

INTERACTION OF DIET AND DISEASE AT THE DONNAHA SITE,  
YADKIN COUNTY, NORTH CAROLINA

by

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#### ABSTRACT

A study of the human skeletal remains from the Donnaha site in Yadkin County, North Carolina, has revealed a high frequency of a particular bone pathology (porotic hyperostosis). Because of the environment of the area an additional cause of this porosis is proposed. Chronic parasitic infection probably interacted with nutritional and physiological causes to produce the observed skeletal pathologies. The bases of these causes are discussed and a potential interaction of all causes is suggested as the cause of the high incidence of porotic hyperostosis.

This report is a study of a bone pathology (porotic hyperostosis) resulting from anemias in forty-seven individuals excavated from the Donnaha Indian site (ca. 1100 A.D.) in Yadkin County, North Carolina, during two field seasons (1973 and 1975), by Wake Forest University's Field Archaeology Program under the direction of Dr. J. Ned Woodall. The occurrence of skeletal

porosity, both cranial and post-cranial, has been observed in 49% (23/47) of the individuals examined from Donnaha.

According to El-Najjar et. al. "Porotic hyperostosis (also known as symmetrical osteoporosis, cribra orbitalia, cribra cranii, or hyperostosis spongiosa) is a descriptive term for cranial and orbital lesions. These appear as widening of the diploë, thinning of the outer table, and the presence of small apertures, giving a coral or sieve-like appearance to the bone. In more severe cases, the lesions may enlarge to such a degree that the outer table becomes unrecognizable." (1976: 477). J. L. Angel extended this definition to include "the observed bone swelling and porosity seen in the long bones...in fully developed examples of this disease." (1967:379). H. U. Williams concluded in an early study of Anasazi infants "that porotic hyperostosis was the result of marrow hyperplasia due to anemia," (1929:839-902). Possible causes of these identifiable bone changes include thalassemia, sickle-cell disease, cyanotic congenital heart disease, iron deficiency, and parasitic infection.

It is widely known that many of the bone lesions occurring in porotic hyperostosis in the Old World were the result of hemolytic anemias. Angel (1967:378) has noted that the distribution of porotic hyperostosis "fits quite well the major

pattern of P. falciparum malaria and the Old World occurrence of the thalasseмии (Chernoff 1959:899; Bannerman 1961) and of sickle cell anemia (Singer 1962:152)." El-Najjar states: "no evidence of sickle-cell, thalassemia, or the G6PD deficiency in unmixed American Indian Natives. All reported cases of these are the result of European or African admixture." (1976:329). Therefore, hemolytic anemias cannot explain the high incidence of porotic hyperostosis in the Precolumbian natives of the New World and cannot be considered significant contributors to the high incidence of porotic hyperostosis found at Donnaha.

Cyanotic congenital heart defects, the next possible cause of porotic hyperostosis, may be ruled out. It is highly unlikely that nearly half of any given population would suffer from severe congenital heart defects. The only reasonable conclusion which can be drawn is that cyanotic congenital heart defects cannot explain the high incidence of porotic hyperostosis found in the New World.

The significance of iron absorption in relation to porotic hyperostosis has been studied in recent years: "since hemoglobinopathies and malaria have not been found in unmixed Indian groups, only a disorder as common as iron deficiency anemia could explain the frequent skull pathology." (El-Najjar et. al. 1976:485).

General malnutrition has profound effects on skeletal and body growth and development. Steward (1975:55) lists the effects of a protein-energy deficient diet on children's bones: retarded growth, short bones and epiphyseal growth and osteoblastosis retardation. At the same time, a vitamin deficient diet would not only slow development, but would also expose the individual, particularly a child, to a high risk of anemia and (an increased) general susceptibility to disease. Further, a generalized mineral deficiency, for whatever reason, would retard body growth, particularly bone development.

El-Najjar et. al. (1976:484) have claimed: "The most common condition associated with marrow hyperplasia in human populations is iron deficiency anemia." Basically, there are only three possible causes of iron deficiency anemia: 1) repeated loss of significant amounts of blood, 2) a dietary cause, 3) a post-natal iron deficiency. Other than individual cases, as in the case of a bleeding ulcer, there are two main possibilities for chronic bleeding: menstruation in females, and parasitic infection. The significance of each in relation to New World porotic hyperostosis must be evaluated.

