CHAPTER THREE

A Health Index from Skeletal Remains

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ABSTRACT

This chapter describes the data used for the Western Hemisphere project, discusses the format in which the information was coded, and explains the health index, which is a method for measuring and comparing health status using skeletal remains. Skeletal lesions measure primarily chronic health conditions, but they can reflect acute infections to the extent that they affect physical growth, the formation of linear enamel hypoplasias, and other conditions that register on bones. The database contains measurements of seven basic health indicators from 12,520 skeletons of people who lived in North, Central, or South America over the past 7 millennia. For purposes of analysis, many of the 218 sites where people lived were combined into 65 sites based on ecological and chronological similarity. The health index adjusts for the age distribution of the population and incorporates the severity of lesions indicating biological stress. The current (Mark I) version of the index gives equal weight to the health indicators, but this assumption and others explained in the chapter could be modified based on additional research. The Mark I health index could also be readily adapted to incorporate length of life. The index rankings reveal considerable diversity in health status, with Native Americans being among the most but also among the least healthy groups who lived in the Western Hemisphere prior to the end of the nineteenth century.

Social scientists have devised many approaches to measuring the standard of living. Economists use national income accounts and related measures, such as gross national product per capita, to depict material aspects of the quality of life. Demographers emphasize the length of life as an important aspect of well-being, and historians employ various devices, such as real wages, wealth, grain output, and hearths per person.

Unfortunately, these traditional measures cannot be used for studying trends over extended periods of time. The raw data simply do not exist for computing income, life expectancy, or other frequently used measures over the millennia. Moreover, even if the data were available, problems of comparability would arise in some instances. Income and wages, for example, have no clear meaning in a hunter-gatherer society.

Biological measures are the most comparable type of indicator across diverse societies because they assess the quality of life from the point of view of a living organism, which is common to all humans. Views on the afterlife aside, length of life and human growth mean about the same thing to modern Americans as they did to ancient Egyptians. Regrettably, lack of evidence on two widely used measures of this type – life expectancy and average height – forces us to look elsewhere for information on very long-term trends.

Skeletons are possibly unique in furnishing reasonably abundant evidence on the standard of living that is comparable over very long periods of time. Recent methodological developments in physical anthropology and bioarchaeology provide investigators with a rich array of information from skeletal remains, including estimates of the length of a person's life and knowledge of chronic pathological conditions while the person was living. The validity of this information on health has been corroborated by evidence from modern populations. Artifacts collected from burial sites also provide additional important information on living conditions.

Here we quantify health status from skeletons using a method that incorporates three key features sometimes lacking in other approaches: multiple indicators, age adjustment, and severity of skeletal lesions. In principle, the method can measure both the duration and the quality of life at a site, but for reasons explained below, the present effort incorporates only quality while living. Our skeletal measures of health include three attributes that reflect primarily conditions in childhood but also affect the adult quality of life – linear enamel hypoplasias, stature, and signs of anemia; two that apply primarily to adults – dental deficiencies and degenerative joint disease; and two that are relevant at any age – trauma and infections. We begin by describing quality-adjusted life-years, a concept used to depict health status in modern populations. This idea is adapted to skeletal remains with the help of several simplifying assumptions about the character of skeletal evidence. The result is a crude health index, but one capable of refinement and testing for the sensitivity of results to the assumptions.

The attributes of the health index are scored at the individual level, and the index could be estimated for an individual or for groups of individuals. If estimated for individuals, it could be used to assess not only average health but inequality of health within groups. Difficulties in using an individual-level index lead us to consider only those estimates for groups at this time. Findings are reported for Native Americans, Euro-Americans, and African-Americans at 65 sites in North America, Mesoamerica, and South America.

I. METHODOLOGY

The health index incorporates the length of life and physical health while living, an approach inspired by the work of medical examiners and physicians who assigned pensions to Civil War veterans based on an individual's degree of disability.[1]

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[1] The Consolidation Act of 1873 specified that disability payments for former Union Army soldiers were to be based upon medical examinations that determined the degree of disability for performing manual labor, with scores ranging from 6/18 to 17/18 disability (Glasson, 1918, p. 137).

Various disability systems, such as workers' compensation and Social Security, as well as courts involved in tort litigation, use similar principles to estimate the loss of a person's functional capacity following accidents or injury (Rondinelli, 2000). In addition, researchers in health economics have devised various indexes for appraising the health of patients and for evaluating health-care policies (see Drummond et al., 1987; Lohr, 1989; and Erickson et al., 1989). Indexes that weigh various dimensions of health to obtain a single measure fit the needs of our project. Two of these, the quality of well-being scale and the health utility index, score functional capacity on a scale of 0 to 1, which is the scale we propose.[2]

We can define a health index for individual j as follows:

$$I^j = \sum_{i=1}^{100} Q_i^j \quad \text{where } Q_i^j = Q_i(x_1^j, x_2^j, \ldots, x_k^j).$$

In these equations i denotes the year of life and Q_i is a function whose arguments are measures of the biological quality of life. The functions Q_i, which take on values from 0.0 to 1.0, measure the quality of health in year of life i. Excellent health is indicated by a function value of 1.0, moderate health by a function value near 0.5, and death by a function value of 0.0.

Some simple examples illustrate the meaning of the index. A person who had excellent health throughout life and died at exactly age 100 would have an index value of 100. Age 100 is an upper limit to the life span, at least in the populations under study, and it provides a convenient maximum numerical value for the index. (Obviously, the index could be scaled to accommodate alternative upper limits to the life span.) Similarly, an individual who lived 40 years in moderate health ($Q_i = 0.5$ for all ages from birth to death) would have an index value of 20. Someone who died at birth would have an index value of zero.

Figure 3.1 illustrates a varied age pattern of health. The graph shows the case of a person who had poor health in early childhood (as indicated, for example, by enamel hypoplasias), but was reasonably healthy during adolescence and early adulthood (attaining height, say, only one standard deviation below modern standards). He or she then declined during the late 30s (evident from infections, degenerative joint disease, and declining dental health) and died at age 40. In this formulation, the index value is interpreted as the area under the curve Q that depicts the biological quality of life at each age.

The ideal information to estimate the biological quality of life would be longitudinal data on a person's state of health from birth to death. A sequence of annual physical examinations would achieve this purpose, but more frequent measurements, such as monthly, weekly, daily, or even continuous observations on health, would be desirable. Unfortunately, such data are rare or nonexistent, even in modern populations. Instead, we approximate an individual's record of health using information contained in skeletal remains. Although the skeletal record provides an incomplete picture of health, emphasizing chronic in contrast to acute conditions,

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[2] For the quality of well-being scale, see Kaplan and Bush (1982). For the health utility index, see Torrance and Feeney (1989); and Feeney, Labelle, and Torrance (1990).

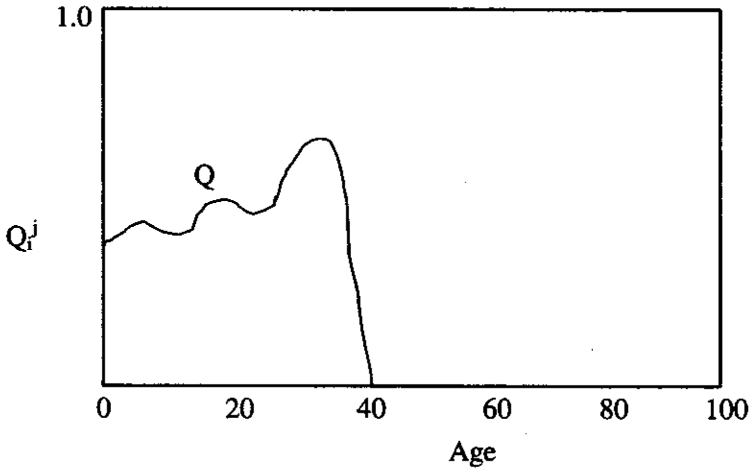

Figure 3.1. An example of the biological quality of life by age.

it nonetheless provides a useful and consistent way of measuring important aspects of the standard of living across diverse populations. Even acute conditions may indirectly affect skeletons, insofar as they affect physical growth, the formation of linear enamel hypoplasias, and other chronic pathological conditions that we do observe.

