

National Space Biomedical Research Institute

Team: Musculoskeletal Alterations – Team Executive Summary

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Background/Scope

Musculoskeletal tissue atrophy is a serious complication of long-duration spaceflight. Crew members making long-duration flights on the International Space Station lose bone from their hips at an average rate of 1-1.5% per month, a rate comparable to the yearly loss observed in postmenopausal women. Moreover, decreased muscle function is also a serious medical risk factor, potentially resulting in impaired balance and reduced performance on the lunar or Mars surface, or during other extravehicular activities (EVA). Together, skeletal atrophy and increased risk of falls may result in increased risk of bone fractures, a potentially catastrophic event. In addition, there are potential life-long risks to bone health on return to Earth after one or more long-duration missions. The Musculoskeletal Alterations Team is carrying out a coordinated program of research to help define the basic mechanisms and characteristics of musculoskeletal tissue atrophy and repair, and to validate the efficacy of exercise- and pharmacological-based countermeasures to reduce musculoskeletal tissue loss.

Goals

The overarching Team goals are to better understand the effect of microgravity and partial gravity on the physiology of musculoskeletal tissues and to develop exercise-based and pharmacologic countermeasures to reduce the risk of musculoskeletal injury through reduction of bone and muscle loss. This effort will involve two main thrusts (i): mechanistic studies in animal models of the effect of simulated lunar gravity and microgravity on musculoskeletal tissue physiology (Bloomfield), including the processes of bone loss, muscle atrophy (Reid), radiation effects (Bateman), drug effects (Schaffler, Midura, Bateman and Carleton) and healing of bone fractures (Midura) and (ii) the development of hardware that directly or indirectly monitor the loads applied to bone during missions and that improve the efficiency and efficacy of exercise countermeasures by integrating multiple exercise modalities into single compact platforms (Lang and Adams).

Support of NASA Needs

The currently-funded research program of the Musculoskeletal Alterations Team supports NASA in development of countermeasures that are flight relevant in the short term and in a mechanistic research program designed to provide a scientific basis for development of novel countermeasures for lunar outpost activity and for long-term exploration. Short-term needs are met by research programs that define the effect of a daily load stimulus on skeletal atrophy in long-duration spaceflights and by investigations that seek to reduce risk of musculoskeletal injury by developing hardware to support time-efficient and highly effective exercise prescriptions that integrate multiple modalities such as resistive exercise, cardiovascular exercise and sensorimotor training. Long-term needs are met by mechanistic studies in animal models that define the effect of microgravity and partial gravity environments, pharmacologic interventions and the space radiation environment on muscle and bone loss.

Deliverables

- Development of flight-ready exercise devices integrating multiple exercise modalities into compact platforms, including one device combining resistive and cardiovascular training, and another that integrates lower and upper body resistive conditioning, cardiovascular conditioning and balance training, and development of hardware to characterize the mechanical loads to the skeleton associated with partial gravity exposure
- Analysis of the combined effects of simulated lunar gravity and the lunar radiation environment's effect on bone cell activity and skeletal metabolism
- Studies of the effect of prolonged simulated lunar gravity exposure on bone loss, muscle loss and fracture healing
- Studies of microgravity effects on muscle cell function and the combined effects of myostatin inhibition and exercise in reducing loss of muscle mass and bone
- Studies of the effect of anti-resorptive and anabolic therapies on bone loss and recovery after prolonged simulated microgravity exposure

Cross-Links

Intra-team cross-linkages: the Daily Load Stimulus Project (Cavanagh) is cross-linked with the Integrated Countermeasure Project (Lang). The Musculoskeletal Health project (Bloomfield) involves collaboration with Dr Kenneth Baldwin, former Muscle Team Leader. Inter-team cross-linkages involve the Musculoskeletal Alterations Team (Lang), with the Sensorimotor Adaptation Team (Bloomberg and Mulavara). NSBRI linkages with elements of NASA/JSC include the Bone and Mineral Laboratory (Sibonga), the Exercise Physiology Laboratory (Spiering), the Cardiovascular Laboratory (Lee), the Neuroscience Lab (Mulavara) and with NASA-funded musculoskeletal investigators (Hogan) and radiation scientists (Nelson).

Enabling Capabilities and Gaps

Readaptation of bone to resumed gravitational loading: How does the structure of load-bearing bone readapt to gravitational loading, and how do the extent and time course of readaptation affect bone strength in injury-relevant skeletal loading scenarios such as falls? Can controlled studies, for example, such as those under bed-rest conditions, be carried out to characterize bone structural readaptation and its effect on bone strength? Are there rehabilitation strategies that can promote readaptation of bone structure in a manner consistent with reduction of risk of fractures secondary to falls?

Effect of long-duration spaceflight on the integrity and function of tendons and ligaments: Ligament tears and tendon ruptures are highly disabling and clinical experience indicates complicated and unpredictable healing patterns. What are the alterations in the ligament and tendon tissue that occur in long-duration microgravity exposure, and do these changes predispose to increased risk of injury? Can bed-rest models be utilized to characterize these changes?

Effect of long-duration spaceflight on muscle strength, endurance and functional performance under realistic EVA conditions: What is the effect of loss of muscle strength and endurance on functional capability in realistic EVA scenarios encompassing the full spectrum of short bursts of high-intensity activity, sustained lower-intensity efforts, and high-intensity efforts of moderate duration? Are such effects compounded by the spacesuit? What studies can illuminate the impact of muscle alterations on performance under realistic EVA and spacesuit conditions?

Sex Differences: Are there sex differences in the response of bone and muscle to altered gravity and does this imply a need for gender-based countermeasures?

Earth-Based Benefits

Earth benefits include the development of exercise hardware that can reduce fall risk in the elderly by improving neuromuscular performance and reducing bone loss. Other benefits include characterization of novel pharmacologic treatments that could potentially be applied to combat muscle wasting associated with aging, cancer and HIV. Mechanistic studies of the effect of microgravity and partial gravity environments on muscle and bone metabolism and function and fracture healing will provide fundamental knowledge about the physiology of musculoskeletal tissues.