The Application of Photon Absorptiometry to Prehistoric Skeletal Material

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Abstract

The physical anthropologist has at his disposal a technique for determining bone mineral content called Photon Absorptiometry. Unlike previous methods involving X-rays, which are subject to substantial error, or sectioning the long bones and measuring the thickness or cortical tissue with a pair of calipers, which is not an accurate measure of bone mineral content and disregards loss of trabecular bone, this new method provides a more accurate measure of what the researcher hopes to measure, osteoporosis. Also, this technique allows more direct comparisons of populations representative of both the temporal and spatial dimensions. The application of photon absorptiometry to prehistoric skeletal material introduces a means of control over variables which are difficult to achieve in the study of osteoporosis in modern populations. Therefore, new insights may result from this type of approach.

"Medicine is replete with disorders that are poorly understood, but few have been as elusive to define as the age-associated reduction in bone mass which so commonly occurs in women beyond middle life . . ." (12).

The osteological condition to which reference is made here is osteoporosis. This condition, as the name implies, is one in which bone becomes less dense or more porous. Albright *et al.* (1) were the first to define the term when they stated, "Adult bone is normally subject to two continuous processes—formation and reduction. The mass of bone may be deficient either because resorption is too great (hyperparathyroidism with osteitis fibrosa generalista) or because formation is too little (osteoporosis, or osteomalacia). Formation of bone may be too little, furthermore, either because the osteoblasts do not lay down sufficient osseous matrix or because the matrix, once laid down, is not calcified. The former condition is osteoporosis; the latter, osteomalacia or rickets." In modern terms, however, Albright's statement that reduced bone formation is responsible for gerontal de-mineralization is not tenable. Between age 30 and 40 the activity levels of formation and reduction are generally well balanced, while after 40 the rate of endosteal resorption exceeds periosteal apposition of bone.

The cause of this bone pathology as indicated by the previous statement by Schwartz (12) is varied. The literature on the subject contains several documented and generally accepted causes for this condition. Osteoporosis is accepted as a result of the aging process and may contribute to the high frequency of bone fractures in older individuals. Other data indicate hormonal influences on its onset and development. This conclusion stems primarily from observed differences in the degree of bone loss between males and females, particularly post-menopausal women. Racial differences have been reported

which suggest genetic factors being involved. Still other data indicate the effects of nutrition on the appearance of osteoporosis (8,9,11,12).

As a result, no single definitive explanation for the cause of osteoporosis has been put forward. This paper suggests a means of controlling a number of variables to a degree heretofore not possible so that the relationship between this disease and the aging process can be further documented.

There are primarily two methods of measuring bone loss *in vivo*. The first involves the use of standard X-ray equipment where the results are common roentgenograms. This method of measuring bone mineral content is based upon the transmission of photon beams through bone as reflected by densitometer measurements of X-ray films. This technique has been criticized for lack of standardization in that it is difficult to maintain a standard distance between the subject and film at moment of exposure while also allowing errors resulting from the variability of X-ray films, and the method of their development. The results of this manner of measurement are correlations between decreased mineralization and: a general increased translucency or radiolucency; irregular areas of decreased density in trabecular bone; thinning of the cortex with the appearance of lamellae and an overall ground glass-like appearance (7, 10). On the other hand, "Absence of these signs does not preclude the presence of reduced mineralization as the reduction must be appreciable before such changes are evident in standard roentgenographs" (2). Lachmann and Whelan (7), after examining serial roentgenograms of bones with known amounts of de-calcification, which was achieved artificially, found that under very favorable circumstances can de-calcification under 20% be diagnosed. In most bones the calcium loss, to be visible, must be in the vicinity of from 20 to 40%. Sante (10) suggests that evidence for de-mineralization must exceed 30% before it can be made apparent in roentgenograms.

The second technique is that of photon absorptiometry. This method was first employed by Cameron and Sorenson (3) and more recently by Johnston *et al.* (6). A diagram of the necessary equipment is shown in Figure 1. The procedure entails the use of a monochromatic photon source; in this case, resin beads have been exposed to radio-active iodine (I^{125}) and then placed in a hole at the lower arm of the apparatus. The hole is designed to direct the photon beam with little or no dispersion of energy. The source is then covered with tin foil which serves to filter all but the desired energy level of 27.3 kev. The energy or incipient photons, known better as gamma rays, are directed through the specimen and strike a sodium iodide crystal at the detector, and cause the release of an electron. The result of the released electron is a flash of light which is then counted by the detector. The number of flashes which vary with bone density are then passed to a photo-multiplier or amplifier which transfers the data visually to an oscilloscope and to a channel in the machine's memory to be processed later and transferred to paper tape for computer use.

