BONE METABOLISM IN BLACK BEARS

TIMOTHY FLOYD[1], Consultant, San Francisco Orthopaedic Residency Training Program, 450 Stanyan Street, San Francisco, CA 94117
RALPH A. NELSON, Chairman, Department of Medicine, University of Illinois, and Director of Research, Carle Foundation Hospital, 611 West Park Street, Urbana, IL 61801

Abstract: Denning bears maintain normal serum calcium concentration and do not develop osteoporosis after months of recumbency. A circulating substance may be responsible for this previously undescribed phenomenon. Further investigation of its potential therapeutic usefulness in man makes preservation of all ursine species an important management priority.

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Black bears (*Ursus americanus)* remain immobile in winter dens for 3 to 5 months. During denning metabolic adaptations occur which obviate the requirements for food and water and waste elimination. Unlike classic hibernators, however, bears maintain a metabolic rate at least half of normal and may require 2,000 to 4,000 kcal of energy expenditure per day. These adaptations are reviewed elsewhere (Nelson 1980, Folk 1982, Nelson et al. 1983, Nelson and Beck 1984, Nelson 1987).

Prolonged immobilization in other animals results in reduction of bone volume (osteoporosis) and urinary elimination of resorbed bone mineral (Minaire et al. 1974, Young et al. 1986, Raisz 1988). This is mediated through the activities of 2 bone cell populations, osteoclasts and osteoblasts, which comprise the remodeling unit. Bone, as a tissue, is in a constant state of turnover by remodeling. Under normal, steady-state conditions, osteoclasts resorb small bone volumes at multiple sites throughout the skeleton. In man, the average volume of bone resorbed per remodeling unit is 0.1 mm^3 (Frost 1985). This is sequentially replaced by an equivalent volume of new bone by osteoblasts. Osteoblasts first synthesize and deposit the organic component of bone (osteoid) and then mineralize this collagenous matrix. The regulation of remodeling activity and location is poorly understood. With increased skeletal activity, greater demands are placed on the skeleton to support the new loads. The metabolic response to increased skeletal loading is increased production of new bone. With skeletal inactivity, less bone volume is required to support the new loads and less new bone is formed. Bone volume decreases. With profound or prolonged decreases in skeletal loading, bone volume decreases to pathologic levels and osteoporosis develops. This occurs, for example, in patients with profound inactivity, such as paralysis (Minaire et al. 1974) and during spaceflight (Morey and Baylink 1978, Roberts and Mozsary 1981). Animals immobilized experimentally also develop osteoporosis by this mechanism. The most common histologic findings are increased osteoclastic bone resorption, decreased or absent osteoblastic bone formation and progressive development of osteoporosis. Bone metabolism has been studied in small hibernating mammals (Mayer and Bernick 1958, Kayser and Frank 1963, Whalen et al. 1973, Haller and Zimny 1977, Doty and Nunez 1985). These animals catabolize bone as expected and develop osteoporosis, albeit at a depressed rate.

Bears maintain a constant serum calcium concentration throughout denning and non-denning periods (David et al. 1988). An immobile, anuric animal should develop hypercalcemia secondary to net bone mineral resorption. The fact that denning bears are anuric yet do not develop hypercalcemia suggests that this mammal may have adapted a mechanism to prevent net bone loss during inactivity.

METHODS

We studied bone metabolism in 3 captive black bears (Floyd et al., in press). Three study periods were used: summer, winter and spring. The winter studies were done 12 to 17 weeks after den entry. In addition to determining serum calcium concentration, we obtained bone biopsies from the ilium of these animals (Rao 1983). The ilium was chosen because it has been shown to reflect overall skeletal metabolism (Pødenphant et al. 1986). Fluorochromes (tetracycline and calcein green) were administered parenterally 2 and 4 weeks prior to biopsy. These compounds bind with calcium and are deposited at sites of active bone mineralization. Their presence in bone is seen under high magnification and epifluorescent light as bright yellow or green bands. We were able to obtain static and dynamic information about bone metabolism including bone resorption and formation activity as well as bone volume, an indicator of the presence of osteoporosis (Baron et al. 1983, Rao 1983).

