OSTEOPOROSIS IN MOOSE ON ISLE ROYALE: A PILOT STUDY OF BONE MINERAL DENSITY USING CT SCANS

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ABSTRACT: Osteoporosis and other skeletal pathologies have been observed in the bones of moose (*Alces alces*) collected in Isle Royale National Park, MI. We hypothesized that bone mineral density of a distal bone may be an indicator of pervasive skeletal pathology. Computerized tomography (CT) scans were conducted on the metatarsal bones of two male moose, one without any noted skeletal pathology and the other exhibiting advanced periodontal disease, severe osteoarthritis, and osteoporosis of the skull. The CT scans, when enhanced using computerized image enhancement techniques, showed measurably less density in the metatarsus of the moose with skeletal pathology than the moose with no observed pathology. The use of this technique in wildlife studies holds promise for investigations of skeletal abnormalities and for determining how these pathologies affect population dynamics.

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Metabolic bone diseases and skeletal pathologies have been studied in humans (Howell 1972, Garn 1980), domestic animals (Hazewinkel 1989, Hill 1990), captive species (Caligiuri *et al.* 1989, Stoller *et al.* 1989), and wild species (Bleich *et al.* 1990, Bubenik *et al.* 1990). Studies in domestic animals have focused on pathologies that may cause lameness or reduced efficiency in breeding herds, such as osteochondrosis and osteoarthritis in pigs (*Sus scrofa*) (Hill 1990), or diseases of small animals in relation to nutrition and its impact on supportive skeletal structures and calcium homeostasis, such as rickets in dogs (*Canis familiaris*) (Hazewinkle 1989). Zoos and exotic animal breeding farms have observed skeletal pathologies that are manifested by anorexia and weight loss, such as periodontal disease in orangutans (*Pongo pygmaeus*)(Stoller *et al.* 1989) and lesions involving long bones and facial bones in Dromedary camels (*Camelus dromedarius*) (Caligiuri *et al.* 1989). Athropathies have been studied in cervids (Wobeser and Runge 1975, Peterson 1988), and osteoporosis has been observed in a few wild species, such as mountain sheep (*Ovis canadensis*)(Bleich *et al.* 1990) and roe deer (*Capreolus* spp.) (Bubenik *et al.* 1990), but the prevalence and significance have not been thoroughly investigated.

Osteoporosis is by far the most common metabolic bone disorder in humans (Howell 1972). The term osteoporosis means increased porosity of the bone, reduced bone mineral content and reduced bone mass (Jackson and Kleerekoper 1990). The skeletal system constantly undergoes the dynamic process of remodeling, a continuous cycle of bone resorption (destruction of bone by osteoclasts) and bone formation (production of bone by osteoblasts) (Marcus 1989). Following the erosion and refilling of a cavity on the bone surface, the outcome of each remodelling episode is a net gain, no change, or a net loss of bone (Parfitt, 1990). With osteoporosis, the rate of bone resorption accelerates while the rate of bone formation decreases, causing an ever increasing loss of bone mass with age (Gillespy and Gillespy 1991). Jubb *et al.* (1985:(1)37) described osteoporosis as loss of bone tissue; a lesion, not a specific disease. They define "osteoporotic" as "the state of a bone or skeleton at a given time. Osteoporosis may be diagnosed subjectively by visual appraisal, or objectively by measurement of radiographs, sawn bones, or microscopic sections".

Because of the widespread incidence and disabling effects of osteoporosis in humans, new techniques have been employed for noninvasive measurements of skeletal bone mass for screening and diagnostics, including quantitative computed tomography (QCT). These methods have been successful in discriminating mineral losses of bone, even at early stages (Cann *et al.* 1985, Genant *et al.* 1987).

Osteoporosis and other skeletal pathologies have been observed in the skeletal remains of moose (*Alces alces*) collected on Isle Royale National Park, MI, from animals dying as a result of wolf predation and other natural causes. As with other disease processes and bone pathologies in prey species such as moose (Peterson 1977), osteoporosis may be a factor in vulnerability to predation. Degenerative joint disease was studied in this population (Peterson 1988), but osteoporosis and the relationships between other skeletal pathologies have not.

