THE EFFECTS OF MECHANOSENSITIVITY ON THE PREDICTION OF BONE FORMATION RATE

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INTRODUCTION

Impacts have the potential to be an influential factor in both the etiology of overuse injury and the promotion of bone strength. Models of canalicular fluid flow [1] and recent animal studies suggest impact patterns influence variables related to osteogenesis independent of magnitude and number of impacts. Repeated impacts can saturate the sensitivity of bone to mechanical stimuli. Rest between impacts or between impact bouts allows bone to recover mechanosensitivity. Knowledge of optimal patterns of loading will allow exercise routines to be developed that maximize osteogenic potential. The purpose of this study was to determine if a model of impact activity that accounts for the effects of saturation and recovery on mechanosensitivity will better predict changes in bone formation than a stimulation model based solely on magnitude and number of impacts.

METHODS

Animal studies which investigated the magnitude, number of impacts or time between impacts were used to evaluate the two models. Studies were included if loading was measured in units of microstrains (με) and the dependent variable was bone formation rate (BFR). At present, six studies were found to meet these qualifications. *Osteogenic stimulation* was defined as the product of impact magnitude and the total number of impacts. *Osteogenic activation* was determined by the magnitude and the pattern of impacts, as influenced by the current state of mechanosensitivity. Saturation was modeled as 1/N, where N was the number of impacts [2]. Recovery was modeled as $1-e^{-t/\tau}$, where t was the time from the last impact [2]. In this study τ was optimized by finding the value that maximized the Spearman correlation between the model derived activation and the BFR from all studies combined (Figure 1).

Once the optimal τ was determined, the stimulation and activation models were correlated with BFR using a Pearson correlation for each individual study that contained more than 2 treatment conditions.

RESULTS AND DISCUSSION

The value for τ that was optimized across studies was 1.1 hours. This corresponds to 99% recovery in approximately six hours of rest. Data from each of the six studies is summarized in Table 1. In all studies, Pearson correlation coefficients indicated ostoegenic activation model was a better predictor of BFR than the stimulation model.

Both stimulation and activation models assume that strain magnitude is directly related to the osteogenic stimulus. In addition the activation model incorporates bone saturation and recovery effects. Previous research has shown that strain rates, which we did not include, play an important role [8]. In addition, neither model takes into consideration the effects of accommodation [9]. Future models will need to incorporate these variables for better prediction of bone formation rates.

Models used to predict optimal exercise patterns must take into account the effects of saturation and recovery. Use of such models would bring us one step closer to developing exercise routines that maximize human osteogenic potential.

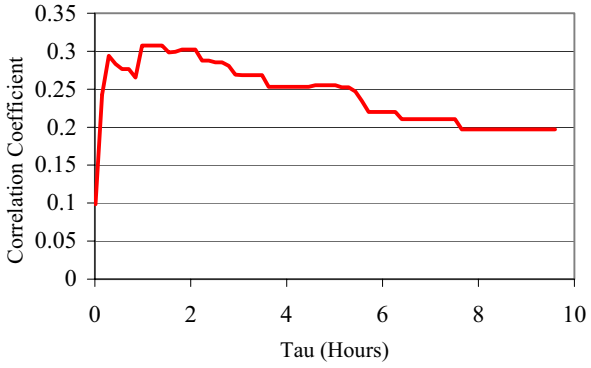

Figure 1: Optimization of tau (τ) across studies.

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Table 1: Summary data for 6 studies of mechanical loading. Correlation coefficients were significant at p<0.01 (†) except study 6 stimulation model which was significant at p> 0.05 (††).

Reference	Independent Variable(s)	Specimens	Stimulation Model Correlation	Activation Model Correlation
1 [3]	Magnitude, time between impacts, # of impacts	49 mice/6 conditions	0.51†	0.64†
2 [4]	# of bouts	18 mice/2 conditions	Only 2 conditions	Only 2 conditions
3 [5]	# of bouts	36 rats/4 conditions	No variability	0.88†
4 [6]	Time between bouts	54 rats/6 conditions	0.65†	0.8†
5 [6]	Time between bouts	36 rats/4 conditions	No variability	0.76†
6 [7]	Magnitude and # of impacts	18 rats/3 conditions	0.59††	0.72†