GRIZZLY BEARS MAINTAIN CORTICAL AND TRABECULAR BONE MINERAL, STRUCTURAL, AND MECHANICAL PROPERTIES DURING DISUSE (HIBERNATION)

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INTRODUCTION

Disuse causes unbalanced bone remodeling which leads to bone loss and reduced bone strength. The remobilization time required to completely recover lost bone is typically 2-3 times longer than the unloading period (Weinreb et al., 1997). However, bears from northern climates experience annual periods of disuse (hibernation) and remobilization that are approximately equal in length, yet they do not lose cortical bone material properties with age (Harvey et al., 2005). Furthermore, trabecular architecture and mineral content are not different in bears before and 2 weeks after hibernation (Pardy et al., 2004). It is not known whether bears completely prevent bone loss during hibernation, or if bone is lost and recovered at a faster rate than most animals. Thus, we investigated bone properties in hibernating and active grizzly bears to determine if bone loss occurs during hibernation.

METHODS

Six age-matched grizzly bears were used for this study; four bears were 1 year old, and two bears were 18 years old. All handling and treatment procedures were approved by the Washington State University Institutional Animal Care and Use Committee. At the time of death, three bears had hibernated for 17-18 weeks and the others had been active following hibernation for at least 14 weeks. One femur from each bear was histologically prepared with basic fuchsin, and porosity (**Por, %**) was quantified from a cortical section distal to midshaft using semi-automated image analysis software (Bioquant OSTEO, Nashville, TN) (n=6).

The contralateral femur (if available) was loaded to failure in three-point bending (n=5). After fracture, cross-sectional properties at midshaft including cross-sectional area (**CSA, mm^2**), section modulus (**SM, mm^3**), and maximum moment of inertia (**I_{max}, mm^4**) were measured using Scion Image (Scion Corporation, Frederick, MD). Mechanical properties including ultimate stress (**σ_U, MPa**), modulus of toughness (**u, J/mm^3**), and energy to failure (**U, J**) were calculated with beam bending theory. Mineral content (**ash frac.**) was quantified by ashing a diaphyseal section proximal to midshaft (n=6).

Trabecular cores (7.6 mm diameter) were removed from the distal femoral metaphysis and epiphysis (n=6 for each site). Trabecular bone architecture was evaluated using a fan-beam microCT system (µCT40, Scanco Medical AG, Basserdorf, Switzerland). The central region (~1.2 mm) of each core was scanned at 6-9 µm isotropic voxel size and evaluated for morphometric parameters. Bone volume fraction (**BV/TV, %**), trabecular number

(**Tb.N, mm^{-1}**), trabecular thickness (**Tb.Th, mm**), trabecular separation (**Tb.Sp, mm**), structure model index (**SMI**), degree of anisotropy (**DA**), and tissue mineral density (**M.Dn, mgHA/cm^3**) were computed.

RESULTS

Cortical porosity was lower in the hibernating bears (p = .003). No differences were detected between the ash fraction, cross-sectional, or mechanical properties of hibernating and active bears (Table 1).

Table 1: Cortical bone properties

Property	***Active***	***Hib.***	***p-value***
Por	7.5	5.3	.003
CSA	389	458	.855
SM	2.2 E3	2.0 E3	.935
I_{max}	4.3 E4	5.3 E4	.873
σ_U	185	214	.308
u	7.0	5.6	.623
U	47.1	57.0	.827
ash frac.	.664	.675	.407

There were no differences between the trabecular properties of hibernating and active bears (Table 2, Figure 1).

Table 2: Trabecular bone properties

Property	***Active***	***Hib.***	***p-value***
BV/TV	15.8	14.2	.750
Tb.N	2.79	2.21	.440
Tb.Th	0.101	0.109	.611
Tb.Sp	0.414	0.472	.649
SMI	2.03	2.19	.542
DA	1.42	1.49	.388
M.Dn	1005	1056	.562

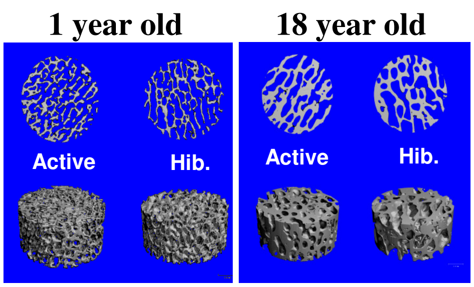

Figure 1: Representative microCT scans

DISCUSSION

Disuse causes unbalanced bone remodeling in most animals, leading to increased cortical porosity, decreased trabecular architecture, loss of mineral, and reduced mechanical properties. However, hibernating grizzly bear femurs were less porous than in active bears. Additionally, the structural and mineral properties of hibernating grizzly bear femurs were not significantly different from active bears. Our findings suggest that grizzly bears do not experience a temporary loss of cortical or trabecular bone during hibernation, possibly because bears maintain balanced bone remodeling during hibernation (Donahue et al., 2006). Serum parathyroid hormone concentrations are positively correlated with serum concentrations of the bone formation marker osteocalcin in hibernating bears (Donahue et al., 2006). Thus, bone formation may be maintained by the anabolic influence of endogenous parathyroid hormone. Further research on the biological mechanism by which bears maintain bone integrity during disuse (e.g., targeting hormones that are differentially expressed between humans and bears during disuse) may provide insight regarding pharmaceutical treatments for human osteoporoses.

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