ARTICLES

Skeletal Health in the Western Hemisphere From 4000 B.C. to the Present

RICHARD H. STECKEL, JEROME C. ROSE, CLARK SPENCER LARSEN, AND PHILLIP L. WALKER

There has been long-standing interest in the history of human health and well-being over the millennia. The major sources of information are written accounts of life in the past, such as wills, diaries, tax records, military records, and court documents. These sources, however, may be inaccurate and are susceptible to distortion by selective reporting and biases in the cultural perspectives and objectives of both writers and users. Data on variation in the heights of people who lived over the last several centuries have recently become available for several populations and provide a less subjective source of information on the history of health (for a review see Steckel[1]). Although valuable, these records are mostly for males living in now-industrialized nations such as Sweden, the United Kingdom, and the United States; they certainly do not provide a comprehensive picture of the history of health across continents or regions. Moreover, height measures only one dimension of health during the years of human growth and development. It does not provide an overall measure of health status throughout the life cycle.

[1]Beginning in the late 1980s, researchers in various fields, especially history, economics, and physical anthropology, discovered a mutual interest in health and its spatial and temporal patterning in human history. Economic historians have been keenly interested in health in recent years, basing their assessments on heights, primarily those of adult men as learned from military muster rolls. Physical anthropologists have studied numerous skeletal remains that can be used to reconstruct living heights from long-bone lengths. They have also documented patterns of health based on various paleopathological indicators.

A key development in the study of health in the distant past occurred with the publication of *Paleopathology at the Origins of Agriculture,* edited by Mark Cohen and George Armelagos.[2] Cohen[3] had argued in *The Food Crisis in Prehistory* that the population increases prior to the Neolithic set the stage for nutritional deficiencies that stimulated the development of agriculture. If this were the case, the evidence for nutritional deficiencies would have occurred before the Neolithic, and this crisis would have been the motivation to shift to primary food production. *Paleopathology at the Origins of Agriculture* compiled paleopathological studies by various researchers from around the world, addressing long-term trends in health, especially the impact of the shift from foraging to farming. These studies showed a generally consistent pattern of increasing morbidity wherever and whenever the transition took place. The book was limited, however, in that contributors used different data coding schemes, which calls into question the comparability of results. Despite this caveat, the contributors' effort confirmed the result of a handful of previously reported regional studies of populations from North America, northeastern Africa, and the eastern Mediterranean, that the agricultural transition beginning in the early Holocene was accompanied by a cost to human health and quality of life.

Richard H. Steckel is Professor of Economics and Anthropology at The Ohio State University, Columbus. With Jerome Rose, he co-directs the History of Health in the Western Hemisphere Project, some of the results of which are presented in this article.

Jerome C. Rose is Professor of Anthropology at the University of Arkansas, Fayetteville. In addition to his work on the Western Hemisphere project, he is currently directing bioarcheological projects in Egypt and Jordan.

Clark Spencer Larsen is Distinguished Professor of Social and Behavioral Sciences and Chair of the Department of Anthropology at The Ohio State University. He has been involved in bioarcheological research throughout North America and Europe.

Phillip L. Walker is Professor of Anthropology at the University of California, Santa Barbara. He has conducted bioarcheological research in California, Russia, and Spain. He is currently excavating a Viking site in Iceland.

Correspondence to: Richard H. Steckel, Department of Economics, The Ohio State University, Columbus, OH 43210; steckel.1@osu.edu.

Evolutionary Anthropology 11:142–155 (2002)
DOI 10.1002/evan.10030
Published online in Wiley InterScience
(www.interscience.wiley.com).

THE BACKBONE OF HISTORY

In the late 1980s, Richard Steckel and Jerome Rose organized a large group of economic and medical historians, demographers, and physical anthropologists in order to document and analyze the history of health in the Western Hemisphere using data from archeological skeletons.[4] In or-

TABLE 1. Distribution of Skeletons in the Database

	Native American				
Period	North America	Middle America	South America	Euro-American	Afro-American
1750+	627	0	0	1201	1380
1500–1749	2580	0	39	113	0
1000–1499	888	236	1095	0	0
1AD–999	1642	594	382	0	0
1000BC–0AD	250	0	247	0	0
Before 1000BC	485	343	418	0	0
Total	6472	1173	2181	1314	1380

Grand total = 12,520.

ganizing the project, they selected participants who had collected comparable data on skeletal collections. Importantly, each team of participants recorded or rescored their data (where necessary) using identical standards.

Each research team compiled individual data from archeological skeletons found in North, Central, and South America. The combined dataset includes 12,520 skeletons from 218 archeological sites representing populations who lived in the Western Hemisphere from about 4,000 B.C. to the early twentieth century. Basic information on the geographic, ethnic, and temporal distribution of the skeletons in the project database is listed in Table 1. Nearly 80% of the 12,520 individuals were Native Americans, with the remainder almost evenly split between Euro-Americans and Afro-Americans. Even with the preponderance of Native Americans in the sample, this is the first serious comparative study with Euro-American populations.

About two-thirds of the Native Americans resided in what is now the United States (noted as North America in the table and in parts of the text), as opposed to 11.9% in Middle America and 22% in South America. Slightly more than one-half (52.6%) lived in the Western Hemisphere before the arrival of Columbus and nearly 14% lived before the birth of Christ. The results of this study are reported in greater detail in Steckel and Rose,[4] *The Backbone of History: Health and Nutrition in the Western Hemisphere*.

A HEALTH INDEX

The research summary begins with the premise that health has two components: length of life and health quality of life. It would be ideal to have abundant information on each for a wide variety of sites that have been occupied over the past several millennia. The project we summarize does report some estimates of life expectancy for many sites,[5] but they are heavily qualified or limited by lack of systematic information on likely population growth rates. Instead, we emphasize the second aspect, quality of life, which we argue is tied to age-specific rates of many types of skeletal lesions that are incorporated into what is called a health index. The conceptual basis of the health index is sufficiently broad to incorporate length of life as well. We trust that readers will not be confused by what we loosely term "health" when referring to skeletal lesions and the health index as estimated and discussed in this essay. In addressing the "osteological paradox," some use is made of the available estimates of life expectancy.

TABLE 2. Values of Health Index and Components for Major Groups Who Lived in the Western Hemisphere

Group	Statistic	Index	Stature	Hyp.[a]	Anemia[b]	Dental	Inf.[c]	DJD	Trauma
Euro-Americans	Average (*N* = 9 sites)	71.4	26.6	79.3	96.6	72.0	81.7	76.6	66.8
	Standard Deviation	2.9	12.5	19.6	2.1	5.2	14.3	14.6	30.4
African-Americans	Average (*N* = 5 sites)	67.1	40.9	42.4	87.1	76.9	55.9	77.6	89.2
	Standard Deviation	5.7	23.6	21.1	17.4	7.9	14.7	6.6	8.6
Native Central Americans	Average (*N* = 8 sites)	64.0	13.4	52.8	80.6	81.7	51.8	75.1	92.3
	Standard Deviation	3.8	9.8	24.8	7.6	7.0	6.0	6.3	3.8
Native South Americans	Average (*N* = 15 sites)	75.1	3.6	82.9	92.9	84.4	82.8	78.4	89.7
	Standard Deviation	9.0	2.8	17.0	6.7	11.7	13.3	14.4	10.8
Native North Americans (East)	Average (*N* = 10)	78.1	32.2	86.7	94.7	81.7	81.6	82.4	90.6
	Standard Deviation	5.6	14.1	8.8	3.6	15.3	12.9	9.9	5.9
Native North Americans (West)	Average (*N* = 18)	73.7	21.3	66.1	83.8	85.5	80.7	80.4	85.2
	Standard Deviation	8.3	15.1	24.5	16.6	6.4	12.8	14.1	11.8
	Average, 65 sites	72.6	20.7	71.1	90.5	81.8	75.1	78.9	85.7
	Standard Deviation, 65 sites	8.0	16.9	24.6	11.5	10.4	17.0	12.3	16.1
	Minimum, 65 sites	53.5	0.4	9.8	53.2	55.3	44.1	41.6	10.8
	Maximum, 65 sites	91.8	67.8	99.7	100.0	100.0	98.7	100.0	100.0

[a] Linear enamel defects.
[b] Porotic hyperostosis and cribra orbitalia.
[c] Osteoperiostitis.