Any health index tabulated from skeletal remains would be imprecise for several reasons. Age-at-death can be reliably determined for children and young adults, but the accuracy of estimates deteriorates for older individuals. Some physical anthropologists think that older adults are systematically underaged. For this reason, we adjust estimated adult ages upward, and we lump older adults (aged 45+) into one age category.

Our objectives are tempered by the reality that skeletal evidence gives an incomplete chronological record of health. The age at which an insult occurred may be known with little precision. The time window of some insults, such as hypoplasias, is reasonably well defined, but may be vague in others, such as infectious lesions or degenerative joint disease. Opportunities for remodeling of bone tissue from many types of insults increases with the time since healing began. Since estimates based on current methods cannot be precise about the timing of many insults, appraisals of health status could be grouped into two broad age categories: adults and subadults. The boundary between childhood and adulthood is placed at 18 years, though a slightly lower age is defensible. One might infer the duration of stress by applying averages from cases where the duration is known, say, from medical studies of biologically stressed populations found in developing countries. The severity of the lesions may also be related to their duration.

The functional impairment may differ across individuals who had similar skeletal lesions. For example, two individuals who had visually similar evidence of arthritis may have had substantially different levels of pain or loss of use. There may be no way to solve this problem, but we are interested primarily in average levels of health across populations, rather than the health of particular individuals (although this would be interesting to know). It is hoped that errors made in judging the health of particular individuals will approximately cancel in tabulating averages.

Measures of health status using skeletal data may exaggerate the quality of health, in part because acute conditions are unlikely to register directly in bone material. The skeletal measures proposed will not identify whether an individual had yellow fever, small pox, measles, or several other diseases (but these diseases could stunt physical growth or otherwise contribute to the formation of skeletal conditions we do measure). However, the upward bias imposed by this feature is made smaller by the fact that acute conditions did not last long: the individual recovered quickly or died. If recovery is rapid, the loss in quality-adjusted life-years is minimal, and death registers immediately in the attribute system (assuming we incorporate length of life into the health index). The bias is larger, however, if individuals often faced a succession of acute illnesses. In addition, skeletons tell us little about some aspects of health, such as vision or hearing, and in the absence of information, our scoring scheme rates these attributes as unimpaired. Obviously, an individual could be blind in ways that fail to show on the skeleton, and some forms of trauma to the skull that result in blindness, but not death, are identifiable. To the extent that individuals were severely limited in one of these attributes – in an era when people made do without eyeglasses, hearing aids, seeing eye dogs or voice enhancers – it is likely the person was at greater risk of death, which is captured by the system of measuring health status. Skeletal materials are unable to detect emotional states and, to a lesser extent, cognition. Anemia and chronic malnutrition, however, may impair cognitive function, and severe emotional stress or cognitive impairment may weaken the immune system or compromise diet, clothing, and shelter in ways that led to death. Even though estimated health quality is biased upward by these shortcomings, relative to what would be measured in interviews of modern populations, the approach provides a reasonably consistent way of measuring health status over time and across space.

Up to this point, the discussion has assumed that the index would be tabulated for particular individuals.[3] In this method, the health of a group would be measured by averaging or otherwise pooling the health states of its members. However, difficulties with individual-level data lead us to favor an aggregate technique. A limitation of the individual approach stems from the fact that the index is sensitive to the age-at-death. This sensitivity is unavoidable – indeed, it is essential – because quality-adjusted life-years are designed to reflect the length of life. As Chapter 2 on demography has shown, however, the distribution of ages-at-death at a particular site is influenced by the birth rate. The average age-at-death declines as the birth rate increases. Because age-specific death rates are U-shaped by age (the highest death rates apply to young children and to old adults), populations in which there were numerous births also had many deaths at young ages. Therefore, variations in quality-adjusted life-years tabulated from individuals could be caused purely by differences in fertility.

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[3] The precise details of a procedure are not specified here because the method is impracticable given the data constraints and other difficulties noted below. But several specific approaches are plausible. For instance, scores for stature, anemia, hypoplasias, dental, and DJD (perhaps assuming no functional impairments for the latter two attributes during the subadult years) could be used to depict the subadult health experience for those who lived to adulthood. All seven attributes might be used to depict adult health (and the health of those who did not survive to adulthood). Possible ways of extending or refining the approach, including linear (or nonlinear) deterioration in health among adults, are noted in the section on "Suggestions for Research."

If the birth rate was known (or could be estimated from evidence available at the site), appropriate adjustments to the age distribution of deaths could be made, but unfortunately, such reliable knowledge is lacking for many sites.

Fertility is not the only potential contaminant of a health index constructed from individual-level data. Selective or seasonal migration may also distort the observed or measured age distribution of deaths at a particular site. If young or old individuals systematically entered or left the population under study, the age distribution of deaths and, therefore, the health index is changed for the site. Seasonal migration, such as movements from summer to winter living places, may produce these effects if the age distribution of deaths varied by season of the year. These potential biases might be compounded by incomplete excavation of burial sites or by destruction of skeletal materials. Field researchers are carefully trained to recover skeletons and related artifacts, but the soft bones of infants and of very young children, and sometimes those of adults, may be poorly preserved, particularly in acidic soils. Moreover, at a particular site, some of the young or the very old might have been buried apart from the location excavated. Therefore, the measured age distribution of deaths may contain several potential biases that distort the health of the population under study.

A practical difficulty with individual-level data also leads us to an aggregate approach: incomplete skeletons. Roughly one-half of the skeletons coded for the project contain enough parts to measure a majority of the stress indicators used in the project. Even though the total sample size is huge (more than 12,500 individuals) by standards of work in the area, the effect on the analysis of deleting the incomplete skeletons is substantial because several sites would not have enough complete individuals to make reliable inferences about health. An approach based on individuals sacrifices a great deal of temporal and geographic diversity in the database.

Instead, we employ an aggregate or site-specific method that incorporates every scrap of information recorded for skeletons in which age-at-death is available. This method also overcomes problems associated with biases in the age distribution of death, but at a cost of losing desirable properties of an overall index tabulated from the index scores of each individual. Following details presented in the next section, the technique relies on age-specific measures of the incidence of each component or attribute in the index (hypoplasias, anemia, degenerative joint disease, etc.). Then, to estimate quality-adjusted life-years, the age-specific rates are multiplied by the age distribution of person-years lived in a standard or reference population, in much the same way that demographers would calculate an age-adjusted crude death rate. The reference population chosen roughly approximates mortality conditions in the societies under study.

The technique purges the health index of intrusions caused by biases in the age distribution of deaths as a measure of the underlying mortality schedule, but the index no longer incorporates health differences that could have been caused by genuine variations in the length of life. Because the index is founded purely on the incidence of pathological lesions, it understates the range of health experience in the Western Hemisphere. We know that quality-adjusted life-years are sensitive to the length of life, and it was almost certainly the case that the past several millennia witnessed significant fluctuations or differences in life expectancy. By assuming that the same life expectancy applied to every site, the index no longer captures a component of health that could have differed across time, space, or ethnic group.

Although the limitation is regrettable, the loss may not be as important as one might think for ranking health across the societies under study. It is likely that the incidence of lesions and average length of life were negatively related because many conditions that affected one also affected the other. If correct, these components of health had a similar effect on quality-adjusted life-years. Hard work, poor nutrition, and communicable diseases lowered the life span but also gave rise to anemia, deficiencies in stature, infections, and other pathological conditions measured in the project.

