1981

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CORTICAL INVOLUTION OF RIB IN TWO PREHISTORIC
AMERINDIAN POPULATIONS

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Bone involution or osteoporosis, as a normal function of the aging process in humans, has been well-documented in studies of both contemporary and archeological populations (Carlson et al., 1976; Dewey et al., 1969; Garn, 1970; Martin and Armelagos, 1979; Nordin, 1966). Results of this research point to the significant onset of cortical and trabecular bone involution just after skeletal maturity, with greater subsequent bone loss incurred by females rather than males. Despite general agreement concerning the mechanics involved, the etiology of bone loss remains largely enigmatic. Clinicians have focused on a wide range of hypotheses in investigating the condition, including hormonal withdrawal, dietary imbalance, physical inactivity and metabolic inefficiency (see Garn, 1975 for a review). The adequacy of any single explanation for the process has been debated, however, prompting one reviewer of a recent symposium on osteoporosis to stress the multiplicity of factors involved, and the inconclusiveness of our knowledge on the subject (Whedon, 1970).

Skeletal biologists working with archeological populations have been similarly divided with respect to the etiology of bone involution. Pan-populational variability in bone loss has been identified in a number of studies, with differences attributed to genetic or environmental factors. Perzigian (1973) downplays the effect of diet on bone involution in his comparison of prehistoric Archaic and Middle Woodland Indian populations. The seemingly better-nourished Hopewellian groups were shown to lose bone at faster rates than their Archaic counterparts, and Perzigian invokes the role of genetic factors in explaining this differential. Ericksen (1976) on the other hand, counters this interpretation in an analysis of Peublo, Arikara and Eskimo populations. She
suggests alternatively that adaptation to differing environmental situations (involving nutrition and level of physical activity) is more directly responsible for conditioning variability in bone involution cross-culturally than is genetic constitution.

In this study, these various propositions concerning bone loss are evaluated through analysis of compact rib tissue from yet another, though particularly well-disposed, prehistoric Indian population. Patterns of bone loss are determined as a function of age and sex, and with respect to changing environmental conditions. Data are provided which are suitable for comparison with other archeological as well as contemporary population samples, and the feasibility of using ribs in studies of bone involution is assessed.

Materials and Methods

The skeletal sample used in this study consists of the remains of 89 individuals (51 female and 38 male) aged from 15 to 50+ years from the Dickson Mounds, a multi-component burial/habitation complex in the Central Illinois River Valley. Three occupational horizons have been defined at the site. The Late Woodland occupation represents a generalized hunting and gathering adaptation and is manifested at Dickson roughly between AD 900 and 1050. The Mississippian Acculturated Late Woodland (1050-1200) is a mixed hunting-gathering/agricultural phenomenon, and represents an indigenous Late Woodland population which was presumably influenced at this time by Middle Mississippian cultural developments in the American Bottoms farther south. For the purposes of this study, the Late Woodland and Mississippian Acculturated Late Woodland population samples are combined and treated as a single analytical unit, designated MALW. Finally, the Middle Mississippian (1200-1300) occupation at Dickson represents the culmination of trends toward increasing specialization on maize agriculture, increasing population density and increasing sedentism. The Middle Mississippian (MM) sample constitutes the second population unit of interest here.

While the occupational history of Dickson Mounds reflects "significant temporal changes in the nature of the cultural-ecological relationships of the population" (Lallo et al., 1978: 18), dental evidence suggests the relative genetic integrity of the combined population samples (Armelagos, personal communication). Consequently, the Dickson series offers an ideal test situation for examining the impact of environmental variables on patterns of bone loss. In this respect, previous investigators have demonstrated that those changing cultural-ecological relationships identified above correlate significantly with
increases in growth retardation, infectious disease, and mortality (Lallo, 1973; Lallo et al., 1978). It is one aim of this study to monitor trends in bone involution within the same "biocultural" perspective.

Studies of bone involution in archeological populations to date have concentrated primarily on long bones of the appendicular skeleton such as the femur, tibia, humerus and radius (Carlson et al., 1976; Dewey et al., 1969; Ericksen, 1976; Perzigian, 1973; Van Gerven, 1973). Conversely, studies of the axial skeleton, particularly the ribs, have been largely confined to clinical laboratories (Epker and Frost, 1966; Sedlin et al., 1963a,b). The rib was initially selected for use in the latter studies due to the presumed relative homogeneity of its biomechanical functions. In time, however, it became evident that the rib also remodels faster than most long bones, and thus reflects sooner than most the consequences of systemic disturbances (Frost, personal communication). This is one rationale selecting for the use of the rib here. A second aim of this study is to evaluate the utility of the rib in macroscopic assessments of normal, age-related bone involution.