In order to compare health across sites, Steckel, Rose, and Sciulli[6] first combined the data from 218 archeological sites into 65 groups based on their chronological and ecological similarity, which was necessary to obtain samples large enough for meaningful population comparisons. Next, they devised a health index reflecting quality of life as measured by the absence of skeletal lesions or other signs of biological stress. Ideally, such an index would also incorporate the average length of life. However, reliable information was not available on this variable for most sites, although future work will endeavor to obtain more information. The index approach was originally inspired by the work of medical examiners and physicians who granted pensions to American Civil War veterans in the late nineteenth century based on the veterans' degrees of disability.[7] The method used here involves a multiattribute system first developed in the 1970s to assess health aspects of the quality of life.[8]

For this research, one aspect of health status (health aspects of quality of life as opposed to length of life) was determined from the scores on seven skeletal attributes of health: stature inferred from long-bone lengths; signs of disrupted dental development (linear enamel hypoplasias); signs of anemia (porotic hyperostosis and cribra orbitalia); dental pathology (caries, antemortem tooth loss, abscesses); lesions associated with skeletal infections; degenerative joint disease; and trauma (fractures and weapon wounds). All measures have been discussed in greater detail by Goodman and Martin.[9]

Heights inferred from long-bone lengths. Modern height studies establish that two periods of intense activity characterize the growth process following birth.[10] Figure 1 shows that the increase in height, or velocity, is greatest during infancy, falls sharply, and then declines irregularly into the pre-adolescent years. During adolescence, velocity rises sharply to a peak that equals nearly one-half of the velocity during infancy, then declines rapidly and reaches zero at maturity. The adolescent growth spurt begins about two years earlier in girls than in boys. During their spurt, girls temporarily overtake boys in average height. As adults, males are taller than females primarily because they have approximately two additional years of growth before adolescence. Various forms of biological stress will depress growth rates and even lower them to zero if the stress is severe. If good times return, the deficit in height for a given age may be closed through catch-up growth, during which growth velocity temporarily exceeds that attained under ideal conditions. However, prolonged and severe biological stress results in stunting.

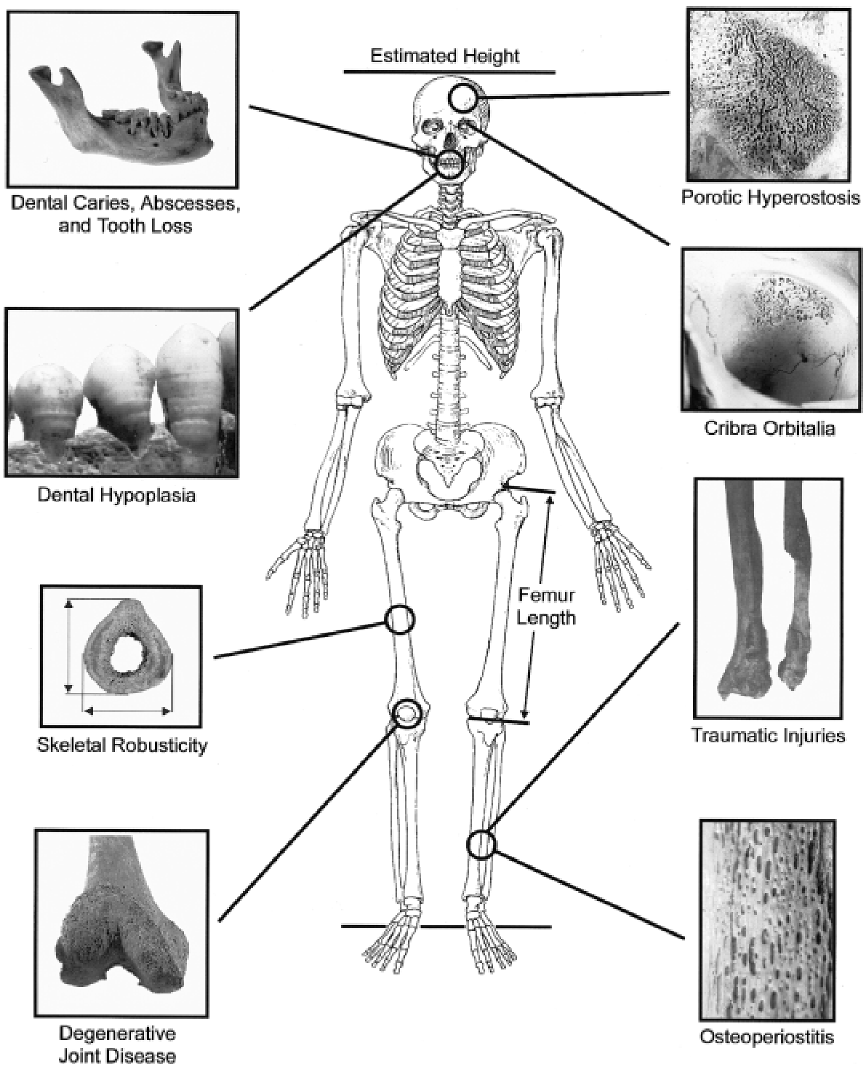
The project we summarize does report some estimates of life expectancy for many sites, but they are heavily qualified or limited by lack of systematic information on likely population growth rates. Instead, we emphasize the second aspect, quality of life, which we argue is tied to age-specific rates of many types of skeletal lesions that are incorporated into what is called a health index.

Height at a particular age reflects an individual's history of net nutrition, or diet minus claims on the diet made by work or physical activity and disease. Metabolic requirements for basic functions such as breathing and blood circulation while at rest also make claims on the diet. The synergy between malnutrition and illness may further reduce the nutrition left over for growth. Poorly nourished children are more susceptible to infection, which reduces the body's absorption of nutrients. The interaction implies that analyses of stature must recognize not only inputs to health such as diet and medical care, but also work effort and related phenomena such as methods of labor organization. Similarly, it is important to realize that exposure to infectious disease may make claims on the diet. An alternative view of stature is the "small but healthy" paradigm emphasized by Sukhatme,[11] in which it is claimed that many individuals adapt to nutritional deprivation with low costs. Dasgupta[12] critiqued this view, emphasizing the high biological cost of deprivation in the form of mortality, morbidity and impaired work performance. In essence, some individuals can survive biological deprivation to live apparently healthy lives, but many cannot.

Although genes are important determinants of individual height, studies of genetically similar and dissimilar populations under various environmental conditions suggest that differences in average height across most populations are largely attributable to environmental factors. In a review of studies covering populations in Europe, New Guinea, and Mexico, Malcolm[13] concluded that differences in average height between populations are almost entirely the product of the environment. Using data from well-nourished populations in several developed and developing countries, Martorell and Habicht[14] reported that children from Europe or of European descent, from Africa or of African descent, and from India or the Middle East have similar growth profiles. Far Eastern children or adults are an exception that may have a genetic basis. About two decades ago, well-off Japanese, for example, reached the fifteenth height percentile of the well-off in Britain.[15] But large height gains have occurred in Japan in the past three decades, suggesting that the portion of the height differential that can be attributed to genetic influences is shrinking and has nearly vanished.

Figure 2 shows the connection between average height and life expectancy in countries for which national height studies and life expectancy are available. The countries are Czechoslovakia, West Germany, the Nether-

Box 1. A Health Index



- A multiple-attribute measure of health
  - The attributes are stature; signs of iron-deficiency anemia; enamel hypoplasias; dental health; degenerative joint disease; trauma; and skeletal infections.
- The index is an additive measure, ignoring the effects of interactions among attributes on functional capacity.
- Attributes are scored for individuals by severity on a scale of 0 (worst) to 100% (best).
- Scores for each attribute are converted to age-specific rates in six age categories: 0–4; 5–14; 15–24; 25–34; 35–44; and 45+.
- Age-specific attribute scores are multiplied by the relative number (proportion) of person-years lived within each age group in a synthetic population (Model West level 4, with life expectancy of 26.4 years and growth rate of 0).
- The sum is multiplied by 26.4 years and expressed as a percent of the maximum attainable, which is 26.4.
- The results for each attribute are averaged (weighted equally) in the overall index.
- The current version incorporates pathological lesions only.
- Length of life could be added in a modified version.

lands, New Zealand, the United States, Japan, South Korea, Egypt, India, Belgium, Denmark, Hungary, Italy, Argentina, and Australia (three countries have two height studies conducted at different dates). The figure shows a relationship for boys aged 12 that is approximately linear, in which average height increases by approximately 0.6 centimeters for every year of gain in life expectancy (LE) at birth. (A similar relationship applies to girls). The estimated regression equation is (t-values are in parentheses):

$$\text{Height} = \underset{(21.53)}{106.57} + \underset{(8.09)}{0.601}\,(\text{LE})$$

$$N = 18,\ R^2 = 0.80$$

In addition to the modern record, anthropometric evidence derived from historical sources indicates a close link between height and economic well-being.[1,16–18] We use formulae for estimated living height from archeological skeletons.[19,20]

Although nonspecific, enamel hypoplasias are informative about physiological stress in childhood in archeological settings.

