AN INTEGRATED MUSCULOSKELETAL COUNTERMEASURE BATTERY FOR LONG-DURATION LUNAR MISSIONS

T.F. Lang[1], T.S. Streeper[1], P.R. Cavanagh[2], I.H. Saeed[1], R.D. Carpenter[1], L.A. Frassetto[1], S.M.C. Lee[3], C.M. Grodsinsky[4], J. Funk[4], A.M. Hanson[3], J.J. Bloomberg[3], A.P. Mulavara[3] and J.D. Sibonga[3]
[1]University of California San Francisco, 185 Berry Street, Suite 350, San Francisco CA 94143-0946
[2]University of Washington, [3]Johnson Space Center [4]Zin Technologies

INTRODUCTION

During extended periods of skeletal unloading, losses in strength and density of the proximal femur will occur. In long-duration spaceflight, resistive exercise is used to replace the normal loads exerted on the spine and hip. At the present time, there is no conclusive evidence that hip bone loss has been prevented in this scenario. Our group has recently developed and clinically evaluated a multifunctional exercise system, the Combined Countermeasure Device (CCD). The CCD comprises a low-footprint Stuart Platform for lower-body resistance exercise and balance training, and a cardiovascular exercise bicycle. A consideration for resistance exercise was targeting of the hip abductor and adductor muscles, which attach directly at the hip and which should subject it to the largest loads. In our training study, we found that CCD exercise increased hip adductor and abductor strength, and modeling results suggest that this exercise exerts forces on the hip of ~4-6 body weights at 1g, compared to forces of ~2.5 body weight y squatting exercise. In our current study, we hypothesize that abductor and adductor exercise will increase the density and strength of the proximal femur.

METHODS

24 subjects (healthy men and women aged 25-55 years with no exercise contraindications) are divided into three equal groups, who exercise three times weekly for 16 weeks. One group carries out only hip ab/adductor exercises, a second group only squats and deadlifts, and a third, both types of exercise. The sessions are designed so that each group carries out the same total number of repetitions. Subjects are undergoing pre- and post-training QCT imaging sessions to assess potential changes in regional bone density and geometry. In addition to standard QCT density and geometric measures, we have added as exploratory measures estimates of hip strength from QCT-derived finite element modeling and assessments of the 3D spatial distribution of bone mineral density of the hip using voxel based morphometry , a technique developed for neuroimaging and extended to bone by Dr Lang's laboratory. We have also added measures of muscle area, to test whether strengthening of the hip musculature results in increases of the cross-sectional area and lean tissue attenuation of the hip muscles. Finally, in addition to the imaging measures, subjects are undergoing 6 collections of serum markers of bone resorption and formation over the course of the 16 week training period.

STUDY STATUS AND INTERIM RESULTS

As of this date, we have completed the recruitment and training of Group 1 and finished training 6 out of 8 subjects for Group 2 with the final subject of that group completed at the end of November 2011. All of the subjects in Group 3 have been recruited, allowing for completion of the study by the end of February 2012. We have analyzed the QCT bone density data for the 8 subjects in Group 1, which is comprised of subjects undergoing only abductor/adductor exercise. Within this group, we have observed trends towards exercise effects on cortical bone in the trochanteric region, with bone mineral density showing a trend towards a small increase (2%, $p=0.06$), and the volume of cortical tissue showing a trend towards a 10% increase ($p=0.07$). A figure of merit which summarizes the strength of the trochanteric region, trochanteric axial compressive strength, showed an increase of 5% ($p<0.05$). Similarly, using finite element modeling, in which the whole bone strength of the hip is estimated in a loading condition simulating a fall to the side, we observe a trend towards an increase in strength (8%, $p=0.12$).

CONLCUSIONS

Thus there is some evidence that the hip abductor and adductor exercise is having an effect on cortical bone in the trochanteric region, where these muscles have their attachment points. Although our observed trends did not reach statistical significance with our current sample size, we believe that this study supports continuing investigation of this exercise approach, particularly with slightly larger sample sizes. Additionally, we will be interested in the results of Group 3, where the exercise of the abductor and adductor muscles are combined with standard squatting and deadlift exercise.

ACKNOWLEDGEMENTS

This work was supported by grant BL-01301 from the National Space Biomedical Research Institute