The methodology applied in the analysis corresponds closely to that employed by Sedlin et al., (1963). Cross-sections made from the mid-diaphysis of the fifth, sixth or seventh rib (depending on availability and/or state of preservation) were superimposed upon a uniform grid of known area. Total cross-sectional area and cortical area were determined by counting the number of grid intersects "hits") contained within the periosteal envelope and overlying cortical bone, respectively, multiplying the result by the total grid area, and then dividing by the total number of intersects in the grid. The formula used was:

\[ \text{AREA} = \frac{(\text{number of intersects}) (\text{total grid area})}{(\text{total possible number of intersects})} \]

Medullary area was calculated by subtracting cortical area from total cross-sectional area. The actual "hit" value used in the computations represented the numerical average of two separate, randomly placed count determinations for each cross-section. In the case of tangential "hits", every other grid intersect was counted.

Results were grouped by age, sex and population, and two indices of relative bone involution generated for analytical purposes. The first of these, Percent Cortical Area or PCA (Garn, 1970), was computed by dividing cortical area by the area of the total cross-section. PCA was selected as a parameter for
analysis on grounds that the space within the periosteal envelope actually occupied by bone represents one of the most powerful indicators of osteoporosis (Huss-Ashmore, 1978). Inasmuch as the periosteal apposition of new lamellar bone has been demonstrated to occur throughout life (Carlson et al., 1976; Epker and Frost, 1966; Garn et al., 1967), cortical tissue loss is best equated with a determination of cortical area, since this parameter takes into account changes in both cortical thickness and periosteal diameter (Van Gerven, 1973).

The second parameter selected for analysis was the Parabolic Index (Epker and Frost, 1964), an indicator of the degree of osteoporosis in a bone which is based on principles of structural mechanics. This index was calculated using the following formula:

\[
\text{Parabolic Index (Y)} = \frac{Ac \times Am}{At^2}
\]

where \(Ac\) represents cortical area, \(Am\) the medullary area and \(At\) the total cross-sectional area. The value of \(Y\) approaches but never exceeds .25, or that numerical value which is optimal for structural columns. The lower the value, the less integrity is there to the structural (i.e., skeletal) member in question. It has been suggested (ibid.) that bone remodelling processes are guided by a control system designed to seek optimal distribution between cortex and marrow, and that this is why ribs and long bones conform to the optimal value of the index. The complete rationale behind use of the index has been discussed at length elsewhere (ibid.), where it was shown to be useful in comparing the degree of osteoporosis in individuals of any age and body habitus.

Results

The relationships between all relevant parameters and age, sex and population were subjected to analysis of variance, and are graphically represented in Figures 1 to 8. With respect to total cross-sectional area (Figure 1), the difference between males and females is statistically significant using one-way ANOVA (\(p=.001\)). This is not surprising, as differences in overall body size between the sexes would contribute to this differential in total cross-sectional area. No significant differences between the sexes are apparent in terms of rates of increase in total area throughout life. Similarly, there is no significant difference between the populations as a whole (Figure 2). Multiple Classification Analysis (MCA) suggests that sex and age explain 18.5 and 6.0 percent of the variance in this parameter, respectively.
The relationship between absolute cortical area and age is graphed in Figure 3, and is statistically significant ($p < .03$). The plot for MM males shows the typical pattern of loss noted in previous studies of rib involution (Sedlin et al., 1963), with cortical area increasing until the period of skeletal maturity, declining sharply thereafter, with a more gradual decline later in life. The fact that the female curves do not exhibit this pattern may be due to the small sample sizes in the critical fourth decade. More importantly, however, there is no significant difference between males and females with respect to rates of decline in this parameter, a condition which was expected given the results of previous research (ibid.). In fact, although females show smaller values than males in the second decade, they show consistently greater values in the fourth through sixth decades. The overall population curves (Figure 4) again show no significant differences, with the MM curve exhibiting the expected pattern. MCA revealed that 13.7 percent of the variance in this parameter is explained by age, nearly 98 percent of the total explained variance.