A devil's advocate might argue that the correlation would be weak or, conceivably, positive. It is possible, for example, that rich societies had enough resources to support those with significant disabilities through family connections, networks, or other means. If these resources substantially increased the average length of life, then under some circumstances, the lesions could have been a sign of lower mortality rates. It is known, however, that the measures of biological stress used in this project were unpleasant. Skeletal infections, trauma, anemia, and other components of the health index were painful and limited activity. Thus, an increased incidence of pathological lesions alone in no way indicates better health or improved quality of life.

The questions are whether additional pathologies somehow signified more plentiful resources, and whether the additional resources were capable of generating a longer life span, which more than offset the unpleasant effects of the pathologies, that is, that quality-adjusted life-years improved. While it might be true that rich societies allocated a portion of their additional wealth to care of the sick or the infirm, this care, if effective, would tend to blunt the progression of the pathologies in question, delaying their onset and possibly reducing their severity. The end result would be a greater number of person-years lived with lower pathology scores, thereby increasing the health index. Degenerative joint disease, for example, reflects wear and tear on the body that could be alleviated, slowed, or possibly arrested with help from others. Moreover, rich societies may have allocated resources to the prevention of chronic disease by improving nutrition or reducing work, which would act to create a negative association between resources and pathologies.

If rich societies had more pathological lesions, then poor ones must have had fewer. In contradiction to this line of thought, we know that some societies whose standard of living deteriorated showed a high incidence of skeletal maladies. The pre-Columbian populations of the American Southwest (Anasazi) and of southern Mexico (Mayans) were heavily stressed and registered the highest rates of pathology among all sites in our sample (see discussion and tables below).

Did additional resources significantly lengthen life? Although a strong gradient between income or wealth and health has been widely reported for industrialized countries in the past half century, the modest evidence available on their relationship in the nineteenth century suggests that the connection was loose, or at least that the wealthy and the poor died at similar rates (see, for example, Steckel, 1988, and Preston and Haines, 1991). If the link was weak a century and a half ago, one might venture to suppose that it was also weak in earlier centuries. While the point cannot be proven, the available evidence suggests that access to resources was somewhat related to length of life in the societies under study.

We are reasonably confident that the estimated health index typically moved in the same direction as quality-adjusted life-years. Consistent with this pattern, tentative statistical analysis presented in the "Conclusions" to the book show a positive correlation between the health index and estimated life expectancy at birth.

II. APPLICATION

The health index is constructed using a modified form of a multiattribute system, an approach developed in the 1970s to assess health aspects of the quality of life.[4] In this method, health has attributes or dimensions, such as vision, pain, mobility, dexterity, hearing, and cognition. Several capacity levels are usually specified for each attribute, varying from severely compromised to normal, and health status is given by the level of the individual on each attribute.

Health status – the scores on various attributes of health – can be converted into a single index number reflecting health-related quality of life by using a scoring or utility function, which expresses weights or preferences to be given to various combinations of health states.[5] For example, a system that had 6 attributes and 3 levels of health for each attribute would have $3^6 = 729$ possible health states, each of which could be given a quality score. Preferences are often elicited through questionnaires or surveys that ask individuals to choose or rank various hypothetical alternative health states. Assuming the comparability of preferences, this in turn allows one to make comparisons of health-related quality of life across time, space, and ethnic groups.

Using skeletal materials, we construct a crude approximation to the quality-adjusted life-year. Although it is based only on chronic conditions that register in bones, the vision of a more complete index used in medical economics serves as a guide and inspiration for further research. The index is defined as the sum of the quality-adjusted life-years lived by a synthetic cohort of individuals whose mortality experience was specified by a Model West level 4 life table (Coale and Demeny, 1983).[6] The assumptions or procedures of the first (Mark I) version of the

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[4] Frank, Gold, and Erickson (1992). For a sense of the evolution of these systems, see Bush et al. (1972); Torrance, Boyle, and Horwood (1982); Cadman et al. (1986); and Feeney et al. (1992).

[5] A utility function is a concept in economics used to describe preferences, or in this context, the satisfaction of various health states or health outcomes. The utility function reflects both the ordinal ranking of health states (the most preferred, next most preferred, . . . , least preferred) and the intensity of preference for each health state.

[6] The index is an example of an additive scoring or utility function. Multiattribute utility theory recognizes three main types of utility functions: additive, multiplicative, and multilinear (Keeney and Raiffa, 1976). Which is appropriate depends upon the type of utility independence that exists. Additive utility independence means that there are no interactions in preferences among attributes. For instance, the evaluation or ranking of hearing would not depend on the level the person was at for mobility or dexterity. In contrast, mutual utility independence, expressed by the multiplicative model, allows for simple interactions

Table 3.1: Scoring Pathologies

Variable	Type
Stature	Continuous
Hypoplasias	3 categories
Anemia	3 categories
Dental Health	
Teeth (75%)	Continuous
Abscesses (25%)	3 categories
Infections	4 categories
Degenerative joint disease	2, 4, or 5 categories, depending on joint
Trauma	2 categories

index are given below, but in view of the tentative nature of some ingredients, we anticipate an ongoing process of experimentation and refinement.

1. The attributes of this system are categories of skeletal lesions or physical characteristics. A detailed technical concept underlies each measure (see Goodman and Martin, this volume), but for convenience in discussing them we use various shorthand terms, including (a) stature; (b) enamel hypoplasias; (c) dental defects; (d) anemia as indicated by porotic hyperostosis or cribra orbitalia;[7] (e) infections as indicated by periosteal reactions; (f) degenerative joint disease; and (g) trauma. These attributes, which are readily recorded by most physical anthropologists, are included in the consolidated database of the project. We minimized the potential problem of interobserver variation in scoring by using slides and physical examples to illustrate the system of coding (see Appendix for details).

2. All attributes of health are weighted equally in the index. While it may be difficult to justify this assumption, given the present state of knowledge it is also difficult to justify any particular set of alternative weights. There is a need for research on the functional consequences of these lesions that could serve as a guide to alternative weights.

3. For each individual, every observable attribute of the health index is scored on a scale of 0 to 100 percent.[8] The scoring is continuous or discrete, depending on the attribute as shown in Table 3.1. For example, stature is scored continuously, and hypoplasias are grouped into three categories: none (score of 100 percent), moderate (score of 50 percent), and severe (score of 0 percent). Scoring is similar for other discrete categories discussed below, that is, if there are 4 categories, the possibilities are 100, 67, 33, and 0.

among preferences across attributes. For example, the ranking of vision depends upon the level of hearing. Because the multilinear form is quite complex and would require many measurements for its estimation, practical work in this area has relied upon the additive and multiplicative forms. Interviews and surveys usually reject the additive model, which is a limitation of this application to skeletal remains.

[7] We recognize that some researchers dispute the association between porotic hyperostosis and anemia. For a discussion of issues and recent research, see Hershkovitz et al. (1997) and Schultz (1993).

[8] It is assumed that an individual's health was not correlated with the bones available for study. If the skeleton was incomplete, we posit that parts were missing at random in relation to the health attributes.

4. The health index takes on a value of 0 at death, which is a standard assumption in multiattribute models. An individual who exhibited the most severe deficiency on each attribute, but lived through a particular year of age, receives a quality score of 0 for that year of age. A health status consisting of the worst case of every attribute is equivalent to death.

5. Stature is inferred from long bone (femur) length. Individuals receive a score of 100 percent if they attained or exceeded modern femur standards for their age, as provided by Marion Maresh (1955). Individuals who fall below the third standard deviation of modern standards receive a score of 0, and intermediate results are linearly prorated. Difficulties in determining stature from femur lengths in adolescence lead us to exclude this category from the list of attributes at ages of death from 11.75 to 17.75 years.

6. Dental health has two components: (a) completeness (weight of 75 percent) and (b) abscesses (weight of 25 percent). Completeness 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. The score for degenerative joint disease is determined by the lowest of the scores estimated for the following joints: shoulder and elbow (five categories); hip and knee (five categories); cervical (four categories); thoracic (four categories); lumbar (four categories); temporomandibular (two categories).

