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EMSI SUIT: ELECTRICAL MUSCLE SIMULATION SUIT FOR COUNTERING MUSCULOSKELETAL CHANGES IN MICROGRAVITY THROUGH INTERACTION WITH POSTURAL MUSCLES.

Abstract

Musculoskeletal response to microgravity constitutes one of the most consequential risks in human spaceflight, especially during long-term missions. Counteracting muscle atrophy is essential to safeguard astronauts' health and performance. High-elasticity compression fabrics integrated into inter-vehicular bodysuits arise as a valid method to counter musculoskeletal deconditioning by imparting astronauts with a load equivalent to their body weight. However, compression alone fails to fully mimic the action of gravity on the human body.

The EMSi (Electrical Muscle Simulation) suit represents a comprehensive countermeasure system designed to deliver muscle compression and low hysteresis using graphene elastic fabric. This passive system is supplemented by an active one featuring biphasic adaptive electro-stimulation. This interactive system provides muscles with requisite stimulation, normally guaranteed by gravity, through an electrical input that induces contraction.

To determine the forces exerted on joints and muscles by the EMSi stimulation system under static and dynamic conditions, a numerical model was developed. Incremental biomechanical loads were registered and integrated into the model for comparative analysis with data from a microgravity simulation model developed in OpenSim. This approach facilitated determination of the stimulation necessary to approximate the one experienced under terrestrial gravity conditions. To provide the expected effects, the administration of stimulation must be tailored to astronaut's needs, implementing a calibration phase. Following meticulous evaluation of materials and designs, a fully functional EMSi suit prototype was developed.

Upon completion of suit activation protocols in line with the current state of technological advancements, extensive testing procedures were necessary. With the support of the Italian Space Agency (ASI) and the Italian Air Force, the EMSi suit was tested during the Axiom 3 mission, making our team the first to trial a technology for human spaceflight within the Crew Dragon spacecraft. Italian astronaut Walter Villadei participated in EMSi suit testing, yielding valuable data. This opportunity heralded a series of experiments within SpaceX's vehicle in forthcoming missions.

This paper not only details the EMSi suit development but also presents findings from post-mission hardware analysis, providing insights into the suit's technology performance in microgravity environments. The study underscores the significance of addressing musculoskeletal challenges in space exploration and highlights the potential of EMSi technology to mitigate these issues effectively.