Enamel hypoplasias (linear enamel defects). Hypoplasias are lines or pits of enamel deficiency commonly found in the teeth, especially incisors and canines, of people whose childhood was biologically stressful. These hypoplasias are caused by disruption of the cells (ameloblasts) that form the enamel. The disruption is usually environmental, commonly occurring as a result of poor nutrition or infectious disease or a combination of both. Although nonspecific, enamel hypoplasias are informative about physiological stress in childhood in archeological settings.[21,22]

Indicators of iron deficiency anemia (porotic hyperostosis and cribra orbitalia). Iron is essential for many body functions, such as oxygen transport to the body's tissues. When iron is defi-

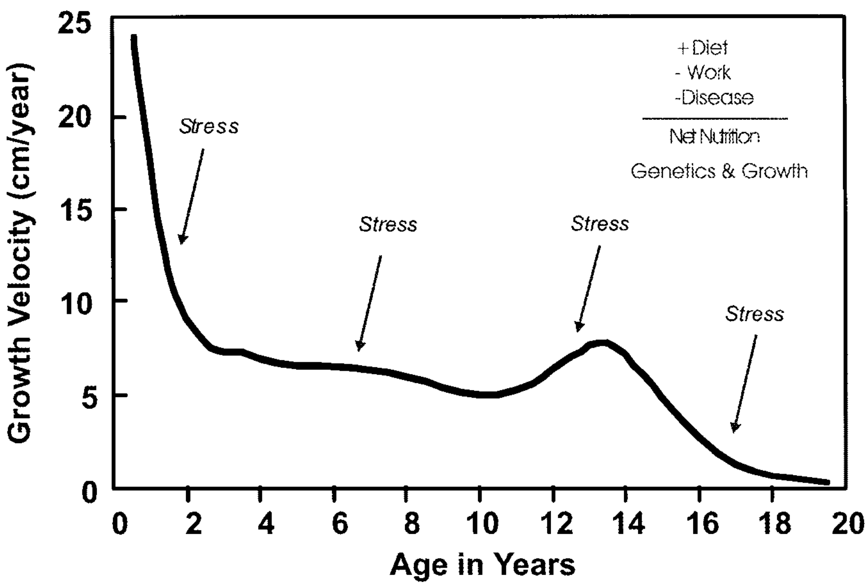


Figure 1. Growth velocity of boys under good environmental conditions.

cient, whether as a result of nutritional deprivation, low body weight, chronic diarrhea, parasite infection, or other factors, the body attempts to compensate by increasing production of red blood cells.[23] The skeletal manifestations appear in areas where red blood cell production occurs, such as in the flat bones of the cranium. The associated pathological conditions are sieve-like lesions. In the cranial vault, these lesions are called porotic hyperostosis; in the eye orbits, they are called cribra orbitalia.[24] The lesions can be caused by other factors,[25] but iron deficiency is among the most common causes. In infancy and childhood, iron-deficiency anemia is associated with impaired growth and delays in behavioral and cognitive development.[26–28] In adulthood, the condition is associated with limited work capacity and physical activity.[29]

Dental health. This is an important indicator both of oral and general health. Dental health in archeological skeletons is assessed from dental caries, antemortem tooth loss, and abscesses.[30,31] Dental caries is a disease process characterized by the focal demineralization of dental hard tissues by organic acids produced by bacterial fermentation of dietary carbohydrates, especially sugars. In the modern era, the introduction and general availability of refined sugar has caused a huge increase in dental decay.[32] In the more distant past, the adoption of agriculture led to a general increase in tooth decay, especially from the introduction of maize.[33,34] The agricultural shift and the later use of increasingly refined foods have resulted in an increase in periodontal disease, caries, tooth loss, and abscesses.[34]

Skeletal infections (osteoperiostitis). Skeletal lesions of infectious origin, which commonly appear on the major long bones, especially the tibia, have been documented worldwide. Most of these lesions are found as plaque-like deposits from periosteal inflammation, swollen shafts, and irregular elevations on bone surfaces.[31] Most lesions are nonspecific but they often originate with *Staphylococcus* or *Streptococcus* organisms. These lesions have proven very informative about patterns and levels of community health in the human past.[30]

Degenerative joint disease. This is commonly caused by mechanical wear and tear on the joints of the skeleton due to physical activity.[35] Generally speaking, populations engaged in habitual activities that are physically demanding have more degenerative joint disease, especially build-up of bone along joint margins and deterioration of bone on articular joint surfaces, than do populations that are relatively sedentary. Studies of degenerative joint disease have been valuable in documenting levels and patterns of activity in past populations.[30]

Trauma. Fractures, weapon wounds, and other skeletal injuries provide a record of accidents or violence. Accidental injuries, such as ankle and wrist fractures, reflect the difficulty of terrain and the hazards of specific occupations. Injuries caused by violence, such as weapon wounds or parry fractures of the forearm, provide a barometer of domestic strife, social unrest, and warfare.[36–38]

In addition to these skeletal indicators of health, skeletal robusticity was assessed by measurements of the size

Figure 2. Life expectancy at birth and height of boys at the age of 12 years. Calculated form data in Eveleth and Tanner[10] and World Development Report.[63]

of diaphyseal cross-sections, including circumference and anterior-posterior and medial-lateral dimensions. Skeletal robusticity, which refers to the general size and morphology of skeletal elements, is an important indicator of patterns of habitual activity.[39,40] It is well known that bones are highly sensitive to mechanical stimuli, especially with regard to the ability of bones to adjust their size and shape in response to external forces. For example, foragers tend to be highly mobile, leading to elongated or oval femoral midshaft cross-sections, whereas farmers are more sedentary and have circular cross-sections.[39] These and other morphological differences reveal much about patterns of physical activity and behavioral change over time.[30,41,42]

The scores for the attributes were converted into a single index number for each site. The health index is defined as the sum of the quality-adjusted life years in which mortality experience is defined by a Model West level 4 life table (life expectancy at birth of 26.4 years), which roughly approximates the life expectancies of the premodern populations under study. Model life tables summarize mortality patterns commonly found in various parts of the world.[43]

Details of the health index are as follows:

(1) Each attribute is scored at the individual level.

(2) The seven attributes are equally weighted and added together in the index, which may be difficult to justify but does serve the interest of simplicity. On the basis of available evidence, however, it is also difficult to justify an alternative set of weights or a pattern of interactions as they affect functional capacity. Clearly, more research in needed on the functional implications of the attributes and their interrelations.

(3) Each attribute is scored on a scale from 0 to 100%, with 0 representing the worst possible health and 100 representing the best health, or at least the absence of lesions or signs of biological stress. The scoring of attributes is either continuous or discrete. For example, stature is scored continuously, but hypoplasias are assigned one of three categories: none (100%); intermediate, or 1 hypoplasia (50%); severe, or 2+ hypoplasias (0%). Two, four, and five categories are scored for degenerative joint disease, depending on the joint being scored (e.g., four: 100, 67, 33, and 0).

(4) If a person showed the most severe deficiency for each of the seven attributes, but lived through a particular year, that person receives a quality score of 0 for that year of age. At the other extreme, a person who had perfect scores for each attribute receives a quality score of 100.

(5) Stature for an individual, determined by maximum femoral length, is scored as 100% if they reached (or exceeded) the modern standard, defined by the Maresh[44] reference population (Denver, Colorado). Individuals who fall below the third standard deviation receive a 0. Intermediate values are linearly prorated according to the Maresh standards.

. . . the calculation of the health index has three key characteristics: it is multi-attribute, it grades lesions or skeletal deficiencies by severity, and it is adjusted for the distribution of ages found at sites. Some of the assumptions underlying the index are obvious simplifications. Refinements await additional research.

(6) Dental health has two parts: antemortem both loss and various teeth (weighted 75% of this component); and abscesses (weighted 25%). The first component is defined by one minus the ratio of the sum of premortem loss and cavities to the sum of teeth and premortem loss. The sum of teeth and premortem loss must be eight or more; otherwise data in this category are deemed incomplete and are not used. Abscesses are scored in three categories: none, moderate, and severe (two or more).

(7) Degenerative joint disease is determined by the lowest score for the major joint groups (shoulder/elbow, hip/knee, cervical, thoracic, lumbar, temporomandibular).

(8) Trauma (mostly fractures) for the major elements is scored as 100% if completely absent from a skeleton and 0% if any element shows trauma (for example, a fracture or cut mark).

(9) Attributes formed in childhood—stature, porotic hyperostosis or cribra orbitalia, and hypoplasia—have functional consequences for the entire life of the individual. Hence, the scores observed at death are assumed to have persisted from birth.

(10) The length of time that an individual had a particular chronic condition and its associated pathology seen at the time of death is difficult to determine. As a working number, the current version of the index (Mark I) uses 10 years for the length of time before death that a person had indications of poor dental health (caries, tooth loss, abscesses), infections, degenerative joint disease, and trauma. More realistic assumptions could be incorporated into the health index based on additional research;

(11) Dental health attributes (antemortem tooth loss, caries, abscesses) and degenerative joint disease are considered to be adult conditions, absent before age 18.