8. Trauma or bone fracture is assessed for the following parts of the skeleton: arm (humerus, radius, and ulna); leg (femur, tibia, and fibula); nasal and nasal process; face other than nasal; skull vault; hand; and weapon wounds to any part of the body or head. An individual receives a score of 100 percent if trauma is absent on all parts observed, and the score is 0 if any part of the skeleton shows trauma. This system does not recognize or otherwise incorporate multiple trauma.

9. Skeletal characteristics formed in childhood (stature, anemia, and hypoplasias) are assumed to have functional consequences from birth to death. Though stature is heavily influenced by environmental circumstances in childhood, the effects of impaired growth are often realized throughout life. Several studies of labor markets in developing countries show that wages or productivity increase with stature, and longitudinal studies have established the importance of childhood nutrition for mental development and the acquisition of human capital (Haddad and Bouis, 1991, and Pollit et al., 1995). If anemia is observed in an adult, ordinarily it persisted from childhood. Hypoplasias signify substantial nutritional stress in early childhood, which we assume has consequences in addition to those measured by stature. This procedure gives high weight in the index to childhood health and nutrition.

10. Bones were living tissue that may have changed or remodeled. Therefore, the skeleton provides a limited window on health. The exact length of time that an individual may have endured a pathological condition, such as degenerative joint disease, can only be approximated. Because a condition of this type is often chronic, it is reasonable to venture that it could have existed for many years. Here we assume that conditions observed at death persisted for 10 years prior to death

for dental health, infections, degenerative joint disease, and trauma. This is clearly a simplifying assumption, but one that can easily be changed in the calculation of the index. In reality, it is likely that the window on health varies by the type and severity of the skeletal lesion, the age and nutritional status of the individual, and so on. We await evidence and research that will clarify these issues.

11. Dental defects and degenerative joint disease are assumed to be absent during childhood (up to age 18). Exceptions can be found, particularly for dental health, but the assumption is reasonably accurate for working purposes.

12. In view of evidence that estimated ages-at-death are too low, the reported ages are adjusted according to the method of C. Owen Lovejoy et al. (1985). Specifically, 1.4 years is subtracted from estimated ages of 18 to 29 years, while the following were added at older reported ages: 0.8 at 30–39; 7.4 at 40–49; 6.8 at 50–59; and 13.6 at 60+.

Calculation of the index for a particular site begins with the construction of age-specific rates of attribute scores.[9] The age-specific scores at particular ages are simply averages of the attribute scores for individuals (at the site) whose health was assessed at those ages. It is assumed that the consequences of stature, anemia, and hypoplasias persisted from birth to death. Thus, someone who had a stature score of 50 percent when he or she died at age 40, for example, would contribute one person year lived at each age from birth to age 40 and a score of 50 percent in each year of life. The age-specific scores are essentially ratios, in which the denominators equal the sum of person-years of health assessed at those ages, and the numerators equal the sum of the assessed scores at those ages.

The rates for the remaining attributes, which have 10-year windows, are constructed in a similar fashion, except that person-years lived (and the scores) apply only to the 10-year interval prior to death. Figure 3.2 illustrates these assumptions for an individual who died at age 40, in which the dark lines show the person-years for which the scores apply. If the dental score, for example, was 65 percent at death, we assume the person lived with that score from age 30 to age 40. We make no assumption about (do not calculate) dental scores prior to age 30 (and above age 18 – see next paragraph). Of course, more complicated (and likely more realistic) assumptions about the typical decline in dental health prior to age 40 are possible, with linear (or even nonlinear) declines and windows other than 10 years being examples. But these assumptions also involve more complex computations, which may be justified if additional research reveals what the actual patterns were likely to have been.

Recall that we assume that dental defects and degenerative joint disease did not exist below age 18 (essentially, scores for these attributes equaled 100 at these ages). Someone who died at age 26, for example, would contribute the scores observed only from age 18 to age 26.

The FORTRAN computer program calculated the age-specific attribute scores for single years of age, but partly to compensate for some tendencies of age heaping, and also to smooth the scores at sites with few individuals, we grouped the attribute scores by age categories. We used categories of 0–4, 5–14, 15–24, 25–34, 35–44, and

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[9] These are not true age-specific rates because the number of individuals alive (at risk) is not known from age-at-death information. Biases could arise if the pathologies hastened the chances of death. However, the problem for ranking health is mitigated if the bias is the same, or at least similar, across populations.

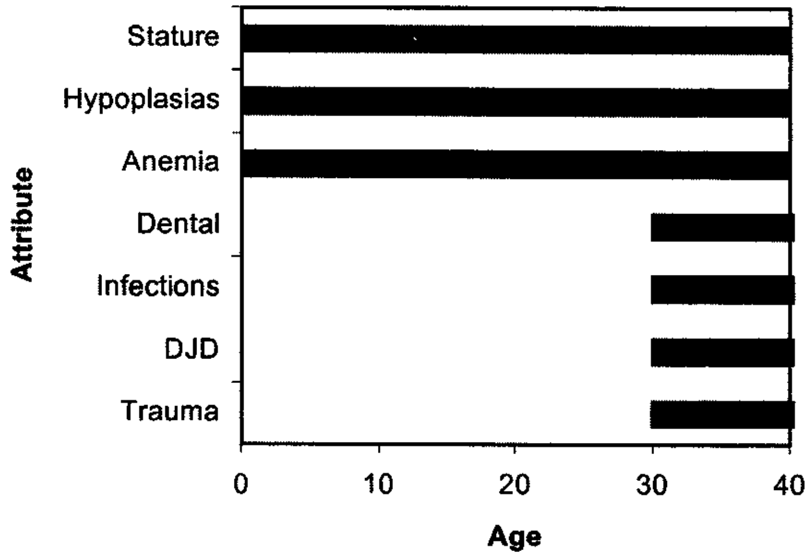

Figure 3.2. Person-years of attribute scores, death at age 40.

45+ years. The last category reflects the fact that the reliability of age estimates declines at older adult ages. In addition, at most sites, relatively few individuals lived beyond age 45.

Next, we calculated an average score for each attribute by first multiplying each age-specific rate by person-years lived in each age category within the reference population. The sum of these numbers divided by life expectancy at birth in the reference population (26.38 years) gives the attribute score as a percent of the maximum attainable. The average of these scores across attributes gives an overall quality score as a percent of the maximum, and this multiplied by 26.38 estimates average quality-adjusted life-years lived at a particular site.[10] The maximum of 26.38 would be attained if pathological lesions or skeletal defects were absent for each individual at every age, that is, if each age-specific attribute rate was 100 percent. Comparisons across sites are facilitated by expressing the result at each site as a percent of the maximum.

If reliable information was available on life expectancy, it could be incorporated into the rankings by multiplying the quality scores by the ratio of the life expectancies at particular sites to life expectancy in the reference population (26.38 years). In turn, these results could be converted to percentage terms by dividing by the highest such score in the sample.

III. RESULTS

The findings for 65 sites are presented in Table 3.2, arranged in descending order of health as measured by quality-adjusted life-years. Perhaps the most striking pattern is that health levels varied enormously in the Western Hemisphere, with quality-adjusted life-years ranging from 53.5 to 91.9 as a percent of the maximum attainable.

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[10] At a few sites, some attributes were not measured, or the age distribution of deaths was such that gaps were left in the age-specific attribute rates. In these instances, the average was taken across the available rates.

