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NAVIGATING MUSCULOSKELETAL CHALLENGES IN SPACE EXPLORATION: MECHANISMS, INTERVENTIONS, AND FUTURE DIRECTIONS

Abstract

Space exploration stands as a testament to human curiosity and resilience, yet it poses unique challenges to astronaut health, notably in the realm of musculoskeletal health.This manuscript explores the major musculoskeletal changes that occur during spaceflight, such as osteoporosis due to loss of bone density, muscle atrophy, changes in the composition of muscle fibers and effects on joints and connective tissues. These physiological adjustments are prompted by the microgravity environment of space, which may jeopardize astronauts long term health and the effectiveness of their missions. Exploring the mechanisms underlying these shifts, using data from recent research and space missions, is a key component of our approach. We emphasize that one of the main causes of bone demineralization and changes in the composition of muscle fibers in microgravity is the decrease in mechanical stress, which has importance for both future space travel and post-mission rehabilitation. In addition, we assess existing approaches to reducing these health hazards critically. This covers in detail the function of nutritional therapies to enhance musculoskeletal health as well as an extensive examination of onboard training devices meant to imitate gravity-dependent stressors. These tactics efficacy, drawbacks, and room for innovation are examined, offering a road map for improving astronaut health and mission performance. This manuscript summarizes existing knowledge while also pointing out knowledge gaps and advocating for further research and technological development to protect astronauts as humanity, expands its reach into space. In order to protect astronauts health and performance on upcoming missions the conclusions and suggestions made here will hopefully aid in the development of stronger defenses against the musculoskeletal difficulties associated with spaceflight.