THE ENHANCED DAILY LOAD STIMULUS (eDLS): ACCOUNTING FOR SATURATION, RECOVERY AND STANDING

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INTRODUCTION

The Daily Load Stimulus (DLS), first proposed by Carter *et al.* (1987), is a method of quantifying daily stress histories of bone in terms of daily cyclic stress magnitudes and the number of daily loading cycles.

$$DLS = \left[\sum_{j=1}^{k} n_j \left(Gz_j \right)^m \right]^{1/2m} \quad (1)$$

Gz = Peak magnitude of vertical component of ground reaction force (GRF)
j = Number of loading conditions
m = Weighing factor {eg. 4}
k = Number of different loading conditions

Recent studies, however, indicate that the osteogenic potential of bone can also be influenced by temporal factors such as saturation (Turner and Robling, 2004), recovery (Robling *et al*., 2001, Gross and Srinivasan, 2006), and standing (Fritton *et al*., 2000). Based on animal data from Umemura et al. (1997), Turner and Robling (2004) demonstrated that bone tissue sensitivity to cyclical mechanical loading can be described by 1/(N+1) where N is the number of cyclic loads after saturation. Robling et al. (2001) were able to show that increasing the time of recovery between bouts of cyclical mechanical loading can enhance bone formation. The recovery of osteogenic potential can then be described by: Recovery (%) = $100(1-e^{-t/\tau})$, where t is time in hours between bouts and τ is a time constant (2hrs). Standing can also play a role in the maintenance of bone due to the micro strains imparted through postural stabilization (Fritton et al, 2000).

Currently, the DLS model does not account for saturation, recovery or standing. Therefore, the purpose of this study is to propose an updated method of determining the DLS that accounts for variables such as saturation and recovery of osteogenic potential with cyclical loading and standing.

METHODS

Ground reaction force (GRF) data was obtained from a previous experiment (Cavanagh *et* al. 2004) in which subjects wore Pedar force measuring insoles (NOVEL Gmbh. Munich, Germany) for entire typical work days. Data were collected using a wearable, portable computer and downloaded for data analysis completed using custom Matlab software (Mathworks Inc. Natick MA).

A peak detection algorithm was used to detect all fluctuations in the GRF data above 5% of body weight (BW). The GRF data was then categorized into sitting, standing, walking, running or other. This was done by an algorithm that took advantage of the repetitive and predictable nature of walking

and running profiles by examining their power spectral density. After 5 min. of continuous running or 10 min. of continuous walking, saturation was assumed to be achieved and each successive peak load (Gz) was multiplied by 1/(1+N). Each successive bout of walking or running that occurred after saturation was then multiplied by the recovery equation ($1-e^{-t/\tau}$) (Figure 1).

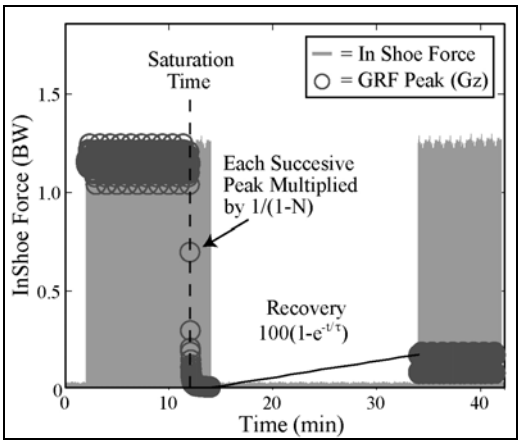

Figure 1: Exemplar walking GRF data with peaks detected and adjusted to account for saturation and recovery.

Eq. (1) can also be simplified as follows:

$$DLS = [DAL]^{1/2m} \qquad (2)$$

where DAL equals Daily Accumulated Load. To account for standing, the DAL from one minute of standing is defined to be equivalent to one quarter of the DAL from one minute of slow walking at 1.0m/s.

The peak magnitudes (Gz) are finally divided into bins (n) and input into Eq. (1) to calculate eDLS (Figure 2).

SUMMARY

This new method of calculating eDLS is currently being validated in an ongoing bedrest study in which the "dose" of exercise prescribed as a countermeasure

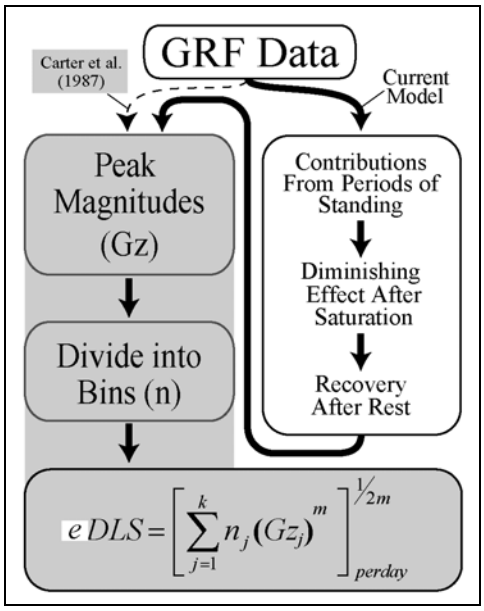

Figure 2: Flow chart of the proposed method of calculating eDLS versus the original method used by Carter et al. (1987).

to bone loss is based on the calculation of the DLS. This new method may also prove useful for exercise prescription for crewmembers on long-term missions to the moon or Mars.

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