Table 3.2: Health Index by Site

Abbrev.	Site no.	Group	QALY	% of Max.	Investigator	Age	Description
LNC	20	N	24.22	91.8	Neves	1200	Coastal Brazil
111	27	N	23.54	89.2	Larsen	1350	Coastal South Carolina
LNP	21	N	22.97	87.1	Neves	3000	Shell mounds, southern Brazil
ESB	58	N	22.41	85.0	Buikstra	0700	Estuquina, Peru
301	29	N	22.10	83.8	Larsen	0325	Coastal South Carolina
osg	12	N	22.00	83.4	Ubelaker	7425	Sta. Elena, Ecuador
WO7	61	N	21.75	82.4	Walker	1075	Coastal Southern California
cot	13	N	21.52	81.6	Ubelaker	2160	Highland Ecuador
BFT	54	N	21.50	81.5	Owsley	0075	Equestrian Nomad, Blackfoot
201	28	N	21.34	80.9	Larsen	0600	Coastal South Carolina
BU2	50	N	21.20	80.4	Owsley	0200	Plains village, Pawnee
101	26	N	21.19	80.3	Larsen	1350	Coastal South Carolina
W42	65	N	21.10	80.0	Walker	5250	Coastal Southern California
W38	64	N	20.85	79.0	Walker	3834	Coastal Southern California
Dk2	46	N	20.82	78.9	Owsley	0155	Plains village, Omaha
KIT	31	N	20.55	77.9	Sciulli	2600	Archaic, Great Lakes region
rea	11	N	20.39	77.3	Ubelaker	4663	Realto, Ecuador
BUF	35	N	20.40	77.3	Sciulli	0350	Buffalo, Great Lakes region
Sfa	18	E	20.29	76.9	Ubelaker	0190	San Francisco church, Ecuador
KX1	47	N	20.16	76.4	Owsley	0155	Plains village, Ponca
W13	63	N	20.14	76.3	Walker	1625	Coastal Southern California
CRW	48	N	20.01	75.9	Owsley	0075	Equestrian Nomad, Crow
W28	60	N	19.96	75.7	Walker	0434	Coastal Southern California
Lib	16	N	19.81	75.1	Ubelaker	1760	South coast, Ecuador
DW2	49	N	19.82	75.1	Owsley	0170	Plains village, Arikara
3AM	52	N	19.65	74.5	Owsley	0475	Plains Arikara & Oneota
WW7	51	N	19.62	74.4	Owsley	0240	Plains village, Arikara
FAB	1	A	19.48	73.8	Rathbun	0105	Baptist Church, Philadelphia
PEA	32	N	19.44	73.7	Sciulli	0900	Pearson, Great Lakes region
303	30	N	19.41	73.6	Larsen	0325	Coastal South Carolina
MON	34	N	19.22	72.9	Sciulli	0650	Monongahela, Great Lakes region
CHY	53	N	19.24	72.9	Owsley	0071	Equestrian Nomad, Cheyenne
WLE	59	E	19.20	72.8	Walker	0075	Northern California
Lat	14	N	19.18	72.7	Ubelaker	2050	North coast, Ecuador
HPK	10	E	19.08	72.3	Sirianni	0108	Rochester NY poorhouse
SF1	19	E	19.04	72.2	Ubelaker	0090	San Francisco church, Ecuador
SUN	33	N	18.90	71.6	Sciulli	0750	Sun Watch, Great Lakes region
cry	2	E	18.82	71.3	Rathbun	0100	Eastern U.S.
Snt	15	N	18.74	71.0	Ubelaker	0395	Quito convent, Ecuador
Sfc	17	E	18.70	70.9	Ubelaker	0300	San Francisco church, Ecuador
Ftl	7	E	18.58	70.4	Sledzik	0150	Military, East
AZ1	44	N	18.40	69.8	Arriaza	1175	Maitas Chirb., Chile
W43	62	N	18.41	69.8	Walker	1359	Coastal Southern California
41D	6	A	18.35	69.5	Condon	0062	Texas frontier
Y1B	57	N	18.32	69.4	Buikstra	0700	Yaral, Peru
Stt	9	E	18.28	69.3	Saunders	0102	Belleville, Ontario, Canada
MR1	45	N	18.09	68.6	Arriaza	6015	Coastal Chile
3C9	3	A	18.06	68.5	Rathbun	0097	Folly Island Union troops
TL2	41	N	18.04	68.4	Marquez	3100	Tlatilco, Mexico

(*continued*)

Table 3.2 (*continued*)

Abbrev.	Site no.	Group	QALY	% of Max.	Investigator	Age	Description
SGB	56	N	17.89	67.8	Buikstra	0700	San Geron., Peru
XCA	43	N	17.87	67.7	Marquez	0990	Xcaret, Mexico
CHB	55	N	17.79	67.5	Buikstra	0700	Chiribaya, Peru
GPS	8	E	17.45	66.2	Sledzik	0080	Military, West
CUI	42	N	17.44	66.1	Marquez	1850	Cuicuilo, Mexico
CO1	39	N	17.42	66.0	Marquez	0790	Cholula, Mexico
3La	5	A	17.28	65.5	Rose	0042	Cedar Grove, Arkansas
J73	40	N	17.01	64.5	Marquez	1350	Jaina, Mexico
Teo	25	N	16.28	61.7	Storey	1625	Tlatinga, Mayan
dol	36	N	15.76	59.8	Stodder	1050	Dolores, Colorado
QUI	22	N	15.60	59.1	Neves	1175	Northern Chile
Co9	23	N	15.56	59.0	Storey	1125	Copán, Rural, Mayan
cop	4	N	15.40	58.4	Storey	1125	Copán, Mayan
3C7	24	A	15.42	58.4	Rathbun	0095	Plantation slaves, SC
la8	38	N	15.11	57.3	Stodder	0448	San Cristobal Pueblo, New Mexico
haw	37	N	14.12	53.5	Stodder	0398	Hawikku, New Mexico

Notes: The abbreviations and site numbers are codes internal to the project and may not agree with those assigned by the original investigators. Group refers to Native American (N), Euro-American (E), or African-American (A). The maximum quality-adjusted life-years (QALY) is 26.38, which corresponds to a complete lack of pathological lesions or deficiencies. Only the lead investigator's in data collection is mentioned in the table (for additional information, see the chapters). The ages, given here in "years before the present" (years BP – before 1950), are roughly approximate for prehistoric sites. As a rule of thumb, the older the site, the less is known about its age.

This conclusion is reinforced by the fact that the health index does not incorporate systematic differences in length of life across sites. If life expectancy rose and fell with the index, then actual variation in health was greater than reported.

Notably, Native Americans were both the healthiest and the least healthy in the entire sample. They occupied the top 14 slots and 26 out of the top 27, but they also held 8 of the last 9 positions. Euro-Americans and African-Americans, who occupied 14 sites in total, overwhelmingly were situated in the middle and lower rungs on this scale. Only 3 out of these 14 sites (two Euro-American and one African-American) were situated above the median. Surprisingly, the health index at the Rochester, New York, poorhouse exceeded that for middle- and upper-class Euro-Americans at Belleville, Ontario. As discussed in the "Conclusions" to the book, this site illustrates an "osteological paradox," or a condition in which the depiction of health by several skeletal indicators diverges substantially from other important health measures, such as mortality rates or life expectancy at birth. The poorhouse was quite unhealthy as measured by longevity, and death rates were so high for the newly admitted that many types of skeletal lesions did not have time to form prior to death.

It is interesting to note that African-Americans had among the best and the worst of health outside Native Americans. The poor health of slaves, particularly children, has been observed in small stature and high mortality rates (Steckel, 1986a, 1986b). That the slaves of the South Carolina plantation ranked lowest among African-Americans is not surprising, but it is remarkable that the slaves were near the bottom in the overall rankings (58.4 percent of the maximum), comparable in health to pre-Columbian Native American populations threatened with extinction. It is also surprising that the antebellum blacks who were buried at Philadelphia's First African Church scored 73.8 percent – second highest of all non–Native American populations and superior to small-town, middle-class whites. These data indicate that it was possible for a socially disadvantaged group to carve out a life with reasonably good health in an early-nineteenth-century city.

