TREADMILL EXERCISE ON THE INTERNATIONAL SPACE STATION: THE EFFECTS OF EXTERNAL LOADING

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INTRODUCTION

Bone loss in the lower extremities during space flight has been a feature of post-flight reports since the Gemini missions. Although these early findings from short-duration flights were later found to be incorrect and linked to inappropriate biomedical instrumentation, the first definitive study on Skylab IV indicated the severity of the problem. Later studies of MIR Station flyers and now data from the first 6 crews on the International Space Station (ISS) have confirmed that bone continues to be lost in long-duration space flight today despite exercise countermeasures [1,2].

Providing Earth-like gravity replacement loads (GRL) during exercise on long-duration space missions may be critical to the maintenance of bone mass. Two devices are currently used on the International Space Station (ISS) to provide a restoring force to return the astronaut to the treadmill surface during treadmill exercise: a subject load device (SLD) and various bungee cord (BC) configurations.

METHODS

In this experiment, the loads on the feet during treadmill exercise on the ISS were measured while different combinations of GRLs were used. The results were compared to similar exercise protocols from the same subject on Earth. In-shoe forces were monitored using modified Pedar insoles (Novel Gmbh, Munich, Germany) placed inside the shoes of a single astronaut, who gave his informed consent to participate in the IRB-approved experiment. Data were recorded at 128 Hz on a wearable computer and saved to a PCMCIA flash memory card. Thirty seconds of exercise data during 10 different loading conditions on orbit were collected and low-pass filtered using a 50 Hz cutoff frequency.

RESULTS AND DISCUSSION

All on-orbit loading profiles showed a marked decrease in peak ground reaction force when compared to 1g loading. The mean active peak force was significantly larger in 1g compared to 0g for all ISS loading conditions (Figure 1).

Daily load stimulus (DLS), a mathematical model used to relate changes in bone mineral density to daily loading histories, was also calculated from the force data for each loading condition using an exponent, m, of 5. During treadmill running the ratio of DLS for a 30 second period of activity in 0g to that in 1g varied from 0.50 to 0.78 over the range of loading configurations. Thus, treadmill exercise in space provided a maximum of only approximately 75% of the stimulus to bone experienced during typical exercise on Earth.

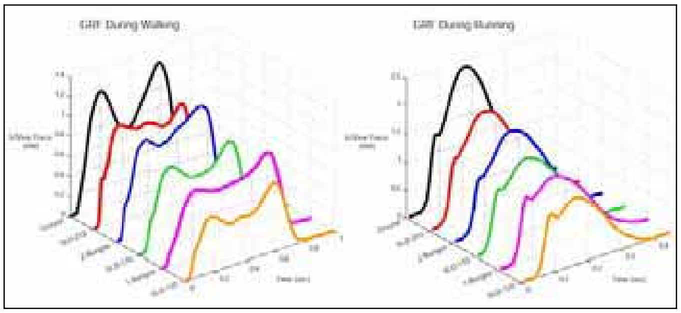

Figure 1: Typical in-shoe force curves for running and walking over-ground (black – far left in each graph) and on-orbit using five different gravity replacement modalities.

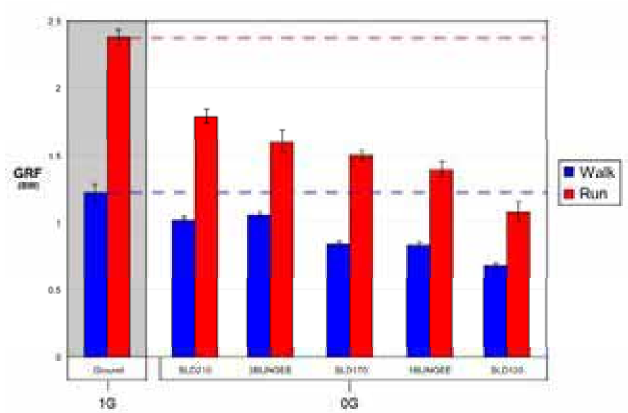

Figure 2: Mean active peak force values for 30 seconds of 0g walking (blue) and running (red) using different loading modalities compared with the values for 1g (shaded area, also indicated by the dashed lines.)

CONCLUSIONS

In order to evaluate treadmill exercise as an effective countermeasure, crewmembers must be able to comfortably apply a GRL of full body weight. However, these data suggest that the common loading conditions studied here that are currently used on the ISS do not produce loading of this magnitude. Further research is needed to improve SLD and harness design so that both load and comfort are improved in order to maximize the osteogenic effects of exercise in space.

REFERENCES

1. LeBlanc et al., *J Bone Miner Res*, **11**, S323, 1996.
2. Lang et al., *J Bone Miner Res*, **19**, 1006-1012, 2004.

ACKNOWLEDGMENTS

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