TEMPORAL CHANGES IN ASTRONAUTS' MUSCLE AND CARDIORESPIRATORY PHYSIOLOGY BEFORE, DURING, AND AFTER SPACEFLIGHT

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BACKGROUND

NASA's planned space exploration missions will require astronauts to safely perform extravehicular activity (EVA) and to safely egress vehicles in a variety of landing scenarios. Prolonged exposure to spaceflight decreases cardiovascular and sensorimotor function, causes loss of bone mineral density, reduces muscle mass and strength, and ultimately diminishes tolerance for physical activity. Although exercise can help mitigate these spaceflight-induced physiological decrements, little is known regarding the time-course of changes in muscle and aerobic performance during spaceflight. Furthermore, these exercise countermeasures are not fully protective. For example, maximal aerobic capacity (VO_2pk), lower body muscle cross-sectional area, and strength all decrease by about 10% to 15% after long-duration missions on the International Space Station (ISS). Future long-duration space missions beyond Low Earth Orbit will employ exploration vehicles with less robust exercise hardware and more constrained exercise capabilities (e.g., less operational volume, less active exercise time) than provided on the ISS. Thus, countermeasures will need to be optimized to protect crew health and performance on exploration-class missions lasting up to 3 years. This requires a more detailed understanding of the dynamic effects of spaceflight on human health and performance, the ability of exercise to protect against this deconditioning, and the interaction of exercise with interrelated factors like nutrition, sleep, and environmental conditions.

METHODS

We will use standardized research and medical testing protocols previously validated in 1 g and 0 g to quantify the time course and the inter-individual variability of changes in physical performance. Primary outcomes of this investigation include cardiorespiratory fitness (VO_2pk), muscle strength (isometric mid-thigh pull [IMTP], isokinetic peak torque), and muscle endurance (isokinetic total work) and will be assessed before, during (VO_2pk and IMTP only), and after spaceflight missions lasting 2 months (n=10), 6 months (n=10), and 1 year (n=10). Secondary outcomes include muscle quality (morphology, density, and electrical impedance myography), bone mineral density and quality (dual-energy X-ray absorptiometry and high resolution peripheral quantitative computed tomography), and simulated capsule egress, as well as in-flight monitoring of exercise, nutrition, and sleep. Additionally, extrapolation models will be utilized to predict physiologic changes associated with 2–3-year exploration missions.

RESULTS

Three subjects have been recruited for this study. Data collection is currently in progress.

SIGNIFICANCE

Our testing protocols will provide valuable information for determining time course of change and the interindividual variability of spaceflight-induced deconditioning of aerobic capacity and muscle strength and endurance over the course of spaceflight missions up to and beyond 1 year. This information will be vital to assess whether humans can be physically ready for deep space exploration, such as on a mission to Mars, using current technology, or if additional mitigation strategies are necessary.

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