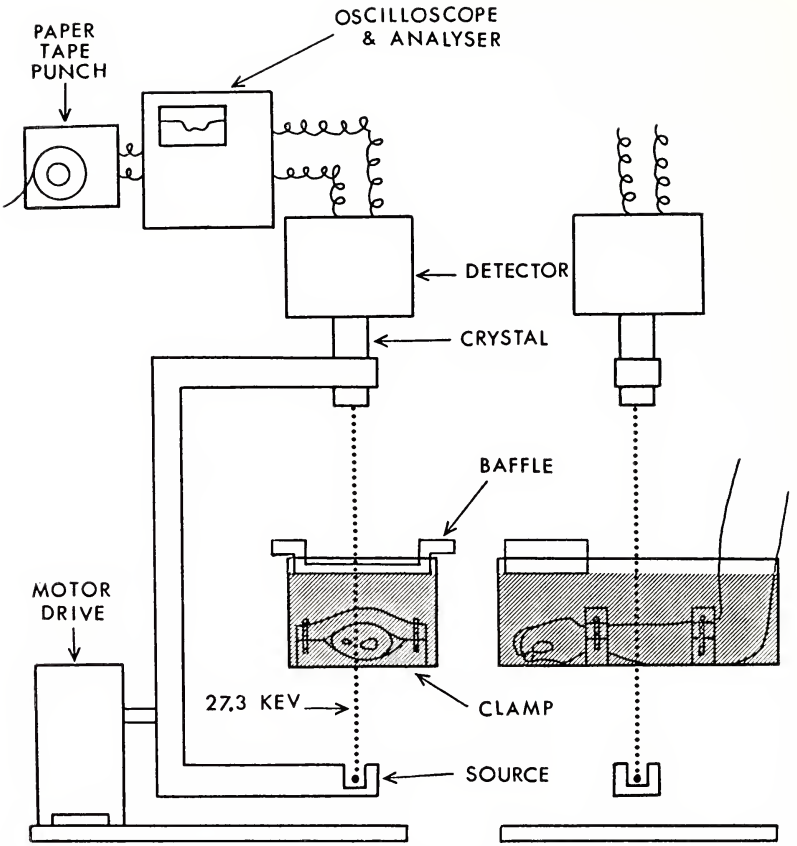

FIGURE 1. *Diagrammatic sketch of the apparatus for determining bone mineral content in Photon Absorptiometry.*

For purposes of standardization the same bone is measured in each patient, in this case the radius, either left or right as long as consistency prevails. The forearm is then placed in a water bath whose volume is maintained at a constant level by the use of a baffle. This standard water volume allows less error due to differences in integumental thickness (soft parts of forearm). In this manner, bone mineral content is the only thing being measured. Also, for purposes of standardization the source and detector pass by the specimen at a constant rate of 1 mm per sec., while the forearm is held immobile by the use of clamps. The site of the reading is also constant. Four readings are taken at each of two sites. One site is 1/10 the length of the radius proximal to the styloid process. This site serves to measure the loss of trabecular bone while the second site, 1/3 proximal to the styloid process, serves to measure cortical bone. Each of the four scans at one site are stored within the memory of the scanner and averaged. There exists within the scanner 100

positions of memory per scan or the equivalent of 400 positions per site. The average is released for transfer to paper tape along with other pertinent information such as age, sex, race, etc., of the individual being examined.

The measure of bone mineral content appears as a curve on the oscilloscope (Fig. 2). The curve height can be aligned by changing a setting on the machine. A dip at the apex of the curve denotes the measurement over the medulary cavity. The beginning and ending of the curve are calculated by a 15% deviation from the reading over water. Measurement below the temporary mean baseline of 0.85 is arbitrarily considered to be measurement over bone. In this manner the width of the bone can be determined. Also, the area within the curve is proportional to the amount of bone mineral per unit length of the reading.

