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ERGONOMIC EVALUATION OF EXTRAVEHICULAR ACTIVITY (EVA) SYSTEMS ON MUSCULOSKELETAL STRAIN AND FATIGUE DURING EXTENDED LUNAR SURFACE EVAS

Abstract

As long-duration spaceflight missions to the Moon and Mars become a key focus amongst governmental space agencies and commercial entities, the necessity for intensive Extravehicular Activity (EVA) introduces significant challenges in astronaut safety and mission sustainability. While on an extraterrestrial surface for extended periods of time, EVA astronauts will encounter heavy physical demands, non-ergonomic working conditions, and restrictive mobility of the spacesuit which can lead to severe musculoskeletal injuries. To address these challenges, this study aims to assess musculoskeletal strain and fatigue of astronaut trainees as they undertake a series of tasks during a simulated lunar surface EVA.

The simulated lunar surface EVA will be conducted at the International Institute for Astronautical Science (IIAS)'s Gravity-Offset Laboratory located at the Florida Institute of Technology, a state-of-the-art facility equipped with an electromechanical system that mimics reduced gravity conditions and features a bed of simulated lunar regolith. This facility supports dynamic gravity adjustment through real-time feedback, enabling precise analogs of lunar, Martian, and zero-gravity environments for the evaluation of Final Frontier Design EVA spacesuits and tool performance. During simulated lunar surface EVAs, trainees will engage in common EVA training such as collecting soil samples, assembling and relocating equipment, and navigating uneven terrain. Trainees will also be equipped with an array of sensors strategically attached on various areas of the skin, all connected to a portable Arduino system positioned under their undergarments while in the EVA spacesuit. A physiological profile will be quantified through these sensors, capturing muscle activation patterns through electromyography, stress and fatigue levels via heart rate variability, and physiological stress indicators through galvanic skin response. This comprehensive profile will offer insights into the physiological stressors and precursors that contribute to the development of musculoskeletal injuries. In addition, ergonomic assessment will be simultaneously evaluated using flex sensors near critical anatomical regions such as the spine, shoulders, elbows, and knees. The integration of physiological profiles and ergonomic analysis will identify correlations between EVA training and musculoskeletal strain, with ergonomic assessments comparing these patterns to musculoskeletal health standards.

These findings aim to pinpoint movements and postures presenting a high risk of injury over prolonged exposure. Thus, this study aspires to understand the impact of lunar surface EVA conditions on astronaut health and operational proficiency, further supporting the advancement of targeted interventions for muscle rehabilitation and performance optimization techniques for long-duration spaceflight missions.