(12) Health has two important dimensions: length of life and health quality of life. In its present form, the health index reflects only the incidence of skeletal lesions, which reflect the health quality of life, and ignores length of life. The latter could be readily incorporated into the index if reasonably reliable information on life expectancy was available for the sites under study.

QUALIFICATIONS

In summary, the calculation of the health index has three key characteristics: it is multi-attribute, it grades lesions or skeletal deficiencies by severity, and it is adjusted for the distribution of ages found at sites. Some of the assumptions underlying the index are obvious simplifications. Refinements await additional research.

Thus, Steckel, Rose and Sciulli[6] refer to the current version of the index as Mark I. It is hoped that additional research will justify the creation of more realistic and refined versions.

The interpretation of the index is straightforward: A perfect index is one in which no defects or deficiencies are observable. This score, called the maximum quality adjusted life years for a site, is 100% times the life expectancy at birth for a Model West level 4 life table, or 26.4 years. This value corresponds to a complete lack of pathological lesions for a group of skeletons from a site or an aggregation of related sites. The further the departure of a site from the score of 26.4, the greater the number of lesions and the lower the index. Perhaps a more comparative way of presenting the health index information is as a percent of the maximum (26.4). The greater this value, the better the quality of life for a population. Sites with low average percents (low health indexes) led lives of greater pain and greater limitations on their capacity for work and enjoyment of life.

The index is obviously limited in focusing on chronic conditions that are measurable on skeletons. But acute infectious diseases that leave no traces on the skeleton usually pass quickly, having little impact on the average quality measured over the typical length of life. One may debate whether the health attributes should be weighted equally, but without additional research on the functional implications of the scores it is difficult to justify an alternative weighting system.

Another potential limitation to this kind of study, with its analysis of health across spatial and temporal aggregates of samples, is what Wood and colleagues[45] have called the osteological paradox. They argue that for a population to show evidence of disease, the affected individuals must be healthy enough to survive. Thus, only relatively healthy (long-lived) populations would exhibit osteological evidence. In this view, bony lesions are evidence of survival. We acknowledge that the documentation and interpretation of health levels using archeological human remains are not always straightforward. That is, temporal changes in the frequency of lesions associated with infection or growth disruption are not always a reliable indicator of change in community health, broadly defined. While the health index adjusts for the age distribution of deaths by converting the prevalence of lesions into age-specific rates, we are well aware of the notion that sudden declines in health might not register on bones simply because the observable lesions take time to accumulate. Hence, it is important to involve multiple health indicators and to consider several lines of evidence that inform the understanding of health in a particular setting, such as subsistence and settlement patterns, environmental context, culture, and population structure. *The Backbone of History* looks explicitly for consistency of patterns and specific exceptions that may represent the appearance of the osteological paradox.

While the health index adjusts for the age distribution of deaths by converting the prevalence of lesions into age-specific rates, we are well aware of the notion that sudden declines in health might not register on bones simply because the observable lesions take time to accumulate. Hence, it is important to involve multiple health indicators and to consider several lines of evidence that inform the understanding of health in a particular setting . . .

One site used in the study clearly illustrates an osteological paradox in that health conditions depicted by the skeletons diverge sharply from information available from historical records. Socio-economic conditions were remarkably different at the poorhouse in Rochester, New York, and among the middle-class Episcopalians of Belleville, Ontario, during the mid-nineteenth century.[46,47] Yet the poorhouse skeletons had fewer lesions or signs of biological stress. The most plausible explanation is that conditions were so bad at the poorhouse that most individuals died quickly, before lesions could accumulate. Moreover, it seems clear that most of those who died in the poorhouse had reasonably healthy childhoods; otherwise they would have scored low on the childhood indicators (stature, signs of anemia, and enamel deficiencies). It seems that some type of economic or social trauma, perhaps related to job loss, death of a spouse, alcoholism, or other traumatic circumstances, drove many of them to their fates.

Could this type of paradox permeate the entire study, widely invalidating health comparisons? This is doubtful because mortality rates must be extraordinarily high (they were nearly 20% per year at the poorhouse) for very stressed populations to die before lesions accumulate, probably far higher than the plausible biological upper limits to the annual birth rate (about 6%). Therefore, the paradoxes are likely to have been limited to exceptional circumstances involving sudden and traumatic reversals of fortunes, which can lead to a misreading of the overall state of health if little contextual information is available. The skeletons found at Pompeii, for example, present another example in which bones mislead: Life expectancy just before the volcanic eruption was very short, but the frequency of lesions would not reveal that death was imminent.

The experience of the Western Hemisphere project suggests that the paradox does not confound the interpretation of health at most sites. It is possible to test the hypothesis of the osteological paradox by comparing the health index to estimates of life expectancy. If the paradox was true, then longer life should have been negatively correlated with skeletal health

TABLE 3. Correlation Matrix of the Health Index and Its Components

	Index	Stature	Hyp.[a]	Anemia[b]	Dental	Inf.[c]	DJD	Trauma
Index	1.000							
Stature	0.304	1.000						
Hypoplasias	0.662	−0.111	1.000					
Anemia	0.668	0.300	0.555	1.000				
Dental	0.412	−0.078	−0.013	0.087	1.000			
Infections	0.461	−0.117	0.471	0.277	0.024	1.000		
DJD	0.664	0.133	0.331	0.438	0.323	0.185	1.000	
Trauma	0.132	−0.202	−0.187	−0.149	0.304	−0.288	−0.033	1.000

[a] Linear enamel defects.
[b] Porotic hyperostosis and cribra orbitalia.
[c] Osteoperiostitis.
Source: Calculated from Table 3.

as represented by the health index. Only crude estimates of life expectancy have been tabulated for 50 sites.[5] These are based on informed guesses of annual population growth rates. A regression of the health index has a slope coefficient for life expectancy of 0.37 ($F(1, 48) = 7.92$; $p = 0.007$), which means that for every year of increase in estimated life expectancy, the health index increased by 0.37 points. The information at hand rejects the hypothesis that the osteological paradox was a general phenomenon. Nevertheless, it can be substantial at particular sites and quite possibly can exist to some degree at others. One must be alert for deceptions (or paradoxes) caused by highly stressful conditions that are obscured by lack of related evidence. Therefore it is essential to interpret skeletons within their context.[48]

The correlation between the health index and life expectancy is modest (0.35), in part because the current version of the health index no doubt misrepresents some of the actual functional consequences of person-years lived with various chronic conditions that impinged on life expectancy. This, of course, contributes to measurement error and reduces the correlation between the health index and life expectancy. Among these limitations of the index is the practice of equally weighting the various attributes and the assumptions made about person-years lived with various lesions before death. Importantly, most of the estimated life expectancies are based on "guesstimates" of population growth rates. To the extent that the guesses are in error, the estimated length of life will be incorrect and the share of the variation explained correspondingly reduced. These problems can be addressed by expanding the sample sizes, improving the health index, and obtaining more contextual information that sheds light on population growth rates.

Euro-American children had above-average attribute scores for stature, hypoplasias, and porotic hyperostosis or cribra orbitalia. At the same time, this group had the worst dental health and the most traumatic injury of any group. African-Americans were the tallest, but had the highest level of hypoplasias and cribra orbitalia and were generally below average in the entire study.

SOME RESULTS

As will be discussed in the remainder of this article, the Western Hemisphere study identified interesting patterns of temporal variation in health that encompassed many different climates, plant and animal communities, cultures, and ways of life. There are some intriguing general tendencies that emerge in this analysis. Note the considerable variation across sites for all attributes, including the extraordinary range of 9.8 to 99.7 for enamel hypoplasias. The average values for the health index ranged from 64.0 for Native Central Americans to 78.1 for Native North Americans from the Eastern Woodlands.[49–51] As measured by the index, the examples of very good health in the 65 samples were for coastal Brazil, coastal Ecuador, and coastal Georgia, while the worst health was found at Hawikku, New Mexico, and among plantation slaves of South Carolina.[52–56] Some of the best and worst health conditions were found in pre-Columbian Native American communities.

The correlations between the scores on the health attributes are generally low (see Table 3), so diverse outcomes are expected when combining the various indicators into a health index for groups. For example, Euro-American children had above-average attribute scores for stature, hypoplasias, and porotic hyperostosis or cribra orbitalia. At the same time, this group had the worst dental health and the most traumatic injury of any group. African-Americans were the tallest, but had the highest level of hypoplasias and cribra orbitalia and were generally below average in the entire study. The latter almost certainly reflects the tough living circumstances of most of the African-Americans in a general state of impoverishment, regardless of whether they derived from enslaved or other groups.