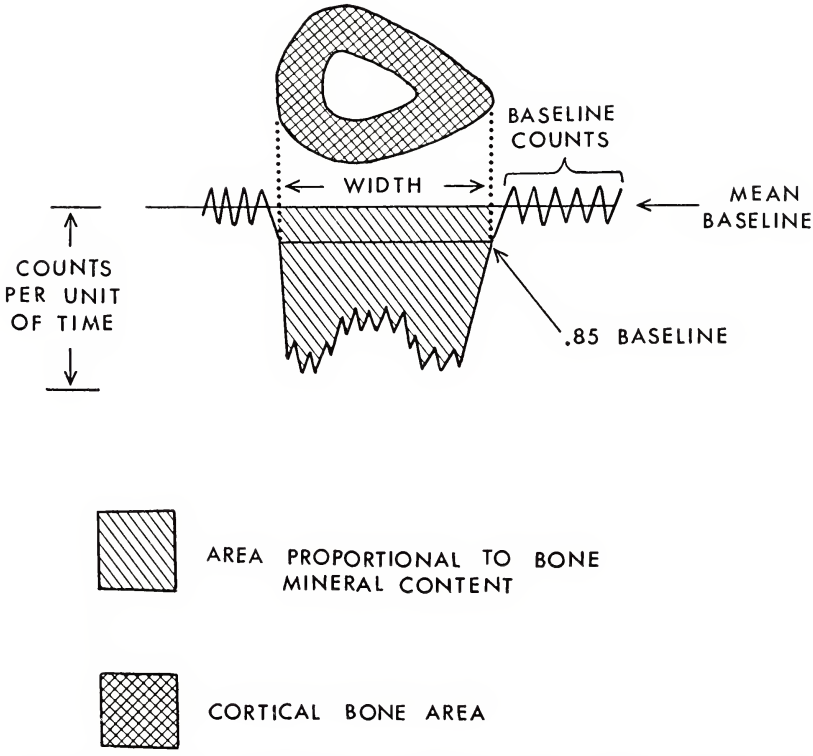

FIGURE 2. *Schematic representation of a single scan across a radius measuring bone mineral content in Photon Absorptiometry.*

The final stage is that of removing the paper tape to an area for a computer analysis (3, 6).

There are basically three techniques for measuring bone density of *in vitro* material. The first is the use of roentgenograms just as those

used *in vivo* and with the same limitations. The second is an amended version of photon absorptiometry in that it is necessary to drill a hole into the medulary cavity of the bone. This is to allow water to fill this area which would be filled by soft tissue in living specimens.

The third technique is that employed by Van Gerven *et al.* (13) and Dewey *et al.* (5) which involves the cross sectioning of bone and the measurement of cortical thickness with vernier sliding calipers at a number of locations believed to be important for diagnostic purposes. This method lacks the sensitivity to measure bone density at sites characterized by trabecular tissue. Even the proponents of this method suggest, "that it may not be possible to assume that cortical thinning results in a decrease in cortical tissue" (13).

Any study concerned with bone density of skeletal material recovered from archaeological sites has certain disadvantages. The first of two important problems encountered is the size and representativeness of the sample. The second is the state of preservation of the material. Cook and Heizer (4) clarify this second problem by stating, "The degree of variability of a series of bones taken from within a single site appears to be somewhat depending upon certain broad factors. Among these is geographical location of the site. . . . Local soil differences are random in occurrence, or at least are unknown to and uncontrollable by the investigator. Hence, as far as we can perceive at present, they cannot be avoided or predicted in advance of any analysis of chemical bone constituents." Therefore, it becomes the problem of the archaeologist to help collect data concerning the conditions contributing to the leaching process in the area of the site by describing amounts and conditions of ground water which help to dissolve and transport organic mineral substance. It is necessary to measure soil acidity at different locations on the site and at different levels. The physical anthropologist is then faced with the problem of interpreting this information in his selection of specimens for study.

The benefits from studying prehistoric skeletal material far outweigh the disadvantages. Prehistoric populations offer certain controls over variables which the investigator of bone mineral content in modern populations has difficulty in achieving. Perhaps the most significant is the fact that one may be able to delimit Mendelian populations and thus deal with genetic isolates in contrast to modern highly hybridized groups. Also, environmental stress factors can be assumed to be more uniformly distributed over the members of the population. As with clinical populations the hormonal variable can at least be partially controlled in prehistoric groups by selecting either males or females for study. The result of this technique is that it allows the researcher to concern himself to a greater degree with the relationship of osteoporosis with the aging process.

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