Females, prior to the onset of menstruation, have no greater requirement for iron than do males of the same age and hence

Should not be differentially affected. Further, by the onset of menstruation, females have already adopted an adult dietary regime, and are capable of extracting the necessary nutrients from their environment--provided, of course, that those nutrients are available. Hence, males and females should be affected equally prior to the onset of puberty and after homeostasis is reached in the female following the period of the onset of menstruation.

Parasitic infection is a well known cause of chronic blood loss which can lead to iron deficiency anemia. Of the many parasites which infect human beings, among those most likely to have contributed to the anemia observed at Donnaha are two species of hookworm: Necator americanus and Ancylostoma duodenale. Scott and Berowitz (1944) have summarized the life cycle of hookworms as a process involving: 1) the presence of larvae in the soil, 2) the larvae pass on contact through the bare skin, 3) enter the bloodstream where they are passed to the heart and lungs, 4) the larvae penetrate the alveoli of the lungs and may then be coughed to the mouth, 5) where they will be swallowed and enter the duodenum, 6) in the duodenum, the larvae mature and lay eggs, 7) which are passed in the feces to the soil, providing the potential for reinfection and the spread of the

parasite. The life cycle progresses in 6 - 10 weeks. Mature parasites may live for years within an individual, and eggs may be forthcoming with regularity for the life of the organism.

Parasites, particularly the species N. americanus (hookworm) are potentially significant contributors to the high incidence of porotic hyperostosis observed in the individuals at Donaha only if their presence in the Southeastern United States during Precolumbian times can be documented. Until recently, N. americanus and A. duodenale were thought to have been historic introductions to the New World. (Darling 1920:221).

As Marvin Allison (1974:103) noted, there is little proof of the existence of N. americanus in the New World in Precolumbian times. Yet, the possibility remains "that either or both species (N. americanus and A. duodenale) have also been introduced into the American continent from Asia, Indonesia, or Polynesia by voyagers or storm-tossed fishermen." (Darling 1920:221).

Three potential sources for the initial infestation of the New World inhabitants have been proposed: 1) from Asia by way of the Bering Straits, 2) from Asia or Indonesia across the Pacific, or 3) from Polynesia across the Pacific.

The hypothesis that the New World peoples were first infested with hookworms by way of the Bering Straits must be rejected on

the basis of climate. Generally, hookworm larvae are best suited to moist shaded areas with loose sandy soils or alluvial deposits, in which the average temperature is about 35° - 40°C. (Belding 1942:291). The environment of the Bering Straits would probably have been much too cold for hookworm larvae to have survived, allowing the migrants to "arrive free from hookworm." (Darling 1920:221).

Citing the many similarities of the Shang and Olmec civilizations, Betty J. Meggers has suggested that the archeological evidence implies Precolumbian contacts between Asia and western America. (1975:22). If contact were made, then perhaps hookworm introduction to the New World also occurred at this time - certainly the environments of the Olmec region of Mexico through Panama and as far into South America as the coastal regions of Peru, were conducive to hookworm.

Poor preservation allows little concrete evidence to support the claim that hookworms were present anywhere in the New World during Precolumbian times. However, there has been at least one diagnosed case of hookworm infestation in a Precolumbian American. In a Tiahuanaco mummy dating ca. 900 A.D., Allison described the "first recorded case of hookworm infestation in the Americas prior to the coming of the Europeans." (1974:103-106).



The significance of this case is clear. Hookworms were probably present in the tropical regions of Central and South America prior to any recorded contact from Europe.

Two further questions must be resolved: 1) was the environment of the Southeastern United States, and particularly of the Piedmont region of North Carolina, amenable to hookworm cycle? and, 2) is it conceivable that hookworms arrived in the area by about 1000 - 1100 A.D., the date ascribed to Donnaha.

The geography of the Southeastern United States provides many hospitable environments for hookworm larvae. The climate is generally one of mild winters and warm summers. The Piedmont and Coastal Plains regions of the Southeastern United States have an abundance of creeks and rivers which provide many ideal sites for both hookworm infestation and Middle Woodland villages.