The Native Central Americans had very low attribute scores for porotic

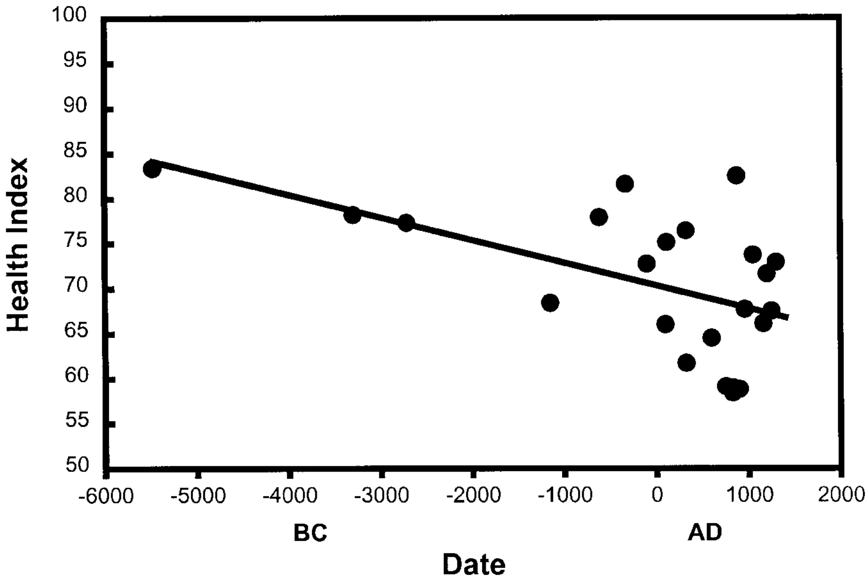


Figure 3. Time trend in pre-Columbian skeletal health. Deterioration in the health index is indicated by the downward trend of the linear regression line associated with these points (R^2 = 0.53; p ≤ 0.05. From Steckel and Rose.[4] The index decline by an average of 2.5 points per millenium.

hyperostosis and cribra orbitalia, infection, and degenerative joint disease. These patterns are consistent with the generally high morbidity reported by researchers who have worked with skeletal series from Central America (for example, collections from Teotihuacan and Mayan sites such as Altar de Sacrificios). Interestingly, Native North Americans from the West (for example, California) had the highest scores for dental health.[57] This reflects the low cariogenic diets of at least some of these populations, particularly those groups not engaged in maize agriculture.

Some fascinating temporal trends emerge from the analysis. Figure 3 shows a scatter diagram of 23 pre-Columbian (pre-1492) sites where all attributes could be reported by the different research teams. The downward trend is quite obvious, and is statistically significant by linear regression analysis ($R^2 = 0.53$; $p \leq 0.05$). The trend is consistent with the aforementioned results of the Cohen and Armelagos[2] compendium of studies, as well as most of the record presented by bioarcheologists and paleopathologists since their book was published more than 15 years ago.[34] Regrettably, few sites are concentrated in the early pre-Columbian period, which complicates the interpretation of the time trend. There are only three data points before approximately 1000 BC. The chronological concentration therefore makes it important to consider possible environmental changes that contributed to the trend.

The key question that this discussion raises is why did health decline? In order to tease apart the potential contributors to decline in health, Steckel and Rose[58] performed a sequence of regression analyses that examined the statistical connection between health and various ecological categories, such as terrain, climate, vegetation, and settlement. This analysis revealed that climate, as readily measurable in categories of tropical, subtropical, and temperate, bore no relevance to the health index. This result was unanticipated and will be studied again using more refined measures of climate.

On the other hand, most other ecological variables appear to have some relevance. One of the most important to emerge is size of the resident community (Fig. 4). Groups living in paramount towns or urban settings had a health index nearly 15 points (two standard deviations) below that expressed for mobile hunter-gatherers and others not living in large, permanent communities. Clearly, something about living in a large community is deleterious to health. And, of course, there is abundant information regarding the health hazards posed by the unsanitary conditions people faced in large premodern communities. Such environments are conducive to the spread of infectious disease and other maladies. Moreover, these larger communities are fueled by an agricultural economy.

Diet was also closely related to change in the health index, with performance being nearly 12 points lower under the triad of corn, beans, and squash than with the more diverse diet of hunter-gatherer groups (Fig. 5). Because the transition to settled agriculture usually occurred with the rise of large communities, it is difficult to obtain precise measures of their separate effects on health.

Among the other environmental conditions that systematically affected health as measured by the health index was elevation (Fig. 6).

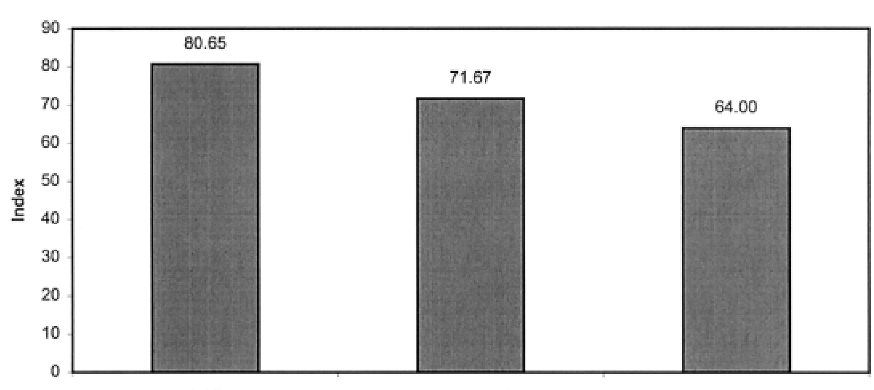


Figure 4. Health index and settlement pattern.

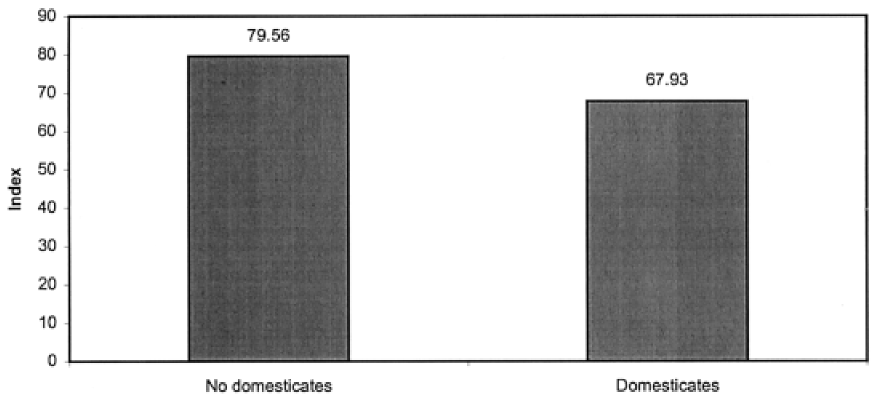


Figure 5. Health index and plants.

People who lived above 300 meters scored about 15 points lower in the index. The exact mechanism for this relationship is unknown, but it is likely that a richer array of foods was available, with less work effort, at lower elevations.

Vegetation surrounding any given site may have affected health via the type and availability of resources it offered for food and shelter. Forests for example, provided materials for food, fuel, and housing, and also sheltered animals that could have been used for food. Semi-deserts posed greater challenges for the food supply than did lush forests or grasslands, but the dry climate might have inhibited the transmission of some diseases. Figure 7 shows that the net effect of these forces favored forests and semi-deserts as opposed to open forests and grasslands, where the health index was about 9 points lower.

Flood-plain or coastal living provided easy access to aquatic sources of food and enabled trade compared with more remote, interior areas, but trade may have promoted the spread of disease. Uneven terrain found in hilly or mountainous areas may have provided advantages for defense, but could have led to more accidents and fractures. Apparently the net benefit to health favored coastal areas, where the health index was about 8 points higher than in noncoastal regions (Fig. 8).

The data in Table 4 point to environmental explanations for the decline in pre-Columbian health. Figures 4 through 8 measured the deleterious effects on health of living at high elevations, in noncoastal areas, under a regime of domesticated agriculture, in open-forest and grassland regions, and in large settlements. Breaking the sample into two chronological periods, before and after 1500 years before the present, we observe in Table 4 that people increasingly lived in less healthy ecological environments. We do not yet know why this may have happened, but one possibility is that population growth directed settlement into less desirable areas where greater work effort was required to provide food. Another possibility is that over time more complex, hierarchical societies emerged, leading to greater biological inequality. Both possible explanations will be considered in future research.

