Example KIN 412 Critique

Rubin, C.T. & Lanyon, L.E. (1984). Regulation of Bone Formation by Applied Dynamic Loads. Journal of Bone and Joint Surgery, 66A(3), 397-402.

Part I -Summary-

A preliminary assessment of strain concerning the mid-shaft of avian ulnae was conducted on two birds in three stages. The first stage assessed the strain during wing-flapping via surgically implanted strain gauges. The second stage re-tested the strain during flapping after implantation of an external fixative device. The final test measured the strain during external loading from the pneumatically operated loading device. Post assessment included a final stress test to the post mortem ulnae. In brief, these methods were conducted to assess the natural strain incurred at the ulna mid-shaft during wing-flapping, then to verify the fixation device would prevent any strain (during non-testing times), and finally to measure the compressive strains accrued by external loading.

Groups of genetically similar rooster ulnae were tested *in vivo* (and later *in vitro*) for the effects of load-bearing on bone tissue characteristics. Uni-lateral ulnae of the left wing extremity were isolated via surgical pinning. The test lasted six weeks. Isolated ulnae were subject to external compressive loading with the surgical pinning acting as a perpendicular base of support for the longitudinal shaft. This was achieved utilizing the loading device capable of delivering a frequency (f) of .5 Hz (f=1/Time), or simply two second cycles of loads comparative to normal wing flapping. It is important to note that the load-bearing device was incapable of please number your pages

simulating strains identical to the natural act of wing-flapping. The peak strains were similar though the area of greatest compression was approximately 90 degrees rotated relative to the natural strain distribution. Individual ulna received a designated number of simultaneously delivered cycles per session (day) throughout the test duration. Subjects that received no cycles resulted in a significantly negative remodeling of 12% bone mineral loss. Those that received four cycles (8 seconds delivered once per day) maintained no resultant change in bone matter. Cycles of thirty-six (and greater) demonstrated new bone formation to as high as 43% increase at four weeks (partially due to bone callus), and resorption in the fifth week left a net bone increase of 33%.

Since only eight seconds of load-bearing per day was necessary to prevent negative remodeling and only seventy-two seconds was necessary to cause a significant increase in bone matter, evidence suggests that normal bone formation is triggered by an osteogenic stimulus, rather than non-specific reparation.

Part II -Critique-

This experiment was performed on avian (rooster) ulnae. Although these ulnae are apt to remodel two to three times faster than human bones, (reference?) both species are vertebrates and should, hypothetically, maintain similar physiochemical characteristics at perhaps different rates.

The results of this experiment fortify the theory that bone formation and maintenance are the result of a physiochemical response such as a particular stimulus, or series of stimuli. This evidence is in opposition to the notion that increases in bone mass were solely the result of lengthy adaptations to an altered environment (as perhaps thought with ballet dancers' feet). This experiment demonstrated that lengthy periods void of weight-bearing resulted in a decrease in bone tissue and mineral quantum. Loading a bone, as in weight-bearing, for as little as eight seconds (one session per day) was adequate to prevent negative remodeling in the avian ulnae. A loading duration of seventy-two seconds (per session per day), was the maximum loading required to increase the bone mass above its original value; greater loading duration (over seventy-two seconds) did not significantly alter the bone matrix different from the seventy-two second duration. The loading intensities resembled the force generated during normal wing-flapping. This study demonstrates that prevention of bone degeneration (incurred by inactivity) may be accomplished by remarkably brief sessions of loading. If these findings translate to human bone, then the medical protocol for many ailments and operations should surely change; they have changed. This classic experiment may have been the primary reason that medical doctors and surgeons are so eager to ambulate their patients near-immediately following a total joint replacement surgery (e.g. knee or hip arthroplasty), or other disease processes most emphatically associated with the geriatric population (due to rapid onset of osteoporosis). Other reasons exist for regularly scheduled ambulating, but the prevention of bone degeneration is perhaps preventable by merely a couple minutes of weight-bearing each day.

Questions and considerations concerning the article are as follows. Since bone density increased above normal with loads lasting seventy-two seconds at a force equal to normal flapping motion, then either the duration was longer than natural, or the angular variation of stress was such to cause this increase in density. I would guess the latter, since the bone was never accustomed to such a loading regimen. Perhaps the density would have increased even greater, had it been loaded in a variety of ways causing the strain to fall uniformly across the cross-sectional area of the bone. The human bone (femur in particular) is potentially subject to all angles of loading, provided that the natural weight-bearing position is perpendicular to the ground (no pronounced deformities as with valgus or varus disorders). Since pre-morbid load is cross-sectionally more uniformly distributed, then the propensity for bone mass post-morbid (and the healing process) would probably not tend to exceed normal bone mass (excluding temporary bone callus).

I also wonder if the bone density would increase greater if subjected to loads of higher intensity (force), rather than strictly duration. Maybe the bone (in the experiment) density increases could have been expedited if they were loaded multiple sessions within the twenty-four hour period. How long the bone requires for growth is still in question. If the six-week duration is an accurate requirement for bone formation, then possibly the bone only needs to be loaded once every other day, or once per week. These are just a few questions that could be answered from repeat experiments with different variables.

It would also be useful to repeat this experiment with ulnae of various maturity, to see if older bone reacts in the same manner as young bone. This would assist in determining if the geriatric populace has similar potential stimuli for osteogenesis and the prevention of bone mass declines.

Another clinical consideration pertaining to rehabilitation is whether weight-bearing with a greater force for a short duration is more therapeutic than partial weight-bearing for a long duration. By this experiment, I believe the first to be sufficient and less time-consuming for bone development, though longer duration will generally be maintained by clinicians due to its effects on muscle endurance and other bodily processes.

Lastly for epidemiological research, it would be important to consider genetic and demographic implications that perhaps dictate the rate and effects of such a "bone-growth" stimulus. What hormone, or dietary supplement could assist in increasing the amount of stimulus allotted? Does bone have a genetic memory that dictates the final density of the bone following a loading regimen? These are just some questions available for future research.

The article was indeed a classic, though I developed some curiosities while reading it. Firstly, the groups consisted of six birds; I wondered where the last bird was utilized if one was a control, and four were loaded at various amounts of cycles. My guess was that it was used for the initial strain assessment. I also wondered how many groups of birds were tested. The fact that the authors noted the error in the strain rates during the loading regimen was quite important, since greater rates of strain generally influence the healing rate and process.

10/10 Very nice summary critique