As noted above, PCA is perhaps the most accurate indicator of cortical changes in a bone. Figure 5 shows the relationship of this parameter to age, sex and population, with differences due to age and sex emerging as statistically significant ($p = .001$). Though the basic curve configurations represented here are congruent with those from other studies, the high percentage of cortex in females relative to males is, again, contradictory to other published findings. Two-way ANOVA reveals that the interaction effect of sex and population on PCA is significant ($p < .02$). This may be a function of the difference in amplitude between determinations for MALW males and females, combined with the more variable and closely-spaced curves characteristic of the MM. Population differences per se (Figure 6) appear otherwise insignificant. MCA shows that age and sex explain 28.0 and 13.7 percent of the variance in PCA, respectively.

Figure 7 graphs the Parabolic Index against age. Differences between males and females are significant ($p = .001$). Once again, however, the enigma of higher female than male values is evident. The female curves are interesting in that they suggest a pattern noted in previous studies of bone loss. More specifically, the decrease in bone in the third decade may reflect nutritional stress in early adulthood due to the rigors of pregnancy and lactation (Dewey et al., 1969; Martin and Armelagos, 1979), followed by an increase in bone in the fourth decade and decline thereafter. Overall population trends are for the most part comparable, and do not deviate significantly from a sample of "normal" modern individuals reported by Epker and Frost (1964).
MCA reveals that the main factors of sex, age and population contribute to explaining 20.0, 16.8 and 2.0 percent of the total variance in Y, respectively. The variation due to population is apparently attributable to differences between groups of males.

Discussion

As noted above, several results of this research are not easily reconciled with those of previous studies. Especially problematic in this regard is the sex reversal in PCA and the Parabolic Index, where females show greater amounts of bone than males. The average age of males and females in each population was determined to check for sampling bias, but these figures do not differ significantly (MALW males = 39.9 years; MALW females = 35.5 years; MM males = 34.9 years; MM females = 34.6 years). It might also be pointed out that studies serving as a comparative baseline for the present research were largely undertaken in the appendicular skeleton, with the exception of the clinical rib studies by Sedlin et al. (1963) and Epker and Frost (1966). Where studies of bone involution have been conducted in the appendicular and axial skeletons simultaneously (Bartley and Arnold, 1967), it was shown that differences between males and females are much less marked in the latter. Nonetheless, even here males still demonstrate slightly greater amounts of bone in all age categories and lower rates of bone loss overall than females.

A potential source of error bearing on this sex reversal may reside in the fact that differences due to size and body build were not considered in the analysis. Such a procedure has been identified as critical by other investigators interested in comparing population trends in bone involution (Dewey et al., 1969; Ericksen, 1976). However, since the interest in this study has been in obtaining relative indices of cortical area (PCA, Y) one intuitively would not expect a correction for body size to significantly alter the results. More likely explanations for the unusual sex differences obtained here perhaps lie in the realm of sampling error, or with the problems in selecting a standard rib sampling site in often poorly-preserved archeological bone. Alternatively, the results reported here may actually be more real than apparent, thereby providing interesting new avenues for future research.

Conclusions

The results of this study do not readily conform to those obtained in other studies of cortical involution in archeological populations, especially with respect to sex differentials in the rate of bone loss. Moreover, the lack of a significant difference
between the MALW and MM populations at Dickson Mounds does not support the notion that changing cultural-ecological relationships at the site affected to any great degree patterns of bone involution. Clearly, however, these conclusions are at best tentative. Additional data on cortical involution of the rib is needed in order to better evaluate the trends reported here, as well as the general feasibility of using ribs in macroscopic analyses of skeletal involution.
REFERENCES CITED


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Figure 1. Total cross-sectional area.
Figure 2. Total cross-sectional area.
Figure 3. Cortical area.
Figure 4. Cortical area.
Figure 5. Percent Cortical Area.
Figure 6. Percent Cortical Area.

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MALW

N 4 15 3 17 7 =46

\[ \bar{X} = 55.25 46.0 40.0 36.0 30.1 \]

MM

N 6 12 9 10 6 =43

\[ \bar{X} = 46.0 42.4 38.7 36.9 34.0 \]
Figure 7. Parabolic Index.
Figure 8. Parabolic Index.