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NUTRITION IN FIRST CENTURY HERCULANEUM

ABSTRACT — The author studied the Roman period skeletal remains from Herculaneum. The health conditions of this population were analyzed and compared with the nutrition and social structure background as is known from archaeological and historical knowledge.

KEY WORDS: Herculaneum — Nutrition and health — Roman population.

INTRODUCTION

Health and nutrition are vital in the development of any civilization. Good health with nutrition as a major factor is needed for the strength and energy to produce technology, art, literature, architecture, government and all that characterizes a great civilization. It is, therefore, as important to study the nutrition of a civilization as to study its battles and treaties.

Methodology

It is instructive, but not adequate, to list the items found at each site. Such a study would indicate which foodstuffs were available but give no indication of relative amounts consumed by either the individuals in question or by the general population. Conclusions about the quality of the diet can be reached only by studying the data afforded by human remains. No single parameter can tell much about nutrition. Two basic anthropological methods were used to study the skeletons of Herculaneum: (1) direct measurement and observation of the bones—including the more nutritionally relevant ones of longevity, stature, pelvic brim index, shaft indices of tibia and femora, dental health and observations of diseased conditions as anemia and infection—and (2) biochemical analysis of bone samples—animal and human—plus soil samples for the minerals calcium, phosphorus, magnesium, zinc and strontium.

DIRECT MEASUREMENT AND OBSERVATION OF BONE

Longevity

Adult longevity is usually a good indication of the general health of a population. Since many factors bear on these statistics, it is impossible to say how large is the share of nutrition. Age can be determined using epiphyseal closures (McKern and Stewart, 1957), tooth eruption (Logan and Kronfeld, 1933), changes in the faces of the pubic symphysis (Todd, 1921; McKern and Stewart, 1957) and general appearance of the bone and skull suture closure (Todd and Lyon, 1927). This author reports mean age as the death of that part of the population which is 15 years or more in age; she also constructs mortality curves. However, for the population of Herculaneum, age at death statistics would be meaningless. Due to accident, the entire population died at younger ages than it would have naturally.

Stature

Stature data are very revealing of health and nutrition. Heredity will dictate the maximum stature possible for an individual. Poor nutrition and/or disease may mean that he or she does not reach this growth potential. Inadequate food supplies result in shorter people, particularly males. Stature is estimated by using lengths of long bones (Martin and Saller, 1959) and the Trotter and Gleser regression formulae (1958).

Pelvic Brim Index

The pelvis, because of the weight of the upper body pressing down on it, reflects any slight softening of bone by becoming flattened. Thus, the pelvic brim index can demonstrate long-standing conditions of poor nutrition (Greulich and Thomas, 1938; Nicholson, 1945; Angel, 1976). The pelvic brim index, Anterior-Posterior/Transverse X100 (Martin and Saller, 1959), is 95 to 105 in healthy modern Americans (Angel, 1975), but can be as low as 65 in archaeological remains.

Shaft Flattening in Long Bones

Shaft flattening in long bones can result from the combination of heavy exercise and relatively poor protein and/or caloric nutrition. More exercise tends to produce more muscle mass; poorer nutrition tends to produce small or slender bones. The bone remodels to supply more surface for the muscle to attach itself to and becomes flat instead of round (Adams, 1969; Buxton, 1938). Bowing of long bones can indicate a more extreme situation in regard to nutrition and exercise. In this study, indices of the femur (platymeric) and of the tibia (cnemic) were taken (Martin and Saller, 1959; Wilder, 1920) with visual assessment of bowing.

Dental Health

Dental health also has a nutritional factor, although its importance is difficult to evaluate. In this study, the number of lesioned teeth (lost ante-mortem, carious and/or abscessed) per mouth as extrapolated from available alveolae to thirty-two alveolae was expressed. Another condition, enamel hypoplasia, gives insight into the health of the individual as a growing child. Periods of illness or malnutrition which occur as the tooth develops can affect tooth by causing an indented horizontal line, indicating the lack of calcium or certain vitamins in the body at that time. No later intake of calcium or phosphorus can make up for this shortage. Thus, an insight into the childhood of the population is possible (Mellanby, 1934; Clement, 1963).

