EXERCISE WITHIN LBNP AS AN ARTIFICIAL GRAVITY COUNTERMEASURE

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INTRODUCTION: Previous exercise in space has lacked sufficient loads to maintain preflight cardiovascular and musculoskeletal mass and function. Lower body negative pressure (LBNP) produces a static force equivalent to one Earth body weight by each 52 mm Hg of LBNP during supine posture. LBNP also provides transmural blood pressures simulating upright exercise. Thus, this artificial-gravity concept may help maintain cardiovascular and musculoskeletal systems of crewmembers during prolonged exposure to microgravity. Currently available, bungee cord assisted, treadmill exercise is limited by harness discomfort, lower than normal loads, abnormal post-flight gait, and the absence of gravitational blood pressures within the vascular system.

PURPOSE: This project evaluates a method to create artificial gravity using supine LBNP treadmill exercise to prevent loss of physiologic function in microgravity simulated by 30 days of bed rest. Identical twins were used as volunteers so that statistical power could be maximized. This countermeasure is being transitioned to space flight.

CURRENT STATUS OF RESEARCH

Methods: Six sets of identical twins (6 females and 14 males, 21-36 years) remained in 6° head-down tilt (HDT) bed rest for 30 days to simulate prolonged microgravity. Six subjects were randomly selected to exercise supine in an LBNP chamber for 40 minutes six days per week (EX group), while their twin brothers served as non-exercise controls (CON). Pressure within the exercise LBNP chamber was adjusted to increase load, hence increasing exercise intensity. During supine treadmill exercise, LBNP (52-63 mmHg) was applied to produce foot ward forces equivalent to those for upright running on Earth at 1.0-1.2 times body weight (BW) and subjects performed an interval exercise protocol (40-80% peak exercise capacity [VO_2pk]). Five minutes of resting LBNP immediately followed each exercise session.

Results: Orthostatic tolerance time decreased significantly after 30 days bed rest in the CON group, but was relatively maintained in the EX group. VO_2pk was maintained in EX males, but not in CON males. Isokinetic knee strength (extension, peak torque) decreased significantly in CON males, but was preserved in EX males. The EX group had significantly higher spine muscle strength after bed rest than the CON group. The cross-sectional area of spinal muscle at L4/5 level decreased significantly in the CON group but not in the EX group. Urinary n-telopeptide excretion, an index of bone resorption, was increased during bed rest in CON, but not in EX subjects. This suggests protection by LBNP exercise against the increase in bone resorption typically seen in simulated and actual microgravity. Significant changes in bone mineral density (BMD) in the spine and ribs were observed in CON subjects, but not in EX subjects.

Conclusions: Our treadmill exercise protocol within LBNP plus a short period of post-exercise LBNP maintains orthostatic responses, upright exercise capacity and other important physiologic parameters during bed rest. These results document the efficacy of our apparatus and exercise protocol for maintaining physiologic structure and function during long-duration microgravity as simulated by 30 days of HDT bed rest.

FUTURE PLANS: More sets of female identical twins are needed to reach significance. The LBNP exercise chamber will be redesigned for flight.

INDEX TERMS: countermeasures, artificial gravity, exercise, cardiovascular, muscle, bone, bed rest, long-duration microgravity, orthostatic tolerance, spine

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