LOWER BODY NEGATIVE PRESSURE TREADMILL EXERCISE PREVENTS SPINAL DECONDITIONING DURING SIMULATED MICROGRAVITY

*Bawa, M; *Groppo, ER; *Steinbach, GC; **Watenpaugh, DE; ***Smith, SM; +*Hargens, AR; +*Meyer, RS  
+*University of California, San Diego – Department of Orthopaedics  
**Naval Submarine Medical Research Lab, Groton, CT  
***NASA-Johnson Space Center, Houston, TX

INTRODUCTION

During exposure to long-term space flight, astronauts experience musculoskeletal deconditioning to gravity such as back pain due to spinal lengthening, spinal muscle atrophy, and bone loss. Post-flight, astronauts have an increased incidence of intervertebral disc herniations. Presently, the optimal exercise protocol and equipment for astronauts in space are unresolved and previous calculations suggest that all exercise in space to date has lacked sufficient loads to maintain preflight musculoskeletal structure and function. We hypothesized that lower body negative pressure (LBNP) treadmill exercise prevents microgravity-induced spinal deconditioning by simulating gravity and upright exercise on Earth. We tested this hypothesis in identical twins exposed to microgravity simulated by bed rest.

METHODS

After informed consent was obtained, eight sets of identical twins (12 males, 22-31 years and 4 females, 21-25 years) remained in bed rest for 30 days to simulate prolonged microgravity. One subject from each twin pair was randomly assigned to exercise supine in an LBNP chamber six days per week (EX) (Fig. 1), while their twin sibling served as a non-exercise control (CON).

Figure 1. Schematic diagram of the Earth-based LBNP treadmill exercise device. A back support and leg suspension system is used to reduce the effects of gravity while exercising in the supine position. Shoulder straps provide about 40% body weight (BW) over the lumbar spine.

During supine treadmill exercise, LBNP (52-63 mmHg) was applied to produce footward forces equivalent to those for upright running at 1.0-1.2 BW and subjects performed a 40-min. interval exercise protocol. Pre- and post-bed rest, subjects completed bone mineral density (BMD by DEXA), serum and urine bone marker, spinal muscle area (MRI) and strength (MedX dynamometer), and lumbar length (MRI) tests. Comparisons were made using repeated measures ANOVA. Statistical significance was set at p <0.05.

RESULTS

Cross-sectional area (CSA) of the paraspinal musculature (Fig. 2), and spinal length (Fig. 3) were preserved in the exercise group but significantly altered in the matched identical twin control group. Spine BMD decreased by 2.6% in controls (p=0.02) but not in exercised twins (p=0.70). Serum and urinary markers of bone resorption were not different from pre bedrest control values in the exercise group but these markers of bone loss were significantly increased in the control group (Fig. 4).

DISCUSSION

Our treadmill exercise protocol within LBNP maintains several indices of spinal structure and bone metabolism during microgravity simulated by 30 days bed rest. These results document the efficacy of our apparatus and exercise protocol for maintaining musculoskeletal structure and function in males, but additional studies of female identical twins are needed to confirm similar benefits in women.

Figure 2. CSA of male paraspinous musculature at the L4/5 level decreased significantly in the control group (p = 0.04) but not in the group receiving daily supine LBNP exercise (p = 0.11).

Figure 3. Due to bed rest unloading, spinal length increased significantly in the male control group (p = 0.05) but not in the men receiving daily supine LBNP exercise (p = 0.10).

Figure 4. Urinary n-telopeptide excretion during bed rest in control (solid) and exercised (open) subjects. This index of bone resorption was increased (p<0.005) during bed rest in control subjects, but not LBNP-exercised subjects. This suggests protection by LBNP exercise against the increase in bone resorption typically seen in simulated and actual microgravity.

ACKNOWLEDGEMENTS

Supported by NASA grant 199-26-12-34, NIH grant to the UCSD GCRC M01 RR00827.