Other Observations of Conditions in Bone

Traumata and anomalies occurring in bone are readily observable. Inflammatory processes affecting bone are but a small portion of the total of infections present in a population, but are, of course, all that can now be observed. Degenerative processes, chiefly arthritis, reflect such factors as general health, environmental conditions, exercise, age, genetic charge and morphology, as well as nutrition, when the condition is in extreme and drastic form. Anemia may be evidenced in the hypertrophy of those portions of bone responsible for red cell manufacture (i.e., the marrow of the long bones and particularly the diploë of the skull and face). This latter manifestation results in the condition of porotic hyperostosis, a thickening of the diploë of the skull and the thinning and porosity of the outer table. Controversy exists over the possible differentiation of bony signs of the various types of anemia—such as thalassemia, iron deficiency, hookworm or other debilitating conditions. The best hypothesis as to the cause of anemia results from consideration of ecological context and the entire population, rather than the appearance of any single individual (Angel, 1966).

BIOCHEMICAL ANALYSIS

Biochemical analysis of bone can give insight into the nutrition of ancient peoples. Bone, both animal and human, was analyzed by atomic absorption spectroscopy for calcium, phosphorus, strontium, zinc and magnesium. Soil from the same site was analyzed for calcium, strontium, zinc and magnesium (see Bisel, 1980).

Iron was not included in the study. It would seem that determination of its presence in bone could give an assessment of anemic conditions; however, since it normally exists in only minute amounts in bone cortex, such analysis could lead to erroneous conclusions. Another element, fluorine, was excluded despite the importance of its relationship with dental caries because its quantitative presence in bone would be misleading. Buried bone tends to accumulate and retain fluorine from the ground water; indeed, the quantitative analysis of fluorine serves as a rough method of dating bones (Middleton, 1844). On the other hand, fluorine analysis has been done on ground water samples from two sites, on the assumption that the present mineral content of the water would be similar to that of ancient times. Lead, not an element of normal nutrition, but indicative of other sociological factors, is also being studied at present. Results will be reported in a later publication.

Reporting the Bone Minerals in This Study

The mineral values reported here for ancient bones are somewhat different from those reported for the modern American population. The latter figures are derived from the raw, unpublished data from the study conducted by Janes, et al. (1975) for the elements calcium, zinc and magnesium. This study generated data for dried bone and for dried, fat-extracted bone. Since it would appear that archaeological bones more closely approximate the latter, these figures have been used. Data on bone phosphorus of modern Americans (*Table 3*) has been derived from Zipkin's study (1970). Archaeological bone differs from modern bone particularly in calcium and phosphorus, the two major elements. Since it has lost the collagen portion of the bone, the relative proportion of bone mineral rises. Calculating mineral content as a ratio with calcium helps overcome the problem of differential loss of calcium and phosphorus in the specimens. This procedure also corrects for possible weight contamination by extraneous materials in the bone. Minerals are reported in the tables as absolute values and as ratios of the four others with calcium. In addition, strontium is reported as a ratio of Sr/Ca with the site-specific sheep-goat bone Sr/Ca so that the strontium level of human bones can be compared from site to site; this will be explained at greater length below.

Techniques Used in Mineral Analysis

Two hundred sixty bone samples, mostly from tibial crest, were cleaned mechanically of surface dirt. Each approximately 500 mg specimen was weighed to 10^{-4} g and dissolved in 3 ml concentrated HCl. For the determination of calcium, strontium, magnesium and zinc, further dilutions for each mineral were made with distilled water as noted below. Each was analyzed with a 303 Perkin-Elmer atomic absorption spectrophotometer, using wavelengths noted below and an air-acetylene flame (Table 1, Perkin-Elmer Corporation, 1971; Mayo Clinic adaption). Values were then calculated as mg/g of calcium and magnesium and as µg/g of strontium and zinc (*Table 3*).