The availability of hemisphere-wide data on the health of earlier human populations opens up many exciting new possibilities for studying the ecological correlates of disease patterns. It is clear that a complete explanation of any group's health status can only be obtained through a detailed site-specific analysis of local cultural practices and living conditions. Nevertheless, a surprising amount of variability in the health index can be accounted for by a few key ecological variables with far-reaching health-related consequences. For example, there is a relationship between health status and local environmental variables available from the Geographic Information Systems, which contains site-specific ecological information from satellite telemetry and other sources. Among the variables are measures of topographical relief, vegetation pattern, and seasonal variation in local primary productivity. Multiple regression analysis reveals interesting correlations between environmental variables and health status. About 40% of the variation in the health index can be accounted for by a model that includes the following variables: elevation, cultigen use, and measures of seasonal variation in green-leaf biomass. In particular, populations living in deserts and areas of high green-leaf biomass had the lowest health-index values. These are populations who depend on agriculture and whose living conditions expose them to a diversity of disease-causing microorganisms. In another analysis, statistically significant correlations were found between the presence of both cribra orbitalia and porotic hyperostosis, skeletal lesions traditionally associated with childhood anemia, and environmental variables including altitude, the Normalized Differential Vegetation Index (a measure of primary productivity), and topographical relief (maximum slope) in the vicinity

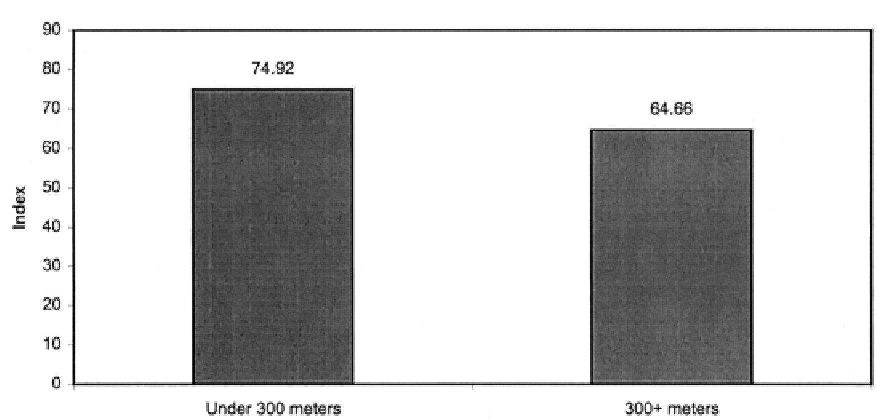


Figure 6. Health index and elevation.

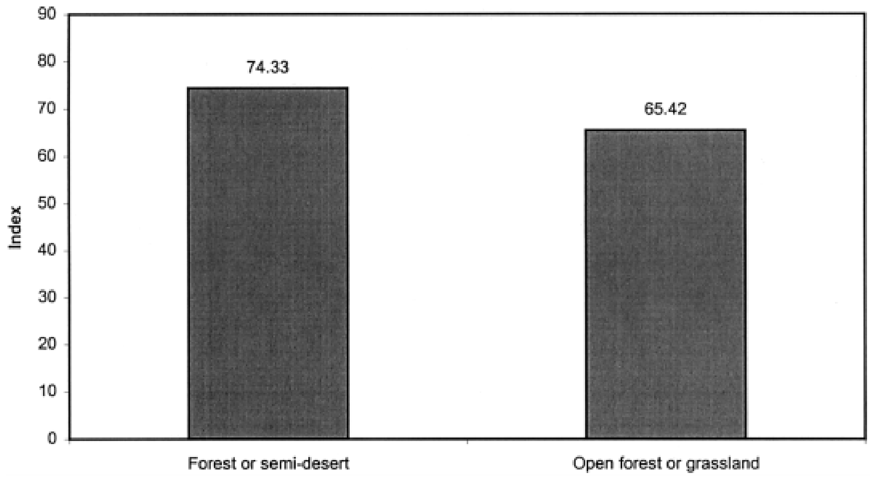


Figure 7. Health index and vegetation.

of the site. Studies such as these clearly have great potential to shed light on the relative significance of the complex set of local cultural and environmental variables that influence a group's health status.

The transition to agriculture has been widely considered a benchmark development for humanity, laying the groundwork for "civilization" and all of its elements, such as democracy, learning, art, literature, and architecture. From this perspective, humans underwent a transition from a way of life that was "nasty, brutish, and short" to one brimming with leisure and excess. The findings from the Western Hemisphere project argue that, in fact, the reverse was closer to reality. This is not to say that life went from rosy and healthy to bleak and unhealthy. That is not the case. There is a misperception by much of the public—at least the American public—that prehistoric Native Americans were the original ecologists, whose impact on the environment was minimal. Moreover, it is commonly believed that few diseases existed before the arrival of colonizing Europeans, who carried with them a suite of infectious pathogens that wiped out many native peoples. In fact, pre-Columbian people show plenty of evidence of disease. Some were among the healthiest in the study, whereas others were among those with the greatest burden of disease. To borrow from Charles Dickens, "it was the best of times and the worst of times."

If health declined with agriculture and settled living, why did people adopt the new subsistence technology in the first place? This is a difficult question to answer, and certainly cannot be addressed adequately in the space available here. The circumstances undoubtedly differed somewhat in the various centers where it first occurred. One possibility is that systematic production of food supported more births and larger populations, even if they were, on average, in worse health. Alternatively, the transition may have occurred out of necessity: As population increased in the Holocene, and in some locations accompanied by environmental deterioration,[59] humans had to adopt new strategies of acquiring food. Agriculture, and domestication generally, were among those strategies. It is also possible, however, that leaders who benefitted from the change were able to convince (or coerce) others to follow or that military or defense objectives could have been relevant.

Another important temporal trend to emerge from this study is the health impact that the arrival of Europeans in the Western Hemisphere had on Native Americans. Several important contrasts emerge in comparing the pre- and post-Colombian populations. Contrary to our general expectation, some health attributes actually improved over time. Correlation coefficients were negative and statistically significant for stature, porotic hyperostosis or cribra orbitalia, and dental health. This change, however, was largely due to the presence of healthy equestrian nomads from the North American Great Plains in the database. The health index for these groups was quite high, and they comprise an important part of the later post-Columbian group, thus biasing the results significantly.

Some interesting patterns emerged in the analysis of Euro-Americans and African-Americans, but the database available for study is modest, including nine Euro-American groups, four groups of free blacks, and one enslaved black group. Moreover, three of the Euro-American samples were unusual for various reasons. For example, a poorhouse in New York State was a small and poor component of the population for the time (the nineteenth century); a military sample had minimal health standards and, as expected, their skeletons revealed high levels of physical exertion and trauma.[47,60]

Euro-Americans fell below the average for the study as a whole, probably for several reasons. Euro-Americans were tall and had good childhood

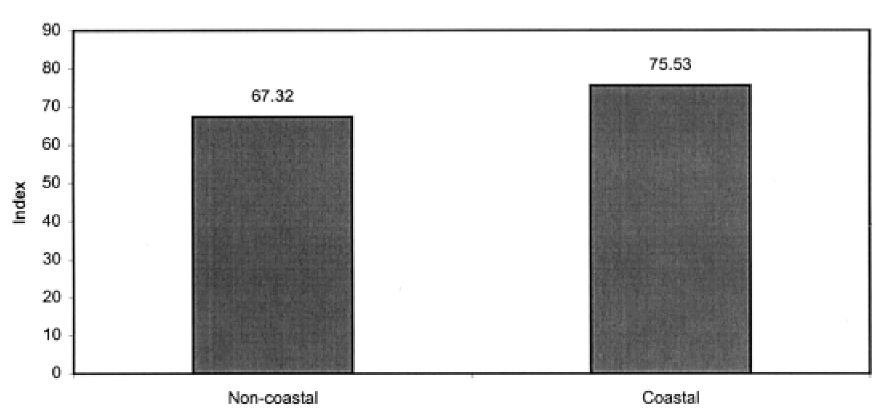


Figure 8. Health index and topography.

TABLE 4. Average Values of Ecological Variables in the Sample, Early and Late Pre-Columbian Periods

Variable	Early: Before 1,500 Years BP	Late: After 1,500 Years BP
300 + meters	0.364	0.500
Dispersed or village	0.545	0.583
Town or urban	0.182	0.333
Open forest—grassland	0.182	0.667
Domesticates	0.636	0.917
Coastal	0.545	0.333
Health Index	74.20	66.46
Number of sites	11	12

health indices. However, they scored quite low for at least one health attribute each. Interestingly, the sample from Belleville, Ontario, a group dating to the nineteenth century and having a high level of material culture, was below average for the health index. Their wealth apparently did little to protect them from the factors that cause poor dental health and degenerative joint disease. Clearly, the emphasis on carbohydrates, including cheap and ready access to refined sugar, contributed to poor dental conditions, as is typical of many other nineteenth-century groups studied by anthropologists. Moreover, repetitive patterns of hard work associated with Euro-American agriculture in the nineteenth century may have been a significant source of degenerative joint disease.[46]

The African-American samples show some interesting similarities and differences. The sample of those who were free displayed high rates of hypoplasias and infections, but childhood health was relatively good.[61] In fact, the pre-Civil War (pre-1861) free blacks from Philadelphia had the highest index of all non-Native American populations, well above that for small-town middle-class Euro-Americans.[55] This finding suggests that even for this disadvantaged group, it was possible to live a life of relatively good health in an early nineteenth century urban setting. In contrast, the enslaved group was quite different from the Euro-Americans and free African-Americans in that they had quite low scores for childhood indicators and especially infection. Consistent with all other studies of enslavement, health was poor for these individuals from just about any perspective.