As part of a larger project that will investigate the prevalence, causes, and effects of osteoporosis and other metabolic processes involving bone in the moose population of Isle Royale, we hypothesized that relationships exist between skeletal pathologies and generalized loss of bone density. The goal of this preliminary study was to assess whether bone mineral density of a distal bone (metatarsus) could be used as an indicator of pervasive skeletal disease. The specific objective was to compare metatarsal bone density of two selected moose, one with known skeletal pathologies and the other without, using computerized tomography (CT) and computerized image enhancement techniques. The expected outcome was that the metatarsal bone from the individual with many skeletal pathologies is less dense than the bone from a moose without any noted bone abnormalities.

STUDY AREA AND METHODS

Moose skeletal remains have been collected on Isle Royale National Park, Michigan (48°N, 89°W) from 1958-1992 by the authors and previous workers during a long-term study of wolf- moose dynamics (Mech 1966, Peterson 1977). A bone inventory was started in 1958, and bones have been collected from over 2,180 individual moose. In many cases only partial skeletons were available for inspection. Metatarsal bones were collected as an indicator of early growth and development (Palsson and Verges 1952). Any bone exhibiting pathology or abnormality was retrieved, and since 1979, all skulls have been collected. The sex of the moose was determined by the presence or absence of antler pedicels on the skull. Age was estimated from counts of cementum annuli in teeth (Wolfe 1969). Skeletons were examined for osteoarthritis, periodontal disease, osteoporosis and other bone abnormalities. Each skeletal pathology was quantitatively graded as: 1=absent; 2=slight; 3=moderate; and 4=severe (Peterson 1977).

Two metatarsal bones were selected from the collection, and matched for size to facilitate comparable scan layout. The first bone (Bone A) was from an 18-year-old male that exhibited diffuse osteoporosis of the skull, advanced periodontal disease, and severe osteoarthritis in more than one location (sacrum, thoracic vertebrae and pelvic acetabula bilaterally). The second bone (Bone B) was from a 13-year-old male in which no skeletal pathology was noted. The abnormal skull exhibited generalized porosity of the bone, with multiple areas of thinning and pitting. On the dorsal surface, there were pitted areas measuring 12 x 15 mm and 21 x 9mm across the frontal bone which exposed the underlying cancellous bone. The maxilla exhibited destruction of the periodontium and resorption of the alveolar bone. Alveolar bone had receded approximately 16mm on the lateral side of P2 and P3 bilaterally, and there was little alveolar support to M1. There was a 12mm diameter crater at the root of M3 on the right, and P1 was exfoliated with the remaining bone reduced to a fragile filigree.

Radiographs demonstrated increased lucency and decreased numbers and thickness of trabeculae. These findings are consistent with a diagnosis of osteoporosis.

The two metatarsal bones were scanned immediately adjacent to each other on a Phillips Computerized Tomography Scanner at Portage View Hospital, Hancock, Michigan. The CT scan was written to black and white film. Then, the resultant film product was scanned at a spatial resolution of 4096 x 4096 pixels by an Eikonix high resolution color scanner and analyzed using Earth Resource Data Analysis (ERDAS) software. The digital image contained 256 gray levels. Values representing air (no bone) were determined by evaluating the range of digital values found in the general area surrounding the bones. Values representing varying bone densities were divided into eight equal categories. These were determined by calculating the difference between the lowest and highest digital values representing bone, and dividing by eight. It is important to note that these values represent relative bone densities. By calculating the percent of total area for each category, it was possible to compare relative bone densities of the two bones.