Health varied considerably by region and time period.[11] Although a more systematic study of determinants of health appears elsewhere in this volume, a superficial glance at Table 3.2 suggests that the American Southwest and Mesoamerica were often tough on health at the sites in the sample. Good health existed on both continents and was often situated on or near coastal areas. There was a tendency for the health of Native Americans to decline over time. The healthiest sites were often quite old, substantially predating the arrival of Columbus, but the equestrian plains nomads were a nineteenth-century exception.

The attribute scores presented in Table 3.3 are useful for diagnosing or explaining differences in the health index.[12] Sites with poor health typically scored low on most attributes, but sites with good health, on average, may not have had uniformly good attribute scores. Some of the healthier populations had relatively low scores on stature. Because stature scores were low in general (average value of 20.7), the lack of information on stature no doubt elevates the index at three of the top four sites. If data were not collected on a particular attribute, the available attributes were weighted equally to form the index. For example, if the missing stature score at the healthiest site (LNC) is replaced by the average score at the top five sites that had stature scores, the index (as a percent of the maximum) falls from 91.8 to 81.5. The top score at a site for which all attributes were observed was 83.4 (Sta. Elena, Ecuador).

The strengths of association among the attributes and between the attribute scores and the health index are specified more formally in Table 3.4. The correlations across sites show that hypoplasias, anemia, and degenerative joint disease were the better

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[11] Site age is highly approximate in many cases. Most burials, with the exception of some that apply to the military, occurred over many years, and as a rule of thumb, the older the site, the less is known about its age.

[12] Table 3.3 also presents a measure of sample size. The number of individuals studied at a particular site is only a rough indicator of the volume of information available because many skeletons were incomplete and the age distribution of deaths may have varied across locations. The last column of the table gives total person-years of information acquired for estimation of the index. Its meaning is illustrated by a couple of examples. Someone who died at age 30 and left a complete skeleton for study would provide 166 person-years of information for the index: 30 years each for stature, hypoplasias, and anemia; 10 years for each of the remaining attributes in the 10 years prior to death; and 36 years for dental and degenerative joint disease, which are assumed to be absent up to age 18. A child who died at age 8 and left a complete skeleton would provide 56 person-years of information (8 years for each of seven attributes). A complete skeleton that typified the reference population (died at age 26) would provide 150 person-years. Dividing the last column of the table by this number gives a rough sense of the whole skeleton equivalents, but we caution that this procedure does not take into account the distribution of ages-at-death. Moreover, because many skeletons were incomplete, the number of individuals studied is greater than the result would suggest. Nevertheless, any site with fewer than 2,000 to 3,000 person-years is small, and the results should be regarded with caution.

Table 3.3: Health Index as a Percent of Maximum, Attribute Scores, and Person-Years Observed by Site

Abbrev.	Site no.	Description	% of max.	Stature	Hyp.	Anemia	Dental	Inf.	DJD	Trauma	Person-yrs.
LNC	20	Coastal Brazil	91.8	*	88.4	100.0	82.9	*	93.4	94.4	1713
111	27	Coastal South Carolina	89.2	59.8	*	98.6	99.9	92.9	91.1	93.2	3764
LNP	21	Shell mounds, southern Brazil	87.1	*	75.4	83.6	87.3	*	98.0	91.2	9301
ESB	58	Estuquina, Peru	85.0	*	60.3	92.7	100.0	78.1	86.1	92.6	13019
301	29	Coastal South Carolina	83.8	31.7	92.4	92.6	93.7	92.2	100.0	*	6179
osg	12	Sta. Elena, Ecuador	83.4	8.7	99.7	100.0	91.1	98.7	94.8	90.8	4643
WO7	61	Coastal Southern California	82.4	42.8	85.0	96.1	97.4	83.8	78.6	93.4	30154
cot	13	Highland Ecuador	81.6	7.4	99.7	97.1	94.0	93.5	85.1	94.4	7991
BFT	54	Equestrian Nomad, Blackfoot	81.5	*	*	95.2	86.6	52.5	87.8	85.5	3948
201	28	Coastal South Carolina	80.9	24.3	*	98.4	94.5	83.3	88.2	96.8	18297
BU2	50	Plains village, Pawnee	80.4	21.0	*	99.2	89.0	89.9	90.6	92.5	7435
101	26	Coastal South Carolina	80.3	9.3	*	100.0	99.7	96.6	90.4	86.0	2630
W42	65	Coastal Southern California	80.0	18.6	81.6	95.5	84.5	92.0	100.0	87.7	16028
W38	64	Coastal Southern California	79.0	12.6	89.4	*	95.0	*	100.0	98.1	2055
dk2	46	Plains village, Omaha	78.9	27.2	*	99.8	91.0	86.3	82.4	86.8	3938
KIT	31	Archaic, Great Lakes region	77.9	48.2	92.2	94.5	75.2	83.1	67.8	84.2	11288
rea	11	Realto, Ecuador	77.3	1.2	96.4	99.3	79.4	95.8	80.5	88.4	4786
BUF	35	Buffalo, Great Lakes region	77.3	36.5	88.3	91.9	64.4	86.2	79.3	94.9	8828
sfa	18	San Francisco church, Ecuador	76.9	16.9	99.4	99.6	62.1	98.3	89.8	72.2	1536
KX1	47	Plains village, Ponca	76.4	2.7	*	100.0	92.5	78.8	89.1	95.5	1718
W13	63	Coastal Southern California	76.3	20.4	82.7	87.6	80.7	89.5	91.8	81.6	23596
CRW	48	Equestrian Nomad, Crow	75.9	49.9	*	93.0	90.6	49.3	82.3	90.2	4350
W28	60	Coastal Southern California	75.7	12.2	87.2	90.5	83.9	84.6	85.2	85.8	34194
lib	16	South coast, Ecuador	75.1	2.7	89.1	93.1	81.8	94.1	77.3	87.6	9730
DW2	49	Plains village, Arikara	75.1	16.8	*	99.3	83.1	87.1	72.6	92.0	3573
3AM	52	Plains Arikara & Oneota	74.5	23.7	*	94.0	78.7	67.4	90.6	92.7	2206
WW7	51	Plains village, Arikara	74.4	17.2	*	97.4	84.3	87.0	76.8	83.6	7215

FAB	1	Baptist Church, Philadelphia	73.8	49.3	66.4	96.9	64.9	81.5	69.1	88.6	8069
PEA	32	Pearson, Great Lakes region	73.7	33.9	70.5	97.1	67.3	79.7	76.4	90.9	8552
303	30	Coastal South Carolina	73.6	22.4	*	92.9	90.7	53.8	82.2	99.5	10591
MON	34	Monongahela, Great Lakes region	72.9	24.5	93.5	92.0	62.8	81.0	73.1	83.2	11007
CHY	53	Equestrian Nomad, Cheyenne	72.9	47.8	*	99.2	89.5	76.3	81.4	43.4	2591
WLE	59	Northern California	72.8	36.1	60.4	97.2	81.3	89.0	68.5	77.1	11674
lat	14	North coast, Ecuador	72.7	6.8	94.2	100.0	89.7	58.1	71.4	88.7	3306
HPK	10	Rochester NY poorhouse	72.3	33.0	80.1	96.1	71.7	54.0	79.3	92.1	31641
SF1	19	San Francisco church, Ecuador	72.2	12.8	91.0	99.7	67.9	95.2	78.9	59.8	3563
SUN	33	Sun Watch, Great Lakes region	71.6	31.6	83.3	89.3	68.9	66.7	75.2	86.5	10557
cry	2	Eastern U.S.	71.3	28.2	43.3	96.9	73.6	68.6	88.7	100.0	2664
snt	15	Quito convent, Ecuador	71.0	4.8	89.1	95.7	69.3	84.8	94.6	58.8	849
sfc	17	San Francisco church, Ecuador	70.9	3.7	98.6	94.6	71.8	72.8	79.8	75.0	3482
ftl	7	Military, East	70.4	31.7	98.6	94.8	74.0	84.1	85.1	24.8	3888
AZ1	44	Maitas Chirb., Chile	69.8	1.1	*	99.8	73.5	98.2	76.2	*	8127
W43	62	Coastal Southern California	69.8	20.2	97.4	*	87.2	54.5	69.9	89.6	7627
41D	6	Texas frontier	69.5	42.8	53.9	94.5	85.9	46.6	74.0	89.0	71159
Y1B	57	Yaral, Peru	69.4	1.2	*	87.1	100.0	71.5	56.8	100.0	4159
stt	9	Belleville, Ontario, Canada	69.3	36.0	71.8	93.9	71.2	81.5	41.6	89.2	44180
MR1	45	Coastal Chile	68.6	0.4	*	88.4	86.4	86.1	81.5	*	5097
3C9	3	Folly Island Union troops	68.5	41.6	39.0	100.0	74.9	46.9	82.5	94.3	918
TL2	41	Tlatilco, Mexico	68.4	13.2	75.1	86.6	76.5	54.2	80.1	93.0	33758
SGB	56	San Geron., Peru	67.8	4.0	*	79.6	89.3	72.7	61.3	100.0	5590
XCA	43	Xcaret, Mexico	67.7	28.4	67.3	70.3	81.8	50.5	79.1	96.8	3237
CHB	55	Chiribaya, Peru	67.5	3.2	48.4	87.5	86.4	80.1	67.7	98.8	13122
GPS	8	Military, West	66.2	40.6	70.8	96.4	74.3	92.1	78.1	10.8	3602
CO1	42	Cuicuilo, Mexico	66.1	7.9	80.5	90.5	84.1	45.2	69.3	85.1	17858

