THE HOPPER: A WEARABLE ROBOTIC DEVICE TESTBED FOR MICRO-GRAVITY BONE-LOADING PROOF-OF-CONCEPT

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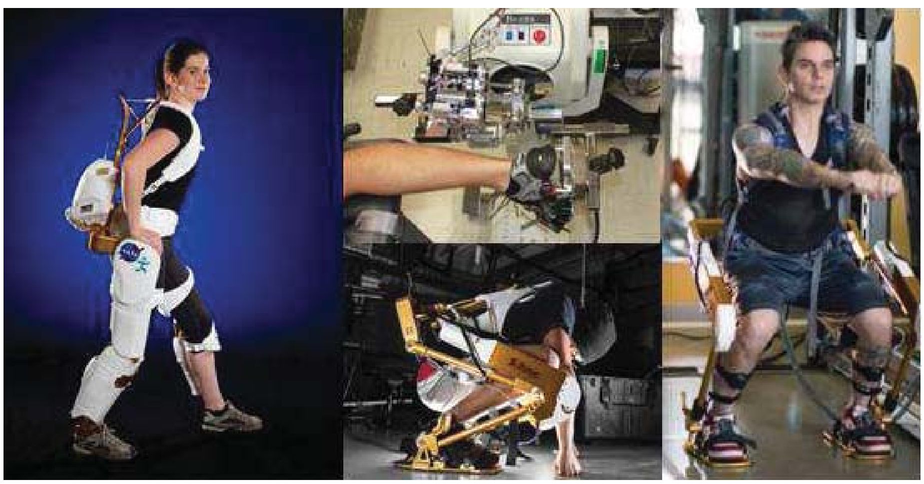
BACKGROUND

Wearable robotic systems are showing increased potential for addressing crew countermeasures needs. Wearable robots offer a compactness, programmability, and eccentric loading capability not present in more conventional exercise equipment. Correspondingly, advancements in the man to machine interface has progressed, allowing for higher loads to be applied directly to the person in new and novel ways. Recently, the X1 exoskeleton, a lower extremity wearable robot originally designed for mobility assistance and rehabilitation, underwent human subject testing to assess its potential as a knee dynamometer. This was of interest to NASA physiologists because currently strength is not assessed in flight due to hardware limitations, and thus there is a poor understanding of the time course of in-flight changes to muscle strength. The study concluded that the X1 compared well with the Biodex, the “gold standard” in terrestrial dynamometry, with coefficients of variation less than 6.0%. In a following study, the X1 powered ankle was evaluated for its efficacy in exercising calf muscles. Current on-orbit countermeasures equipment does not adequately protect the calf from atrophy. The results of this study were also positive (targeted muscle activity demonstrated via comparing pre- and post-exercise magnetic resonance imaging T2 measurements), again showing the efficacy of wearable robotic devices for addressing the countermeasure needs of our astronauts. Based on these successes and lessons learned, the Grasshopper was co-developed between IHMC (Florida Institute for Human and Machine Cognition) and NASA.



THE HOPPER DEVICE

The Grasshopper, or the Hopper for short, is a wearable robotic device designed to address muscle and bone density loss for astronauts spending extended periods of time in micro-gravity. The Grasshopper connects to the user's torso like a hiking backpack, over the shoulders and around the waist. At the feet are footplates that strap to the user. There are two actuators, one at each "knee" joint, which are capable of high fidelity torque control. Because the Hopper uses motors instead of gravity to create the load on the user, the device is suited for use on space missions. Exercise in zero-gravity conditions is critical to maintain muscle strength and bone mass.

In operation, the actuators try to fold up, or collapse, the device, putting a compressive load between the user's feet and torso. This force is similar to carrying a heavy backpack. The user then bends and extends his or her knees, replicating a weightlifting squat exercise. The applied load is precisely controlled by a computer, and can be programmed to simulate gravitation loads or any desired load prescription, such as free-weight squat exercise. It is even possible to perform eccentric exercises, or negatives, without the need for a spotter. Because the hip joints, as well as the spine and long leg bones, are in the applied load path, there is the potential to stimulate bone growth, countering the typical bone loss when astronauts return from extended duration space travel.