RESULTS AND DISCUSSION

Digital analysis of the metatarsal bones indicates that the bone from the moose with osteoporosis of the skull and other skeletal pathologies (Bone A) is less dense than the bone from the moose in which no skeletal abnormalities were noted (Bone B), by a comparison of the percentages in each density grade. The graph of the histograms of the two bones (Fig. 1) demonstrates about even percentages of bone in the five mid-grades of density, but over twice as much low-density bone (grade one) in Bone A (4.60%) as Bone B (2.26%). In the two highest density grades, there is only a slight percentage of the Bone A in grade seven (0.32%) and in grade eight (0.00%) compared with 4.13% and 4.38%

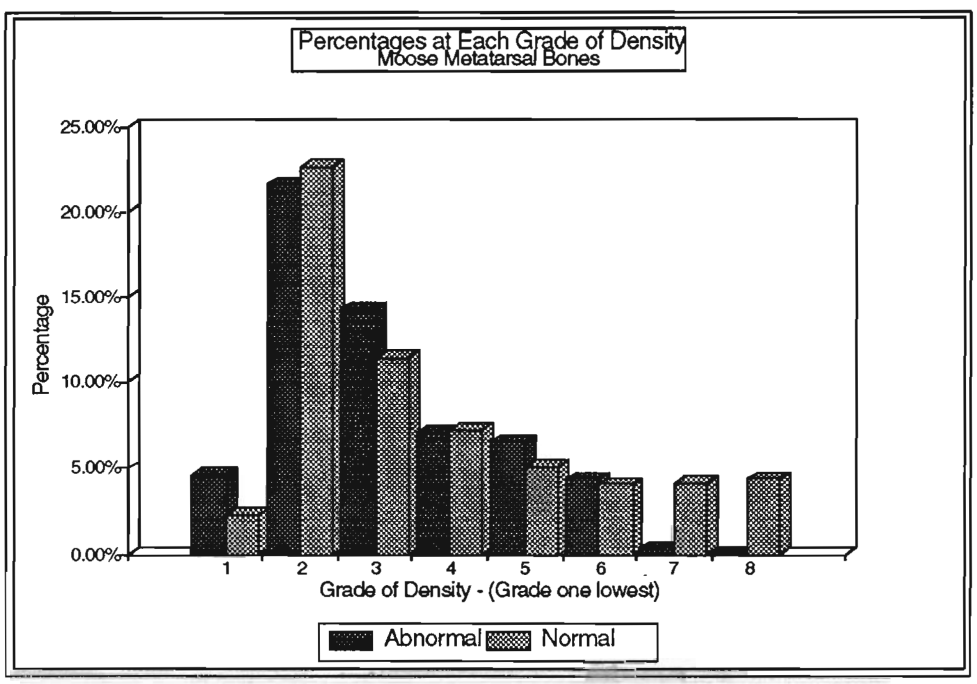

Fig. 1. Percentage of total metatarsal bone area for each grade of density calculated with univariate statistics on ERDAS software. Bone A is a bone from a moose exhibiting multiple skeletal pathologies and Bone B is from a moose without pathologies.

respectively in Bone B.

This preliminary result provides justification for pursuing the use of this technique in analyzing bones for generalized bone mineral changes within individuals, using the metatarsus. This is consistent with the concept expressed by Howell (1972:1190) that osteoporosis is "diffuse as opposed to localized bone atrophy." Because metatarsal bones are available for almost 1,000 moose in our archives, this technique can be replicated with a large sample size.

All of the skeletal pathologies observed in this population show increasing incidence with age (Peterson *et al.* 1982). Although osteoporosis and osteoarthritis are generally considered to be associated with wear and tear of aging, Dequeker (1985) states that osteoporosis and osteoarthritis are two separate disease entities with pathological bone changes and are not simply physiological consequences of normal aging.

CONCLUSIONS

Although the success of this pilot study is encouraging, we recognize that it is premature to make assumptions about relationships between diffuse skeletal pathology and decreased density of a distal bone. This nondestructive technique will now be used in a large sample size to study metabolic bone disorders in moose. Information about skeletal pathologies in moose will contribute to the understanding of predator-prey dynamics and population quality. Methodologies used in this project may be useful for other species.

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REFERENCES

BLEICH, V. C., J. G. STAHMANN, R. T. BOWYER and J. E. BLAKE. 1990. Osteoporosis and cranial asymmetry in a mountain sheep (*Ovis canadensis*). J. Wildlife Diseases, 26(3):372-376.

BUBENIK, A. B., G. A. BUBENIK and D. G. LARSEN. 1990. Velericorn antlers on a mature male moose (*Alces a. gigas*). Alces 26:115-128.