(continued)

Table 3.3 *(continued)*

Abbrev.	Site no.	Description	% of max.	Stature	Hyp.	Anemia	Dental	Inf.	DJD	Trauma	Person-yrs.
CUI	39	Cholula, Mexico	66.0	7.6	70.7	76.1	80.2	55.5	79.9	92.1	11881
3La	5	Cedar Grove, Arkansas	65.5	67.8	9.8	87.2	77.6	55.0	85.6	75.6	7008
J73	40	Jaina, Mexico	64.5	3.1	54.4	75.7	89.6	58.2	74.2	96.1	5232
teo	25	Tlatinga, Mayan	61.7	12.5	20.3	89.2	88.5	59.7	72.5	89.1	4397
dol	36	Dolores, Colorado	59.8	7.9	34.8	55.0	79.1	91.0	66.8	83.8	2841
QUI	22	Northern Chile	59.1	1.9	71.2	90.0	55.3	64.1	51.4	80.2	20557
co9	23	Copán, Rural, Mayan	59.0	6.0	18.7	82.1	85.1	46.9	81.9	92.2	22168
cop	4	Copán, Mayan	58.4	28.4	35.6	74.3	67.9	44.1	64.0	94.2	4651
3C7	24	Plantation slaves, SC	58.4	3.2	42.7	57.1	81.3	49.5	77.0	98.3	6958
la8	38	San Cristobal Pueblo, NM	57.3	1.7	46.5	53.2	78.5	88.1	52.8	80.2	21118
haw	37	Hawikku, NM	53.5	4.0	26.9	55.8	73.6	80.0	50.0	84.3	13751
Mean			72.6	20.7	71.1	90.5	81.8	75.1	78.9	85.7	
s.d.			7.98	16.86	24.59	11.53	10.39	16.97	12.26	16.12	
Median			72.8	17.2	77.8	94.5	82.9	80.6	79.8	89.4	
Min.			53.5	0.4	9.8	53.2	55.3	44.1	41.6	10.8	
Max.			91.8	67.8	99.7	100.0	100.0	98.7	100.0	100.0	

Note: *denotes data are missing or were not collected for the attribute at that site.

Table 3.4: Correlation Matrix of the Health Index and Its Components

	% of max.	Stature	Hyp.	Anemia	Dental	Inf.	DJD	Trauma
% of Max.	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

Source: Calculated from Table 3.3.

indicators of general health. It is interesting that trauma was weakly associated with the overall index, a finding that holds even if the three military sites are removed from the database. Trauma was surprisingly egalitarian: The individuals at both the healthy and the unhealthy sites were subject to injury that left broken bones. Fractures and expressions of violence were mildly and negatively correlated with several other health attributes. Note, too, that the correlations between the attribute scores were generally low (only one – that between signs of anemia and hypoplasias – exceeds 0.50, amounting to only 0.55), which points to the importance of relying on multiple indicators of health. In short, no single attribute of health substitutes well for others.

IV. SOME IMPLICATIONS

In recent years, a small industry of researchers has emerged to interpret the experience of Native Americans in the Western Hemisphere. While the neglect of Native American history by serious scholars is regrettable, the recent contributions to the literature by historians are, as a whole, idiosyncratic. There has been little exchange of views or cross-fertilization of ideas between historians and physical anthropologists. In their isolation, historians have focused heavily, if not obsessively, on population size in 1492 and on the decimation of Native Americans in the aftermath of contact (see, for example, Cook, 1981; Dobyns, 1983; and Stannard, 1989). Criticism can also be directed at physical anthropologists for failure to tailor their publications and shift their research energies in the direction of questions of interest to the large audience of historians and other social scientists.

While population size in 1492 and the aftermath of contact are certainly interesting questions that are important for Native American history, our results suggest that a richer, more diverse experience is worth exploring. Moreover, population size is, at best, a crude measure of health or the quality of life, and there is a pressing need to place conditions in 1492 and thereafter in long-term perspective. The huge variations in health witnessed by Native Americans prior to 1492 call for explanations and interpretations. The Western Hemisphere before the arrival of Europeans was so diverse that parts of it, at certain times, were like a Garden of Eden or an impoverished wasteland of health by standards of world history prior to the twentieth century. For this reason, it is highly misleading to speak of the health or quality of life of Native Americans as if it was relatively homogeneous, or as if conditions in 1492 were typical.

Euro-Americans and African-Americans tended to occupy the middle and lower portion of the distribution, an intriguing niche in the rankings of health. Comparisons of stature and mortality rates in the eighteenth and nineteenth centuries suggest that Euro-Americans were better off than Europeans. Therefore, skeletal data for the latter might place them very low in the rankings. One might suppose that Europeans in Europe, and especially in the Americas, would have done better given their notable technology, their access to resources, and their institutions of commerce, law, and politics that were placed in the service of global colonization. If these aspects of European or Euro-American life were advantageous, then there must have been significant disadvantages, as least for health, to their way of life.

It may be tempting to argue that most Europeans were victims of inequality. Perhaps their societies were rich and prosperous on average, but only a few lived well while the vast majority accumulated pathological lesions. While Europe in the eighteenth and nineteenth centuries is notable for its inequality, Euro-Americans had no such burden. Occupational differences in stature, for example, were virtually nil on the eve of the American Revolution (Sokoloff and Villaflor, 1982). It has been argued that inequality increased in nineteenth-century America, but it seems hard to believe that a major transformation could have occurred by the middle of the 1800s. The skeletons studied at the Belleville, Ontario, site represented middle- and upper-class Euro-Americans who were not oppressed by inequality, yet they attained only 65.5 percent of maximum quality-adjusted life-years – below the median for the Western Hemisphere sites as a whole.

In searching for explanations, it is useful to consider the advantages that Native Americans may have enjoyed. In the early stages of settling the Western Hemisphere, prime sites were available, resources were remarkably abundant, and population density was very low. In a diverse and resource-abundant environment, there may have been little need for trade, and moreover, low-population density and frequent moves related to local resource depletion probably inhibited commercial relationships and the spread of communicable diseases. Rates of exposure to infectious diseases were very low and food was abundant, resulting in few skeletal signs of chronic conditions.

Increasing population density and depletion of the resource base, including the decline of megafauna, may have been dynamic factors contributing to a long-term deterioration in health. Climatic change was likely a factor in the biological stress noted at some sites, including those in the Southwest. Social scientists often associate technological change with progress and higher living standards, but new methods or devices need not improve health if they were accompanied by repetitive movements that led to DJD, injuries, or the spread of communicable diseases. The cycles in height found in the United States and in the United Kingdom during industrialization are cases in point (Steckel and Floud, 1997).

