AMPDXA GCS* MEASUREMENTS OF BONE STRUCTURE FOR PRE- AND POST-FLIGHT TESTING OF ASTRONAUTS

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INTRODUCTION

The focus of the advanced multiple projection dual energy x-ray absorptiometry (AMPDXA) scanner systems project is the development of precision instruments for monitoring the deleterious effects of weightlessness on the human musculoskeletal system during prolonged spaceflight. The instruments use dual energy x-ray absorptiometry principles and are designed to measure bone mineral density (BMD), decompose soft tissue into fat and muscle, and derive bone structural properties (cross-sections, moments of inertia). Such data permits assessment of microgravity effects on bone and muscle and the associated fracture risk upon returning to planetary gravity levels. Ultimately designed for use on the space station or other long duration space missions, the flight AMPDXA will weigh less than 45 kg in its flight version and be capable of near real-time monitoring of bone loss as well as the effects of countermeasures. The AMPDXA test beds have been able to detect changes of less than 1% in bone mass and geometry and less than 5% in muscle mass.

METHODS

The key to understanding the mechanism of bone (and muscle) loss in space (microgravity) lies in the bone's structural details and the changes in the structure due to prolonged weightlessness. Current bone and muscle mass measurements (via conventional DXA or ultrasound) are regional averages that obscure structural details. Since the mechanical consequences of lost bone and muscle are reflected in the structure, an absolute determination of skeletal mechanical competence is needed to supplement the loss measurements. Engineering properties of the bones can be derived from DXA-generated BMD data. Our method derives geometrical measurements from the BMD images. From such images, we extract BMD profiles at important skeletal locations (e.g., proximal shaft and femoral neck). Key properties measured and derived from these profiles include the BMD, the subperiosteal width, the section modulus (related to strength), and the cortical dimensions.

RESULTS

The focus of our activities has been on: (1) instrument development, (2) algorithm development for BMD image extraction and structural analysis, and (3) bone reconstruction and modeling techniques. A full sized (1-m source-to-detector distance) Laboratory Test Bed (LTB) has been constructed and is operational. The LTB has produced excellent results, significantly surpassing commercial system performance. Next, a Clinical Test System (CTS) was developed that incorporates high-precision rotational and translational stages to provide the scanning capability necessary to carry out qualification tests on human subjects. The CTS is operational and has been used for human testing. Human subject images have been taken with results surpassing those of the LTB. Figure 1 is a BMD image showing improved structural detail. Currently, APL is developing the AMPDXA Ground-based Clinical System (AMPDXA GCS) for the ground-based testing of astronauts (pre- and post-flight). The GCS detection scheme, which is based on a novel design not found in conventional DXA imaging systems, will use small arrays of single-element detectors. This design mitigates cone beam issues and nonlinearities caused by scatter and optical glare. Furthermore, it lowers costs when compared to the flat-panel detector used in the LTB and the HTB. An artist's concept of the GCS is shown in Figure 2.

Figure 1. BMD Structural Image from HTB.

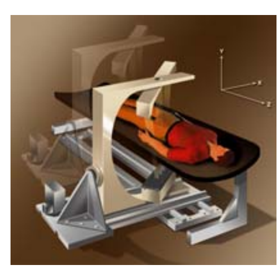

Figure 2. Artist's concept of the GCS.

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