Pulsed Electromagnetic Fields—A Countermeasure for Bone Loss and Muscle Atrophy

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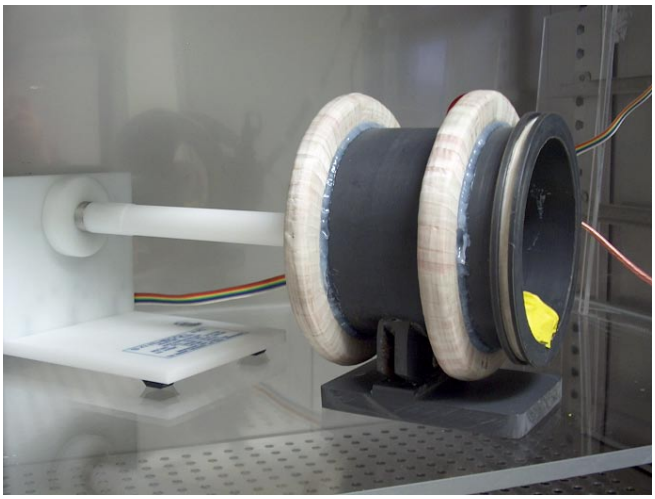
Currently, there is a critical need to develop effective countermeasures for bone loss and muscle atrophy to enable future human space exploration to the Moon, Mars and beyond. Progressive muscle atrophy can lead to weakness, fatigue, the inability to perform efficiently assigned tasks, and compromised emergency egress operations. Bone loss causes increased risk of bone fracture and kidney stones, which can also negatively affect mission objectives and success.

The purpose of these studies is to develop a pulsed electromagnetic field device for use as a noninvasive countermeasure to enhance bone retention, prevent or alleviate muscle atrophy, and augment natural healing/regeneration processes. This research represents a major contribution toward enabling humans to live and work safely in space, and is especially relevant to projected human space exploration. On Earth, this device could be useful in the treatment of various muscle diseases, age- and cancer-related muscle atrophy, osteoporosis, and other bone diseases.



PEMF prototype device for initial studies.

It has become increasingly evident that weak, nonionizing electromagnetic fields can exert athermal effects on biological targets. One successful therapeutic application of pulsed electromagnetic fields (PEMF) is to facilitate healing in patients with refractory broken bones; that is, bones that are unable to heal despite repeated surgical procedures. In addition, previous studies suggest that PEMF might be useful in the treatment of some muscle disorders.

Although studies on PEMF have been ongoing for more than 20 years, little is known about the molecular and cellular mechanisms involved in their beneficial therapeutic effects. In particular, the field energetics must be precisely defined and optimized for specific applications, such as frequencies, pulse shape, waveforms, amplitude, and spatial orientation. To determine whether PEMF could be used as an effective countermeasure, scientists developed a device with accompanying software to enable the precise control of various parameters. This device will help identify which PEMF frequencies are most effective in producing a biological response in bone and muscle cells. Studies at the molecular and cellular levels will define the alterations induced by modeled microgravity and the ability of PEMF to reverse the alterations related to muscle atrophy and bone loss. Ultimately, the long-term objective of these studies is to produce a garment incorporating a specifically designed PEMF device to be worn by astronauts as a noninvasive countermeasure.

In collaboration with the Engineering Directorate at Johnson Space Center, we developed the required hardware and software enabling the assessment of various PEMF frequencies, waveforms, and pulse durations. In addition, we created a signal monitoring/feedback capability for stable magnetic control and a Helmholtz coil design, and we performed a full simulation

before construction. This device and the associated software will help identify the most effective PEMF parameters for space-induced bone loss and muscle atrophy. We performed the field characterization of the magnetic fields in terms of frequency, sine wave/pulsed inputs, frequency response, field amplitude, and harmonics.