In summary, the analysis of this large database from the Western Hemisphere reveals patterning in health in a number of respects. One key finding to emerge from the study is the downward trajectory of health before the arrival of Europeans. Historians, economists, and other social scientists have long celebrated the contributions of technological change to improvements in the human condition. However, our research underscores the importance of distinguishing between material and health aspects of the quality of life.

THE FUTURE

Health has long been regarded as a key factor in the outcome of warfare or other organized conflict between human groups. The success of Europeans in colonizing the Western Hemisphere was supported significantly by pathogens they introduced, and by metal weaponry, guns, and horses. However, the poor quality of life of native populations, brought about by deteriorating quality of diet, sedentism, and population aggregation, was also a major contributor to European success. The groups most readily conquered were those living in upland urban areas and who were the most dependent on agriculture.

The health index is an imperfect but useful measure of health conditions that provides us with a useful means of making analytical comparisons between numerous skeletal samples. It is hoped that this research will stimulate efforts to improve the health index and to clarify the patterns found in the Western Hemisphere database. Also on the research agenda are many of the parameters for the various attributes, especially in regard to how results are sensitive to assumptions of the duration of pathological conditions prior to death. For example, the pathology timing of ten years prior to death for dental health, infection, degenerative joint disease, and trauma might be adjusted to various other time intervals and the impact of that adjustment on the health index examined. It is important to know much more about the functional consequences for each of the attributes. Some of them, such as stature, are well known; others are not. Orthopedic surgeons suggest, for example, that there may be no clear relationship between the amount of disability and apparent severity of joint injury. Some individuals lead full, comfortable lives, yet seem to express severe manifestations of degenerative joint disease. Others have barely discernible lesions associated with the disorder, yet complain of great discomfort. More should be done to study the relationship of the health index to social inequality and gender.

This research project does not provide the last word on the "osteological paradox," which hypothesizes that improved health, as measured by longevity alone, allows more skeletal pathologies to accumulate before death. The poorhouse in Rochester, New York, provides an example of the paradox, which resulted from sudden reversals of fortune into an environment of very high mortality rates where skeletal lesions had little time to accumulate. However, in environments we know to have been quite stressful over long periods, such as those affecting the collapsing Mayans, American slaves, and tribes of the American southwest, the incidence of lesions was considerably above that in more hospitable settings. Contrary to the paradox hypothesis, the health index was positively and significantly correlated with crude estimates of life expectancy. The osteological paradox is probably not a general phenomenon that ordinarily misleads the assessment of health. But it is essential to adjust the incidence of lesions for the age distribution; use multiple skeletal indicators in assessing health; and interpret skeletons in their environmental or ecological contexts. Additional research is needed to determine more precisely the conditions under which average life expectancy and multiple indicators of skeletal health may diverge.

Finally, another obvious direction is to apply the methodology developed for *The Backbone of History* to a global setting. The Western Hemisphere is interesting, but it represents only one part of the history of the human condition. Together with anthropologist Paul Sciulli, we are developing a large public-use database allowing researchers to reinterpret the history of human health from the late Paleolithic era to the early twentieth century. During this period, human health and welfare were transformed enormously by the transition from foraging to farming, the rise of cities and complex forms of social and political organization, European colonization, and industrialization. With a global network of collaborators, we hope to undertake large-scale comparative studies of the causes and health consequences of these and other dramatic changes in arrangements for work, living, and human interaction. These data have enormous potential to help researchers address a wide range of problems. Among these are long-term trends in patterns of trauma and violence; biological inequality; aging and health; health during the rise and fall of civilizations; geographic patterns of health; and degenerative joint disease and work. The project will also lay the groundwork for analysis of population genetics and migration patterns using ancient DNA and will help future researchers identify regions of the globe where DNA research on ancient pathogens might be most productive.

ACKNOWLEDGMENTS

The authors thank the editor and two referees for comments and suggestions. Funding was provided by the National Science Foundation and by Ohio State University.

REFERENCES

1 Steckel RH. 1995. Stature and the standard of living. J Econ Lit 33:1903–1940.

2 Cohen MN, Armelagos GJ. 1984. Paleopathology at the origins of agriculture. Orlando: Academic Press.

3 Cohen MN. 1977. The food crisis in prehistory. New Haven: Yale University Press.

4 Steckel RH, Rose JC. 2002. Patterns of health in the Western Hemisphere. In: Steckel RH, Rose JC, editors. The backbone of history: health and nutrition in the Western Hemisphere. New York: Cambridge University Press.

5 McCaa R. 2002. Paleodemography of the Americas. In: Steckel RH, Rose JC, editors. The backbone of history: health and nutrition in the Western Hemisphere. New York: Cambridge University Press.

6 Steckel RH, Rose JC, Sciulli PW. 2002. A health index from skeletal remains. In: Steckel RH, Rose JC, editors. The backbone of history: health and nutrition in the Western Hemisphere. New York: Cambridge University Press.

7 Glasson WH. 1918. Federal military pensions in the United States. New York: Oxford University Press.

8 Kaplan RM, Bush JW. 1982. Health-related quality of life measurement for evaluation and research and policy analysis. Health Psychol 1:61–81.

9 Goodman AH, Martin DL. 2002. Reconstructing health profiles from skeletal remains. In: Steckel RH, Rose JC, editors. The backbone of history: health and nutrition in the Western Hemisphere. New York: Cambridge University Press.

10 Eveleth PB, Tanner JM. 1990. Worldwide variation in human growth. Cambridge: Cambridge University Press.

11 Sukhatme PV. 1982. Newer concepts in nutrition and their implications for policy. Pune: Maharashtra Association for the Cultivation of Science Research Institute.

12 Dasgupta P. 1993. An inquiry into well-being and destitution. New York: Oxford University Press.

13 Malcolm LA. 1974. Ecological factors relating to child growth and nutritional status. In: Roche AF, Falkner F, editors. Nutrition and malnutrition: identification and measurement. New York: Plenum Press. p 329–352.

14 Martorell R, Habicht J-P. 1986. Growth in early childhood in developing countries. In: Falkner F, Tanner JM, editors. Human growth: a comprehensive treatise, vol. 3. New York: Plenum Press. p 241–262.

15 Tanner JM, Hayashi T, Preece MA, Cameron N. 1982. Increase in length of leg relative to trunk in Japanese children and adults from 1957 to 1977: comparisons with British and with Japanese Americans. Ann Hum Biol 9:411–423.

16 Komlos J. 1989. Nutrition and economic development in the eighteenth-century Habsburg monarchy: an anthropometric history. Princeton: Princeton University Press.

17 Floud R, Wachter KW, Gregory AS. 1990. Height, health, and history: nutritional status in the United Kingdom, 1750–1980. Cambridge: Cambridge University Press.

18 Steckel RH, Floud R. 1997. Health and welfare during industrialization. Chicago: University of Chicago Press.

19 Sciulli PW, Schneider KN, Mahaney MC. 1990. Stature estimation in prehistoric Native Americans of Ohio. Am J Phys Anthropol 83:275–280.

20 Buikstra JE, Ubelaker DH. 1994. Standards for data collection from human skeletal remains. Arkansas Archaeological Survey Research Series 44.

21 Goodman AH, Rose JC. 1991. Dental enamel hypoplasias as indicators of nutritional status. In: Kelly MA, Larsen CS, editors. Advances in dental anthropology. New York: Wiley-Liss. p 279–293.

22 Hillson S. 1996. Dental anthropology. Cambridge: Cambridge University Press.

23 Walker PL. 1986. Porotic hyperostosis in a marine-dependent California Indian population. Am J Phys Anthropol 69:345–354.

24 Stuart-Macadam P. 1992. Porotic hyperostosis: a new perspective. Am J Phys Anthropol 87: 39–47.

25 Schultz M. 1993. The initial stages of systematic bone disease. In: Grupe G, Garland AN, editors. The initial stages of systematic bone disease. Berlin: Springer-Verlag. p 185–203.

26 Lozoff B, Wolf AW, Jimenez E. 1996. Iron-deficiency anemia and infant development: effects of extended oral iron therapy. J Pediatr 129:382–389.

27 Walter TI, Andraca CP, Perales CG. 1989. Iron deficiency anemia: adverse effects on infant psychomotor development. Pediatrics 84:7–17.

28 Ryan AS. 1997. Iron-deficiency anemia in infant development: implications for growth, cognitive development, resistance to infection, and iron supplementation. Yearbook Phys Anthropol 40:25–62.

29 Scrimshaw N. 1991. Iron deficiency. Sci Am Oct: 46–52.

30 Larsen CS. 1997. Dioarchaeology: interpreting behavior from the human skeleton. Cambridge: Cambridge University Press.

