Quantifying Activity in Men Aged 70 and Older: Effects of Daily Activity Level on Bone and Muscle

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Introduction

It is known that habitual load-bearing activity plays a critical role in the maintenance of bone and muscle mass (Lanyon et al. 1984, Convertino et al. 1995). However, there is a paucity of quantitative data describing “typical” daily loads imposed on the human skeleton, since the primary surrogate measures of skeletal load - ground reaction forces (GRF) and electromyographic activity (EMG) - have not been measured systematically over extended periods of daily living. The present paper describes work performed in preparation for an International Space Station (ISS) life sciences experiment. Equipment recently developed for the ISS Human Research Facility was used to record and store GRF and EMG data in twelve healthy, elderly men over the course of their daily activities. This data was investigated for relationships between individual daily activity level, and skeletal health.

Methods

Subjects were selected from an elderly population of men aged 70 to 79 years. To exclude influences on bone density that were unrelated to activity, all subjects were male and were screened against elevated osteoporosis risk due to such causative factors as diet, medication history, habitual use of alcohol and tobacco, hereditary predisposition, endocrine status, and medical history (NIH 1984).

After selection, the musculoskeletal health of all subjects was assessed. A clinical grade dual X-ray absorptiometry (DXA) machine was used to obtain DXA scans of the right hip, lumbar spine, and whole body that quantified bone mineral density and body composition. Additionally, muscle strength was measured isometrically at the knee and ankle using a Biodex™ dynamometer.

Daily activity was recorded over a ten-hour epoch. Ground reaction forces were measured at both feet using a capacitive insole system specifically designed for long-term data acquisition. Daily mechanical load stimulus (DMLS) to the lower skeleton was quantified by applying GRF data to the power-law relationships described in Eq. 1 (Whalen et al. 1988) and Eq. 2 (Beaupré et al. 1990).

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DMLS \propto \left[ \sum n_i \text{GRF}_i^m \right]^{1/2m}
\]
(1)

\[
DMLS \propto \left[ \sum n_i \text{GRF}_i^m \right]^{1/m}
\]
(2)

In these equations, \( GRF_i \) represents the magnitude of the peak force recorded within a single loading cycle, \( n_i \) is the number of peaks at that magnitude recorded over one ten-hour day, and \( m \) is a power factor used to weight the significance of the peak magnitude in relation to the frequency. Ground reaction force data was separated into peak magnitude histograms (figure 1), and used to generate multiple DMLS estimates. Daily mechanical load stimulus was calculated at various values of \( m \), and then related to DXA measurements in an attempt to determine which relative weighting of frequency and magnitude could best predict a subject’s bone density status.
Rectified, low-pass-filtered, surface EMG data from five leg muscles was integrated over 10 hours to yield an estimate of daily neural drive to each muscle. Further, superimposed joint excursion profiles recorded at the right knee and ankle permitted delineation of neural drive into concentric, isometric and eccentric activity (Winter et al. 1991) (figure 2). Daily neural drive was then investigated as a predictor of an individual’s muscle strength and bone mineral density.

Results & Discussion

Subjects were separated into “high BMD” and “low BMD” groups according to DXA measurements at the hip. Daily mechanical load stimulus estimates formed by incrementally varying the exponential weighting parameter “m” from 1 to 8, were used as predictors in ANOVA’s between BMD groups. A regression analysis of hip BMD on DMLS estimates was also performed. While no relationship was determined to be statistically significant, BMD data were best fit by Eq.1 with exponent “m” = 1 (R²=0.24, p=0.098) and by Eq. 2 with “m” = 2 (R²=0.21, p=0.092). Because of poor statistical power afforded by the limited number of subjects and inherent variability in “typical” daily activities, it was difficult to draw definitive conclusions regarding an optimal combination of GRF peak magnitude and frequency to best fit the experimental BMD data. However, a general trend between elevated activity and increased BMD can be observed in figure 3.
Analysis of all recorded 10-hr GRF loading profiles revealed that very few observed GRF peaks exceeded magnitudes characteristic of walking. This may have contributed to the poor correlation between DMLS and BMD since high magnitude loads, even at very low daily repetitions, have been shown to have a significant impact on bone density (Lane et al. 1986, Duppe et al. 1997). Also, a number of influences that were uncontrolled in this study such as heredity, nutrition, and the quality and quantity of activity that occurred throughout the lifespan are likely to have had a large impact on BMD (Seeman et al., 1989).

Trends were also identified in which daily net neural drive was related to elevated hip BMD (figure 4). However, no significant relationship was identified between daily NND, isometric joint strength at the knee or ankle, or BMD.

The trends found in the present study suggest that the long-term measurement of EMG and GRF may be a promising approach to examine the influence of skeletal loading on bone and muscle status. Future studies should determine the reliability of the method and examine alternative formulations of the daily load stimulus.

![Figure 4. Net neural drive for selected muscles by BMD group](image)

**References**


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