[1] Present address: Ursine Bone Research Laboratory, 145 Cielo Via, Walnut Creek, CA 94598.

RESULTS

These bears remained recumbent and anuric in cement culverts throughout denning but were active in enclosures during the other seasons. The mean serum calcium concentration during denning was 8.9 ± 0.32 mg/dl. The mean value during activity was 8.7 ± 0.52 mg/dl.

Bone volume was maintained throughout the entire denning period. That is, we found that osteoporosis did not develop in denning bears. In addition, active bone formation continued throughout the denning period despite an absence of mechanical loading to support this anabolic process. This continued bone formation appeared to balance bone resorption as if the animals were ambulatory and active. Osteoid formation and mineralization rates were comparable in the 2 time periods indicating that osteoblasts were functionally identical. Bone biopsies taken in spring, 10 weeks following arousal, demonstrated a hypermetabolic state. Bone volume increased and bone was formed and mineralized at rates higher than either summer or winter. This massive remodeling is probably in response to resumption of weight-bearing. (Fig. 1)

DISCUSSION

No other animal studied to date has demonstrated the phenomenon we observed in these bears. These metabolic adaptations are necessary for survival in the denning bear. The bear has evolved mechanisms which enable it to remain metabolically active yet independent of food and water for months at a time. Water is conserved in denning bears by the recycling of nitrogenous wastes. The cessation of urination during recumbency places another metabolic stress on bears, however, that of handling resorbed bone mineral. Greater than 99% of total body calcium is stored in the skeleton. Resorption of bone mineral can cause a rapid, significant and lethal rise in serum calcium concentration unless a mechanism exists to handle the calcium. In most animals, this is processed by urinary elimination. In denning bears, this calcium load is processed by recirculation back into bone.

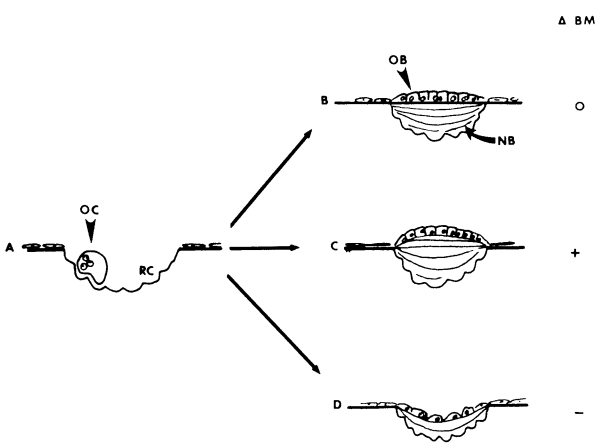

Fig. 1. Bone remodeling. A. Osteoclasts (OC) resorb a given volume of bone creating a resorption cavity (RC). B. Under steady-state conditions osteoblasts (OB) fill in this cavity with an equivalent volume of new bone (NB). C. Under conditions of increased skeletal loading more new bone is formed that was resorbed. Bone mass increases (ΔBM +). D. Under conditions of decreased skeletal loading less new bone is formed and bone mass decreases (ΔBM –). Osteoporosis develops. This latter process is observed in immobilized animals. Denning bears, however, continue to form bone as depicted in B such that bone mass does not decrease. In spring, bears develop a transient net gain in bone mass (such as in C) in response to resumed activity.

MANAGEMENT IMPLICATIONS

If subsequent studies confirm these preliminary findings, protection of all ursine species will become an even more important management priority. This study demonstrates that denning bears have a protective mechanism against the development of osteoporosis. This osteometabolic adaptation may be regulated by a circulating substance(s) produced by denning bears. Such a substance would have obvious beneficial uses for man. In the United States alone, osteoporosis affects more than 20 million people at an annual cost in the billions of dollars. We believe that denning bears may produce a substance which will help prevent and treat this disease.

Because of their small population sizes, wild bear populations are genetically homogeneous (Wathen et al. 1985) Experience with the cheetah has shown that highly homozygous carnivore populations are at an especially high risk of extinction (O'Brien et al. 1985). Given the potential usefulness of ursine osteoregulatory substances, we feel that protection of all ursine species, including ecologically isolated and endangered subspecies, should be given high management priority.

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