TABLE 1. *Specifications for Atomic Absorption Spectroscopy of Bone Mineral*

Element	Total Dilution	Wavelength
Ca	1—75,000	422.6
Sr	1—150	460.7
Mg	1—1, 500 and 1—7,500	285.2
Zn	1—150	213.8

To determine phosphorus content, the samples previously dissolved in concentrated HCl were further diluted 1—1,000 in distilled water. Two ml each of the standard phosphorus reagents amino-naphthol-sulphonic acid and ammonium molybdate were added to 1 ml of dilute sample (Fiske and Subbarow, 1925). Values were read at 630 on a Perking-Elmer Hitachi 200 spectrophotometer and calculated as mg/g.

The soil samples were analyzed for the available calcium, magnesium, strontium and zinc. Each sample of approximately 500 mg was weighed to 10^{-4} g. For the determination of calcium, magnesium, and strontium, the sample was shaken together with 5 ml of 1 N ammonium acetate for half an hour and filtered. Further dilutions were made: 1—500 for calcium, 1—50 and 1—500 for magnesium and none for strontium. For the determination of zinc, 1 ml of the solution of 0.005 M diethylene triamine pentacetate +0.1 M triethanolamine +0.1 M calcium chloride was added to the sample. This was shaken together for two hours and filtered. No further dilution was made. Readings for all minerals were made on the Perkin-Elmer atomic absorption spectrophotometer, wavelengths as noted above (U.S. Soil Conservation Service, 1979; Linday and Norvall, 1978).

The Data and Their Interpretation

The schematic data summarized in *Table 2* indicate minimal differences between the Herculaneans and the Athenians. The number of Athenians is too small to give more than a suggestion of age at death statistics—which, as stated before, are impossible to calculate for the Herculaneans. Stature, however, is significant and can be compared. The Herculanean mean stature for both sexes is much less than that of the modern Americans (7 cm for females and 5 cm for males) undoubtedly due in large part to less adequate nutrition. It can also be noted that the Herculaneans were taller than modern Neapolitans are. The mean stature of modern Neapolitans males is 164.0 cm and the female mean is 152.6 cm (d'Amore, Carfana, Matarese, 1964)—about 5 cm and 3 cm shorter, respectively, than the ancient Herculanean male and female. Thus, the ancient Herculaneans can be assumed to have been better nourished than their modern counterparts.

In the bone flattening statistics of pelvis and of long bones, the Herculaneans and Athenians are roughly equivalent, but both populations are significantly flatter in all statistics than modern Americans. The pelvic brim index of both sexes together for the Herculaneans is 85.9, significantly flatter than the U.S. modern mean of 92.1. The platymeric index average for both genders at Herculaneum is 82.4—5 points below 87.1, the U.S. modern mean. Probably most of the ancient Herculaneans experienced heavy exercise as opposed to fewer of the modern Americans, but the nutritional factor is still very important in these data as well.

The dental health of ancient Herculaneans was excellent. The total number of dental lesions per mouth, here defined as the total of antemortem loss, plus caries and abscesses, is quite low: the mean is 3.7 (N = 79). Compare these scores to the 17.0 mean dental lesions of the modern U.S. population (N = 170). Part of this striking difference can be explained by a lack of sugar in the diet. Sugar was not introduced to Europe until the Middle Ages when it was brought back from the Crusades. Honey was known to the Romans, but its use would have been considerably less than that of sugar in modern America. During the Roman period, people also ate a high proportion of rougher foods which would have had a cleansing action on the teeth by wearing away caries before they could develop. Incidence of trace to moderate hypoplastic lines in first century Herculaneans is 30 % of the population (N = 79), roughly equivalent to that of the modern United States (N = 111). It would appear that the incidence of childhood illnesses in both populations was about equal. It should be noted that the U.S. population here reported grew up before antibiotics were used.