There are no data which provide proof of direct trans-Caribbean contact between the Panama/South American area and the Southeastern United States. James A. Ford has noted however, that the circular villages and ceramic types found both in the area around the Isthmus of Panama and the mouth of the Savannah River suggest that long before 1000 A.D. "a voyage was made on the Atlantic Coast of the Americas...the route probably passed through the straits of Yucatan around western Cuba, through the

Florida Straits, and northward to the mouth of the Savannah River" (1969:185). Despite the lack of concrete evidence, it is conceivable that hookworms were carried into the Southeastern United States prior to the arrival of the European explorers.

The Donnaha site is located in an environment which is somewhat marginal for hookworm infestation. The damp sandy loam found in the alluvium at Donnaha provides an excellent environment for the transmission of hookworm from late Spring through early Fall. During Winter in Piedmont North Carolina cold temperatures have prevented the hookworm larvae from developing in the soil (Scott, Bercovitz 1944:794). Since Donnaha is a marginal environment for hookworm, one must ask how a periodic infection would have affected the inhabitants at Donnaha. It has been noted by Scott and Bercovitz that "persons infected with only a few worms have moved to a locality where further infection was impossible, but the eggs continued to appear in the stools for as long as seven years." (1944:793). Hence, in a seasonal environment such as that at Donnaha, one can easily postulate periodic (even yearly) re-infection of the individuals.

The severity of the anemia produced by hookworm infection is primarily based upon three factors: "1) the number of worms harbored by the patient, 2) the length of time he has borne them,

3) and his ability to compensate for their debilitating effects." (Scott, Bercovitz 1944:794). At Donnaha, transmission of hookworms is impossible throughout the winter months, except by direct contact with feces, leading one to suspect that the number of worms in any individual at Donnaha was usually sufficient to produce only a sub-clinical infection in a healthy individual. Yet, since both iron deficiency and chronic malnutrition are conceivable at Donnaha a periodic infection, no matter how slight, may have been sufficient to produce a severe anemia. Thus, hookworms may have been a major contributing factor to the high incidence of porotic hyperostosis observed in the 47 individuals at Donnaha.

Iron deficiency studies done among infants and young children have shown that: "By about six months of age, children have depleted the iron stores accumulated in utero and must depend on a sufficient dietary intake of iron to satisfy growth requirements...Factors that diminish the intra-uterine accumulation of iron predispose a child to the onset of iron deficiency anemia in the first six months of life." (El-Najjar, et. al. 1976:484). In any population in which infants are not supplied with the proper amounts of iron, porotic hyperostosis should be widespread.

With the exception of menstrual blood loss and parasitic infection, diet and nutrition should be responsible for the majority of cases of iron deficiency anemia in the New World and as a corollary, porotic hyperostosis. There are two means by which diet may play a role: 1) the diet might simply be insufficient in iron content to meet metabolic requirements, 2) when the diet is sufficient in iron content, something may interfere with the absorption of iron by the body.

Iron deficiency anemia resulting from simple dietary insufficiency may occur for one of two reasons: 1) if iron is not available in the environment neither children nor adults can get the necessary amount of iron: 2) cultural practices may restrict the intake of iron by a certain group. For example, infants may be breast-fed for the first several years of their lives simply because that is the easiest way of providing food. Moseley (1961:651), in research done on a three-year-old Puerto-Rican male, concluded that iron deficiency anemia experienced by the child was the result of a diet consisting almost exclusively of milk. Clearly, a diet of this nature will result in severe growth and metabolic problems.

Compounding the problem of cultural preference is an important aspect of nutrition which is often overlooked--the

effect of a diet which inhibits the absorption of certain vitamins and minerals. Wintrobe (1967:585) has suggested the high calcium intake inhibits the assimilation of iron in the human body. Also, it has been shown that the phytic acid present in all varieties of maize inhibits the absorption of whatever iron is ingested. (Reinhold et. al., 1973). In an agriculturalist population subsisting primarily on maize, iron absorption is severely restricted. Further, if iron absorption is restricted due to either or both of the above conditions, body growth and development will be severely retarded. El-Najjar, et. al. (1976:485) concludes that "in view of the problems of iron absorption in maize dependant diets, iron deficiency may have been fairly common. Women and children, because of their high iron requirements, are expected to show more severe signs of iron deficiency anemia in the form of porotic hyperostosis.