31 Ortner DJ, Putschar WGJ. 1985. Identification of pathologica conditions in human skeletal remains. Washington: Smithsonian Institution Press.

32 Corbett ME, Moore WJ. 1976. Distribution of dental caries in ancient British populations, IV: the 19th century. Caries Res 10:401–414.

33 Larsen CS, Shavit R, Griffin MC. 1991. Dental caries evidence for dietary change: an archaeological context. In: Kelley MA, Larsen CS, editors. Adv Dental Anthropol. New York: Wiley-Liss.

34 Larsen CS. 1995. Biological changes in human populations with agriculture. Ann Rev Anthropol 24:185–213.

35 Hough AJ, Sokoloff L. 1989. Pathology of osteoarthritis. McCarty DJ, Koopman WJ, editors. Arthritis and allied conditions, 12th ed. Philadelphia: Lea & Febiger. p 1571–1594.

36 Martin DL, Frayer DW. 1997. Troubled times: violence and warfare in the past. Amsterdam: Gordon and Breach.

37 Walker PL. 1989. Cranial injuries as evidence of violence in prehistoric southern California. Am J Phys Anthropol 80:313–333.

38 Walker PL. 2001. A bioarchaeological perspective on the history of violence. Ann Rev Anthropol 30:573–596.

39 Ruff CB. 2000. Biomechanical analyses of archaeological human skeletons. In: Katzenberg MA, Saunders SR, editors. Biological anthropology of the human skeleton. New York: Wiley-Liss. p 71–102.

40 Pearson OM. 2000. Activity, climate, and postcranial robusticity: implications for modern human origins and scenarios of adaptive change. Curr Anthropol 41:569–607.

41 Ruff CB, Trinkaus E, Walker A, Larsen CS. 1993. Postcranial robusticity in Homo. 1. Temporal trends and mechanical interpretations. Am J Phys Anthropol 91:21–53.

42 Bridges PS. 1995. Skeletal biology and behavior in ancient humans. Evol Anthropol 4:112–120.

43 Coale AJ, Demeny P. 1983. Regional model life tables and stable populations. New York: Academic Press.

44 Maresh M. 1989. Linear growth of long bones of extremities from infancy through adolescence. Am J Dis Child 89:725–742.

45 Wood JW, Milner GR, Harpending HC, Weiss KM. 1992. The osteological paradox: problems of inferring prehistoric health from skeletal samples. Curr Anthropol 33:343–370.

46 Saunders S, Herring A, Sawchuk L, Boyce G, Hoppa R, Klepp S. 2002. The health of the middle class: the St. Thomas Anglican Church Cemetery project. In: Steckel RH, Rose JC, editors. The backbone of history: health and nutrition in the Western Hemisphere. New York: Cambridge University Press.

47 Higgins RL, Haines MR, Walsh L, Sirianni JE. 2002. The poor in the mid-nineteenth century northeastern United States: evidence from the Monroe County poorhouse, Rochester, New York. In: Steckel RH, Rose JC, editors. The backbone of history: health and nutrition in the Western Hemisphere. New York: Cambridge University Press.

48 Johannson SR, Owsley D. 2002. Welfare history on the Great Plains: health and mortality, 1650–1830. In: Steckel RH, Rose JC, editors. The backbone of history: health and nutrition in the Western Hemisphere. New York: Cambridge University Press.

49 Storey R, Marquez Morfin L, Smith V. 2002. Social disruption and the Maya civilization of Mesoamerica: a study of health and economy of the last thousand years. In: Steckel RH, Rose JC, editors. The backbone of history: health and nutrition in the Western Hemisphere. New York: Cambridge University Press.

50 Marquez Morfin, McCaa L, Storey R, Del Angel A. 2002. Health and nutrition in some prehispanic Mesoamerican populations related with their way of life. In: Steckel RH, Rose JC, editors. The backbone of history: health and nutrition in the Western Hemisphere. New York: Cambridge University Press.

51 Sciulli PW, Oberly J. 2002. Native Americans of Eastern North America: the southern Great Lakes and the upper Ohio Valley. In: Steckel RH, Rose JC, editors. The backbone of history: health and nutrition in the Western Hemisphere. New York: Cambridge University Press.

52 Neves W, Wesolowski V. 2002. Economy, nutrition and disease in southern, coastal Brazil. In: Steckel RH, Rose JC, editors. The backbone of history: health and nutrition in the Western Hemisphere. New York: Cambridge University Press.

53 Larsen C, Crosby A. 2002. Biohistory of health and behavior in the Georgia Bight: the agricultural transition and the impact of European contact. In: Steckel RH, Rose JC, editors. The backbone of history: health and nutrition in the Western Hemisphere. New York: Cambridge University Press.

54 Ubelaker DH, Newson LA. 2002. Patterns of health and nutrition in prehistoric and historic Ecuador. In: Steckel RH, Rose JC, editors. The backbone of history: health and nutrition in the Western Hemisphere. New York: Cambridge University Press.

55 Rathbun TA, Steckel RH. 2002. The health of slaves and free blacks in the East. In: Steckel RH, Rose JC, editors. The backbone of history: health and nutrition in the Western Hemisphere. New York: Cambridge University Press.

56 Stodder ALW, Martin DL, Goodman AH, Reff DT. 2002. Cultural longevity in the face of biological stress: The Anasazi of the American Southwest (AD 800–1400). In: Steckel RH, Rose JC, editors. The backbone of history: health and nutrition in the Western Hemisphere. New York: Cambridge University Press.

57 Walker PL, Russell Thornton R. 2002. Health, nutrition, and demographic change in native California. In: Steckel RH, Rose JC, editors. The backbone of history: health and nutrition in the Western Hemisphere. New York: Cambridge University Press.

58 Steckel RH, Rose JC. 2002. The backbone of history: health and nutrition in the Western Hemisphere. New York: Cambridge University Press.

59 Bar-Yosef O. 1998. The Natufian culture in the Levant, threshold to the origins of agriculture. Evol Anthropol 6:159–177.

60 Sledzik PS, Sandberg LG. 2002. The effects of 19th century military service on health. In: Steckel RH, Rose JC. 2002. The backbone of history: health and nutrition in the Western Hemisphere. New York: Cambridge University Press.

61 Davidson J, Rose J, Gutmann M, Haines M, Condon K, Condon C. 2002. The quality of African American life in the Southwest near the turn of the 20th century. In: Steckel RH, Rose JC. 2002. The backbone of history: health and nutrition in the Western Hemisphere. New York: Cambridge University Press.

62 Kuczmarski RJ, Ogden CL, Grummer-Strawn LM, Flegal KM, Guo SS, Wei R, Mei Z, Curtin LR, Roche AF, Johnson CL. 2000. CDC growth charts: United States. Adv data vital health statistics. 314:1–28.

63 World Bank. World development report, various years. DC: World Bank.

Books Received

- Rogers, L.J. and Andrew, R.J. (eds.) (2002) *Comparative Vertebrate Lateralization*. ix + 660 pp. New York: Cambridge University Press. ISBN 0-521-78161-2 (cloth) $120.00.
- Miller, L.E. (ed.) (2002) *Eat or be Eaten: Predator Sensitive Foraging Among Primates*. xi+ 297 pp. New York: Cambridge University Press. ISBN 0-521-01104-3 (paper) $40.00.
- Mitchell, R.W. (ed.) (2002) *Pretending and Imagination in Animals and Children*. xviii + 370 pp. New York: Cambridge University Press. ISBN 0-521-77030-0 (cloth) $80.00.
- Klein, R.G. and Edgar, B. (2002) *The Dawn of Human Culture: A Bold New Theory on What Sparked the "Big Bang" of Human Consciousness*. 288 pp. New York: John Wiley and Sons. ISBN 0-471-25252-2 (cloth) $27.95.
- Zuk, M. (2002) *Sexual Selections: What We Can and Can't Learn About Sex from Animals*. xi + 239 pp. Berkeley: University of California Press. ISBN 0-520-21974-0 (cloth) $24.95.
- Laland, K.N. and Brown G.R. (2002) *Sense & Nonsense: Evolutionary Perspectives on Human Behavior*. ix + 369 pp. Oxford: Oxford University Press. 0-19-850884-0 (cloth) $29.95.
- Browne, K.R. (2002) *Biology at Work: Rethinking Sexual Equality*. x + 282 pp. New Brunswick: Rutgers University Press. 0-8135-3053-9 (cloth) $28.00.
- Donald, M. (2002) *A Mind So Rare: The Evolution of Human Consciousness*. xiv + 371 pp. New York: W.W. Norton & Co. 0-393-32319-6 (paper) $16.95.
- Hartwig, W.C. (ed.) (2002) *The Primate Fossil Record*. xiv + 530 pp. New York: Cambridge University Press. 0-521-66315-6 (cloth) $175.00