Incidence of vertebral arthritis in slight to moderate degree is fairly common in the Herculanean population. The male segment had a higher occurrence of 47.5 % (N = 53), while that of the female segment was 36.4 % (N = 44). Although almost all of the population was engaged in physical activity, a higher

TABLE 2. *Parameters of Health and Nutrition, Herculaneum, Roman Athens, Modern U.S.A.*

	Herculaneum				Athens[1]				U.S.A.[2]			
	female		male		female		male		female		male	
	$\bar{x}$	n	$\bar{x}$	n	$\bar{x}$	n	$\bar{x}$	n	$\bar{x}$	n	$\bar{x}$	n
Age at Death	—		—		33.3	4	37.0	2	78.5	census	71.0	census
Stature (cm)	155.2	43	169.1	51	155.88	4	163.2	2	163.4	68	174.2	92
Platymeric Index	83.1	43	81.9	48	85.7	4	79.4	2	85.7			159
Cnemic Index	71.8	38	69.5	45	69.0	4	66.0	2				
Pelvic Brim Index	89.5	35	82.9	43	90.7	2	85.8	2	92.1			113
Total Dental Lesions	3.9	35	3.6	44	2.7	3	4.4	2	17.0			170
Percentage Population Hypoplastic Lines	27 %	35	27 %	44	53.3 %	3	100.0 %	2	37 %			111
Percentage Population Vertebral Arthritis	36.4 %	44	47.5 %	53	25.0 %	4	50.0 %	2	67 %			138
Percentage Population Porotic Hyperostosis	40.9 %	45	28.3 %	53	33.3 %	3	0 %	2	8 %			163

[1] Bisel, 1980
[2] Bisel, Angel, 1985.
Statistics, other than age at death or stature, are combined gender.

proportion of males engaged in heavier work. The average of both sexes together is 42.5 %, much lower than the 67 % of modern Americans who experience any degree of vertebral arthritis. The American population here reported is much older than the Herculanean one; therefore, the U.S. figures reflect degenerative disease more than stress.

Signs of slight, but healed, anemia in the form of porotic hyperostosis are fairly common in the population. Mean incidence of both sexes together is 34.1 % (N = 98). Porotic hyperostosis can occur as a result of thalassemia, nutritional iron deficiency, hookworm, or a chronic debilitating disease (Angel, 1960). It is impossible to know which of the several possible etiologies is the main cause of the porotic hyperostosis.

Bone Mineral

Bone mineral analysis as reported in *Tables 3* and *4* does not give any unusual results for human bone mineral or for animal bone or soil controls. There is no sign of sex related difference. The calcium and phosphorus data are about what would be expected from ancient material: bone partly fossilized over time. Magnesium values at Herculaneum are not markedly different from the data from other sites. Mean of combined sexes for zinc (Zn/Ca) at Herculaneum is .314, or about half the value for the modern U.S. population. These data may be significant, suggesting that the diet of Herculaneum was somewhat lower in red meat than the modern U.S. diet and higher in the less refined cereal products. The phytates of unrefined cereal products can bind zinc (as well as iron) in the gut and allow it to pass from the body unmetabolized.

Means of strontium values for sexes combined for site-corrected Sr/Ca is .672, slightly higher than in many other ancient populations. The strontium data can be interpreted in two ways. Slightly higher values can indicate a higher reliance on vegetable-source protein, as opposed to terrestial animal source protein, or it can mean a higher reliance on seafish source protein as opposed to terrestial animal source protein. Herculanean values probably reflect both of these situations together (*Table 3*).

TABLE 3. *Human Bone Mineral of Herculaneum, Roman Athens, and Modern U.S.A.*

	Ca mg	P mg	Mg mg	Zn µg	Sr µg	Ca/P	Mg/Ca	Zn/Ca	Sr/Ca	Sr/Ca	Sr/Ca Cor Site
Herculaneum											
N = 46	x	317.38	196.79	2.57	98.06	91.54	1.66	.00808	.323	.285	.638
	S.D.	40.24	37.19	.39	19.18	25.61	.24	.00104	.113	.062	.142
N = 51	x	318.67	182.61	2.55	98.15	99.48	1.78	.00786	.305	.315	.702
	S.D.	30.08	33.04	.43	17.02	18.51	.27	.00176	.063	.053	.119
Athens											
N = 3	x	310.4	173.3	1.72	143.6	158.7	2.15	.0055	.465	.512	.844
	S.D.	30.3	20.6	.44	47.4	19.3	.10	.0012	.082	.044	.073
N = 2	x	286.0	130.5	2.55	135.8	92.8	1.79	.0072	.471	.310	.512
	S.D.	87.0	22.3	.43	24.6	53.6	.30	.0005	.002	.093	.153
U.S. Modern Both Sexes											
N = 40	x	220.4	102.5	2.81	147.1	—	2.15	.0127	.671	—	—
	S.D.	30.7		.33	49.8						

