 6-month expeditions. Additionally, in a corresponding study we are using the FTT protocol on subjects before and after 70 days of 6° head-down bed-rest as an analog for space flight. Bed-rest provides the opportunity for us to investigate the role of prolonged axial body unloading in isolation from the other physiological effects produced by exposure to the microgravity environment of space flight. Therefore, the bed rest analog allows us to investigate the impact of body unloading on both functional tasks and on the underlying physiological factors that lead to decrement in performance and then compare them with the results obtained in our space flight study.

Functional tests included ladder climbing, hatch opening, jump down, manual manipulation of objects and tool use, seat egress and obstacle avoidance, recovery from a fall and object translation tasks. Physiological measures included assessments of postural and gait control, dynamic visual acuity, fine motor control, plasma volume, heart rate, blood pressure, orthostatic intolerance, upper- and lower-body muscle strength, power, endurance, control, and neuromuscular drive. ISS crewmembers were tested three times before flight, and on 1, 6, and 30 days after landing. Bed-rest subjects were tested three times before bed-rest and immediately after getting up from bed-rest as well as 1, 6, and 12 days after reambulation.

Results showed that functional tests requiring a greater demand for dynamic control of postural equilibrium (i.e. fall recovery, seat egress/obstacle avoidance during walking, object translation, jump down) showed the greatest decrement in performance. Functional tests with reduced requirements for dynamic postural stability (i.e. hatch opening, ladder climb, manual manipulation of objects and tool use) showed less reduction in performance. Similarly, subjects exposed to prolonged bed rest showed the same trends in performance change as ISS subjects, namely a reduction in performance on functional tests requiring a greater demand for dynamic control of postural equilibrium. For both ISS and bed rest subjects these changes in functional performance were paralleled by similar decrement in physiological tests designed to specifically assess postural equilibrium and dynamic gait control.

These results indicate that body support unloading experienced during space flight plays a central role in postflight alteration of functional task performance. These data point to the importance of providing significant axial body loading during inflight treadmill and resistive exercise. In addition, balance training should be used to supplement current inflight aerobic and resistive exercise activities. Currently our laboratory is developing a treadmill-based balance and gait training system using virtual environments. Forward work will focus on the development of an inflight training system that will integrate aerobic, resistive and balance training modalities into a single interdisciplinary countermeasure system for exploration class missions.

Age-related sensory changes and deterioration in ability to compensate in older adults can contribute to increased incidence of falling. One of the most important factors underlying morbidity in the older adult population is injurious falls and the restriction of activity due to falls. Integrated balance and gait training programs have earthbound application in rehabilitation of patients with balance disorders, and for fall prevention training among seniors. Training programs developed at NASA-Johnson Space Center have been used to improve balance and gait performance in elder subjects and points to the general applicability of this type of training in different clinical populations.