LOWER EXTREMITY LOADING DURING ENTIRE DAYS OF SPACE FLIGHT

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INTRODUCTION

Bone loss in the lower extremities is an established consequence of long-duration human space flight, whereas bone mass in the upper extremities appears to be maintained [1]. This difference may be the result of disuse of the lower extremities in space. Reduction in load bearing on the feet may play a key role in these changes, but no quantitative data showing loads in-orbit currently exist.

The purpose of the present experiment was to measure loads on the feet over an entire day in the same subject during daily life on the ground and on the International Space Station (ISS).

METHODS

In-shoe forces were monitored with modified Pedar insoles (Novel Gmbh, Munich, Germany) placed inside the shoes of a single astronaut on a 161-day ISS mission. DXA scans were also performed pre- and post-flight. All instrumentation was built into a Lower Extremity Monitoring Suit custom made for the subject, who gave informed consent to participate in the IRB-approved experiment. The force data were analyzed by a custom routine written in MATLAB (Mathworks Inc.).

Daily load stimulus (DLS), a mathematical model used to relate changes in bone mineral density to daily loading histories, was calculated using in-shoe force profile data [2].

RESULTS AND DISCUSSION

Average monthly BMD losses in the proximal femur, total hip, and lumbar spine regions were 0.64%, 0.72% and 2.31%, respectively. There was a net BMD gain of 0.32% per month in the arms.

Peak force histograms from sample days in 0g and 1g (Figure 1) show a marked shift in the two main modes of loading (walking and running from 260% and 120% BW in 1g to 160% and 90% BW in 0g). The total number of peaks above 5% BW is greatly reduced (10,112 peaks in 1g vs. 2,569 peaks in 0g) and force peaks greater than 200% BW are absent in 0g.

The ratio of mean DLS in 0g to that in 1g varied from 0.44 to 0.55 (using values of m between 3 and 8). Thus, exercise in space over an entire work day provided only approximately half the stimulus to bone experienced during a typical work day on Earth.

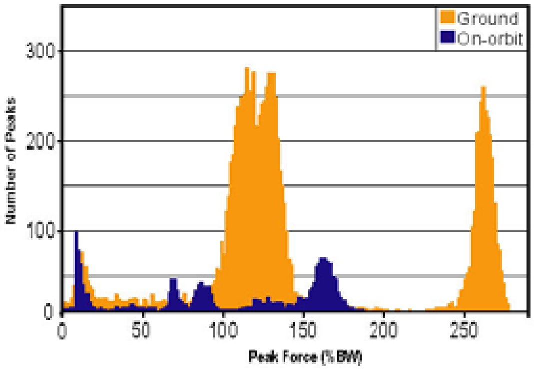

Figure 1: Peak force histograms in percent body weight (%BW) units for typical days on Earth (light – yellow) and on the ISS (dark – blue).

CONCLUSIONS

A number of countermeasures have been attempted, so far unsuccessfully, to prevent loss of bone mass during long-duration space flight. The fact that cosmonauts and astronauts have lost bone mass despite exercising on-orbit has led some authorities to suggest that exercise is not a suitable countermeasure. When the reduced loading during locomotion on-orbit found in the present experiment is considered together with what appears to be a markedly lower total daily load to the feet, these results, if confirmed by ongoing measurements on other ISS astronauts, will present strong evidence that the "mechanical dose" derived from exercise needs to be increased. Such an increased dose could be obtained by increasing the load in the SLD, increasing the speeds available on the ISS treadmill, or by novel exercise. Since ground experiments in simulated zero gravity have shown that subjects can tolerate SLD loads of 1 BW [3], we believe that SLD loads should be increased for exercise on future ISS increments.

REFERENCES

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