S. Bisel, 1980, from Janes et al., 1975 and Zipkin, 1970.

TABLE 4. *Soil and Animal Bone Mineral Means, Herculaneum*

	Ca mg	P mg	Mg mg	Zn µg	Sr µg	Ca/P	Mg/Ca	Zn/Ca	Sr/Ca
Soil N = 3	7.95	------	1.61	------	4.2	----			
Ovis/Capra	269.87	145.4	1.89	83.1	122.1	1.86	.00701	.308	.453
Bos N = 4	340.53	180.4	2.58	80.6	131.7	1.89	.00758	.237	.387
Sus N = 3	329.68	175.1	2.40	114.8	145.2	1.88	.00729	.348	.440

Food Remains at Herculaneum

The remnants of foodstuffs, either plant or animal, found at Herculaneum have not been studied scientifically. Personal communication with the excavators has permitted this author to make a list of items found. The quantities found cannot be determined, but they probably would not be a good indication of amounts actually used in any case. Animal bones include sheep, goat, cattle and pig. Fishing can be inferred from the equipment found. Since hen eggs were also found, chicken meat can also be assumed to have been used. Grains included both hard and soft wheat and barley. Loaves of bread were also found. Other vegetable foods include lentils and fava beans, carrot, walnuts, pine nuts, almonds, cyprus berries, figs, dates, pomegranates, grapes, garlic and onions. Olive oil and wine were available. Fish sauce was also found; this would have been used as an accompaniment for meals. Other foods undoubtedly were eaten and are attested to in contemporary literature, but these have not yet been found at this site.

Conclusions

The population at Herculaneum is mixed in both heredity and socio-economic class. Generalizations should be viewed with that thought in mind. Obviously, members of the upper class were better nourished and exercised for the fun of it. They are, in general, taller and other data are correspondingly better. Almost everyone of every class was well exercised, either from hard labor or from sport. The general standard of health was fairly high. Children had episodes of illness serious enough to interfere temporarily with calcium metabolism. As far as the diet is concerned, we can draw a few conclusions: enough protein and calories were available to achieve moderate growth, better than that of modern Neapolitans. Reliance on fish as a protein source would have given a high fluorine intake; this situation would also help account for the excellent quality of the teeth.

A diet high in vegetable protein and seafish would also be low in iron. This would account for the relative high incidence of slight anemias. Lower iron in the diet also increases incidence of infection (Weinberg, 1974). This would help account for the high occurrence of hypoplastic lines in the dental enamel. Both vegetable protein and shellfish are incomplete proteins. Beans and lentils are low in the amino acid, tryptophan, and either methionine or cystine; grain is low in lysine, shellfish are low in isoleucine and the sulfur-containing amino acids (Scrimschaw and Young, 1978). If several of these incomplete proteins are eaten together at the same meal, the quality of the protein consumed can be rendered complete. Otherwise, incomplete protein can be utilized only for energy. Other food like fish are complete protein, as are terrestrial animal meat, eggs and dairy products. Use of olive oil and unsaturated fat would have helped to keep cholesterol levels down, a fact which was probably not so important in this relatively young population. Olive oil would, however, have been an important source of energy. Fish and vegetable protein are low in fat and, therefore, relatively low in calories.

The population of Herculaneum offers us a unique opportunity to study health, nutrition, and social structure of a Roman period population. However, it would be unwise to generalize extensively about the entire Roman civilization based on the data generated by the study of this population, and a statistically insignificant Roman period population of Athens. Other populations of this period have not yet been studied. New studies undertaken of this and other cultures may change our understanding of the Roman era.

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