CALIGIURI, R., G. V. KOLLIAS and C. SPENCER. 1989. Metabolic bone disease in Dromedary Camels (*Camelus dromedarius*). J. Zoo and Wildl. Medicine 20:482-487.

CANN, C. E., H. K. GENANT, F. O. KOLB, and B. ETTINGER. 1985. Quantitative computed tomography for prediction of vertebral fracture risk. Bone, 6:1-7.

CURREY, J. D. 1988. The effect of porosity and mineral content on the Young's Modulus of elasticity of compact bone. J. Biomechanics, 21:131-139.

DEQUEKER, J. 1985. The relationship between osteoporosis and osteoarthritis. Clinics in Rheumatic Diseases, 11:271-296.

GARN, S. N., C. G. ROHMANN and P. NOLAN. 1980. The developmental nature of bone changes during aging. *in* Relations of Development and Aging. J. E. Birren, ed. Charles C. Thomas, Springfield, IL.

GENANT, H. K., B. ETTINGER, J. E. BLOCK, and P. STEIGER. 1987. Diagnosis and assessment of osteoporosis using quantitative CT. Applied Radiology, 87:55-61.

GILLESPY, T. and M. P. GILLESPY. 1991. Osteoporosis. Radiologic Clinics of North America. 29:77-84.

HAZEWINKEL, H.A.W. 1989. Nutrition in relation to skeletal growth deformities. J. Small Animal Prac. 30:625-630.

HILL, M.A. 1990. Causes of degenerative joint disease (osteoarthrosis) and

dyschondroplasia (osteochondrosis) in pigs. JAVMA 197:107-113.
HOWELL, D. S. 1972. Metabolic bone disease. Pages 1178-1199. *in* Arthritis and allied conditions. J.L. Hollander and D.J. McCarty, eds. Henry Kimpton Publishers, London.
JACKSON, J. A. and M. KLEEREKOPER. 1990. Osteoporosis in men: Diagnosis, pathophysiology, and prevention. Medicine. 69:137-152.
JUBB, K. V. F., P. C. KENNEDY, and N. PALMER. 1985. Pathology of domestic animals. Vol. 1, 3rd ed. Academic Press, Orlando, Florida, 574pp.
MARCUS, R. 1989. Understanding and preventing osteoporosis. Hospital Practice 89:189-218.
MECH, L. D. 1966. The wolves of Isle Royale. U.S. Natl. Park Serv. Fauna Series No. 7.
PALSSON, H. and J. B. VERGES. 1952. Effects of the plane of nutrition on growth and the development of carcass quality in lambs: Part I - the effects of high and low planes of nutrition at different ages. J. Agr. Sci., 42:1-92.
PARFITT, A.M. 1990. Pharmacologic manipulation of bone remodelling and calcium homeostasis. Pages 1-27. *in* Kanis JA ed. Calcium Metabolism. Prog Basic Clin Pharmacol. Basel, Karger.
PETERSON, R. O. 1977. Wolf ecology and prey relationships on Isle Royale. U.S. Natl. Park Serv. Sci. Monogr. Ser. No.11.
_______. 1988. Increased osteoarthritis in moose from Isle Royale. J. Wildl. Diseases, 24:461-466.
_______, J. M. SCHEIDLER, and P. W. STEPHENS. 1982. Selected skeletal morphology and pathology of moose from the Kenai Peninsula, Alaska, and Isle Royale, Michigan. Can. J. Zool. 60:2812-2817.
STOLLER, N. H., K. M. ELA, P. P. CALLE, J. SLOTS and N. S. TAICHMAN. 1989. Periodontal disease in the Orangutan (*Pongo pygmaeus*). J. Zoo and Wildl. Medicine 20:454-460.
WOBESER, G. and W. RUNGE. 1975. Arthropathy in white- tailed deer and a moose. J. Wildlf. Dis. 11:116-121.
WOLFE, M. L. 1969. Age determination in moose from cementum layers of molar teeth. J. Wildl. Mgmt. 33:428-431.