#### POPULATION SPECIFICS

Of the 47 individuals surveyed, 12 were so severely eroded or so poorly represented as to render them useless in analysis of bone pathologies resulting from anemias. Of the 35 remaining individuals, 65.7% (23/35) showed evidence of skeletal porosis

(see Table I). Included in this sample were eight females ranging in age from 15-45, ten males ranging in age from 1.5-40 years of age, and five individuals of undetermined sex ranging in age from 1.0-40 years of age. In nine of the cases, it was determined that the porosity was probably resorption due to age. The three males of this group yielded a mean age of 36.3 years. The five females of this group ranged in age from 30 years to 45 years of age, yielded a mean of 37.2 years. The individual of undetermined sex was about forty years old.

Among the 14 cases of porotic hyperostosis probably due to anemia, it was determined that 71.4% (10/14) were cases of porotic lesions in a healing stage. The six males represented ranged in age from 18-45 yielding a mean of 29.6 years. The two females were about 20-25 years of age. One individual of undetermined sex was about 20 years old, the other about 5 years old.

In the four cases of active anemia, two individuals were of undetermined sex. One was less than 12 years of age, the other about 1 year old. In the cases of known sex, one was a 15 year old female, the other probably a male between 1.5-2.5 years of age.

## DISCUSSION

In the cases diagnosed as active anemia, all four individuals are quite easily explained. Jensen, et. al. (1977:40) state that the average age for the onset of menstruation for females is around 13 (between 10 and 14) years of age. Hence, a girl of 15 should be expected to display some degree of iron deficiency simply in response to her novel and periodic blood loss. It is also reasonable to assume that infants would be suffering from an iron deficiency, particularly if they were restricted to a diet high in calcium (maize gruel) until the age of about 4-6 years, at which time the children could begin to eat substantial quantities of meat and meat fats. (Cook and Monsen 1977). The individual which showed healed porosity at 5 years of age seems to support this idea. It would appear the females about the age of 20, well past the onset of menstruation, had adjusted to the physical changes brought about by adolescence. In effect, their bodies would have attained homeostasis. Generally speaking, it would appear the menstruation in post-adolescent and early adult years is not a great factor, indicating that the adult diet was probably adequate in iron, and generally well-balanced.

## CONCLUSION

Many factors must be considered when attempting to explain the high incidence of porotic hyperostosis observed in the skeletons from Donnaha.

Primarily, they are: 1) physiological factors such as age and sex; 2) cultural factors related to age and sex; 3) nutritional factors; and 4) parasitic infection. Each of these factors must be considered possible contributors to the anemias which resulted in the observed lesions. In all likelihood, there was no single cause for this anemia. Rather, the anemia was probably caused by a combination of all the factors. Only with such combination of causes can such a high incidence of anemia be explained. The model suggested by the Donnaha data is that of individuals of a particular age and sex, and therefore, susceptible to anemia, faced with dietary insufficiencies and possible periodic parasitic infection. Further studies at Donnaha should elucidate the proposed interaction of physiology, diet and disease through the recovery and analysis of more faunal, floral, and human remains from the site.



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TABLE I

CASES DUE TO ANEMIA						
Individual No.	ACTIVE Sex	Approximate Age	Individual No.	HEALED Sex	Approximate Age	
34-28	Female	15 years	#1 (16-6)	Female	20-26 years	
34-144	Male	1.5-2.5 yrs.	#8b	Female	25-30 years	
40-10a	?	1 year	#2	Male	30-45 years	
36-19	?	12+ years	34-56	Male	25+ years	
			34-143	Male	18-19 years	
			35-4	Male	25+ years	
			34-166	Male	40+ years	
			#13	Male	35-45 years	
			40-9	?	5 years	
			EU-17	?	20 years	

## CASES DUE TO RESORPTION

Individual No.	Sex	Approximate Age
#9	Female	30 years
#11	Female	35-45 years
40-13	Female	40 years
40-106	Female	33-35 years
34-118	Female	39-45 years
1972-S	Male	40+ years
#5	Male	29 years
Sur.	Male	40+ years
#4	?	40+ years