More relevant to the situation at hand, the development of corn, beans, and other crops associated with the rise of settled agriculture may have led to a decline in dietary diversity and the spread of communicable disease. Political upheavals and warfare no doubt played some role in overall patterns of health among Native Americans.

V. SUGGESTIONS FOR RESEARCH

The health index is capable of refinement, and we hope that these preliminary efforts inspire research to clarify the meaning and enhance the consistency of comparisons across sites. Several assumptions that underlie the Mark I version, while perhaps reasonable, are not easily justified in the face of plausible alternatives. We plan sensitivity tests on several assumptions, examining the outcomes for important changes in rankings. For example, the window of time on health provided by skeletons might be changed in light of research on the rate at which various pathologies are remodeled. As an experiment, the window of time might be changed from 10 to 8 or 12 years for dental, infections, degenerative joint disease, and trauma. Alternatively, we could allow dental health and degenerative joint disease to decline linearly (or even nonlinearly) from age 18 to death (for those who died after age 18). It would be desirable to undertake research that could establish the length of time that lesions had existed, which would clarify the longitudinal picture of functional impairment.

The methods for calibrating DJD scores could be made more extensive and realistic, using likely functional impairments at various joints as a guide. Indeed, the functional implications of DJD, as well as other components of the health index, clearly depend upon culture, lifestyle, and technology in use. Severe DJD, for example, is much more disabling among hunter-gatherers constantly on the move and requiring considerable physical labor than in a society assisted by a variety of mechanical devices and pain medications. Similarly, loss of teeth becomes less consequential if mechanical devices and methods of preparation are available to soften food, and even less so if techniques of modern dentistry are available.

The method of tabulating stature scores uses average stature (femur length) as a standard, but sometime in the distant future, research might make it possible to use genetic material, in its place, to assess individual potential for growth. This step would be particularly useful in comparing the health of numerically small populations, where genetic differences may not approximately cancel.

It is reasonable to think about adding other attributes to the index. We chose the seven based on widespread availability, low cost of collecting, and general acceptance as reflecting important aspects of health. Components such as stature, dental health, and degenerative joint disease speak to general aspects of health during childhood and in the aging process. But these measures give an incomplete picture of health as might be learned from skeletons (and of course, an even less complete picture of health in general). As more components are added, though, especially those that are less general indicators of health, then weighting them according to functional significance becomes even more important.

Research should be done on the implications of weighting the age-specific quality scores by person-years lived in a Model West level 4 life table. Ideally, all populations compared by using the health index (the present, Mark I version) should have about the same life expectancy, and one close to this level. At this point, we do not know (with any reasonable confidence) the actual levels at most of the sites (see McCaa's chapter in this volume), but we impose this assumption in the belief that most of the populations (with the exception of the Rochester poorhouse) fell into a premodern range of roughly the low 20s to the middle 30s, where distortions would not be so great as to lose most of their comparative value. It is clear from the methodology expressed in Figure 3.1 that departures from approximate equality in life expectancies will distort comparisons of health, defined as reflecting both length of life and health quality of life while living. Hence, it is important to improve the reliability of life expectancy estimates, and to modify the health index to incorporate length of life, that is, to better estimate the area under the curve in Figure 3.1 (adapted to a group).

It would be interesting to know more about the possible effect of incomplete skeletons, that is, whether the assumption that bones are missing at random has any important impact on the health index. We will have greater confidence in our procedures if the results are highly correlated under alternative assumptions.

Inequality of health may be studied using the index in the same way that inequality of income or wealth is studied for insights into access to resources. We would like to know, for example, how men and women fared and the extent to which there were differences across classes within societies. The sample sizes are sufficiently large at some sites for this type of analysis.

This chapter merely scratches the surface of the possible causes and consequences of the social, economic, and historical implications of these new measures of health. Investigations of the data are still in the exploratory stage. In the chapter on "Patterns of Health in the Western Hemisphere," we link variations in the health index and its components with such site characteristics as settlement size, topography, plants and animals available for use, and climate. We seek explanations for the long-term decline in health among Native Americans before the arrival of Columbus and for geographic and ethnic patterns of health.

We caution that the health index tabulations should not be viewed as the end product of research, the last things to be done in a research agenda. In an important sense, they should be only the beginning. The index and its components should be objects of study, to be explained by various environmental or ecological variables. It is also important to probe whether the assumptions of the index approximately fit the sites under comparative study with respect to life expectancy, functional implications of impairments, the relevance of skeletal aspects of health not captured by the index, and so forth. Thus, the index should not be taken mechanically at face value, but explored for its weaknesses and for explanations of the patterns observed.

In sum, we have proposed what should be regarded as only an important first step – a work in progress – toward measuring health from skeletal remains. Thorny questions remain and much research lies ahead. But the concept of the health index is a flexible one that can be adapted to incorporate changes that research may bring.

And where empirical evidence may be lacking for its assumptions, sensitivity analysis will provide a range of plausible outcomes that can be compared.

APPENDIX: DATA CODING SCHEME

Introduction

The goal is to develop a numerical index of well-being (adaptation) from skeletal data. Knowledge of both economic indicators (such as gross national product) and health status assessments suggests that useful indexes can be developed from imperfect data. Our collection of skeletal data comes from a large array of genetic, geographic, and temporal groups, which permit us to measure levels of health and to investigate their possible environmental causes.

Inevitably, projects such as this face a trade-off between number of observations and the detail collected per observation. We emphasize number of observations (large number of individuals at a variety of sites) over detail (a complex coding scheme that records numerous features for each observation). We prefer this strategy (a cast of thousands) because diverse sites enhance our comparative perspective. Moreover, even simple coding schemes, such as the one adopted here, can be very effective in representing important aspects of health. For our purposes, the value of additional observations in a variety of ecological settings outweighs extraordinary detail on health for a smaller number of individuals at fewer sites.

Site/Collection Identification

The given skeletal collection is identified by eight (8) alpha / numeric characters. These could be a site number (e.g., 23CG0234) or an abbreviated name (Cedargro).

Individual Identification

Each individual is identified with a unique series of five (5) alpha / numeric characters (e.g., 00345 or 0956B).

Inventory

Any statistical study of lesions must provide information about observable skeletal components. Thus, the coding scheme contains a category indicating that the appropriate skeletal components were available for observation. Any data available for a skeleton was recorded.

Demography

The age and sex distributions of a population reflect mortality and fertility, which are the ultimate measures of adaptive success in past human groups. Moreover, these distributions are useful for delineating differential effects of disease, nutrition, and stress generally by specific age, sex, and status groups.

Sex. It is assumed that the methods employed in the determination of sex are those used in standard analysis. A definite designation is one in which criteria from the pelvis, especially the pubis, is clear and used in conjunction with additional features. The pelvis can, at times, produce ambiguous sex information and thus result in an unknown or probable designation. A probable designation is employed when the pelvis cannot be used but cranial and postcranial attributes predominately indicate one sex or the other. Any designation using fewer than four nonpelvic criteria must remain in the unknown category.

The sex of the individual is designated with the single numeric code as follows: 1) Female, definite designation, the sex is certain; 2) Probable Female, possible designation, but the investigator is uncertain; 3) Male, definite designation, the sex is certain; 4) Probable Male, possible designation, but the investigator is uncertain; 5) Sex is undetermined because the individual is less than 15 years of age and sex determination would be uncertain; 6) Unknown, the sex of the individual cannot be determined with any degree of reliability.

Age. There are a number of aging techniques and many investigators use one technique more effectively than others. Dental development is considered the best for the youngest ages, while epiphyseal closure is used for the later growing years. Adult ages determined from the pubic symphysis and auricular surface of the pelvis are considered the most reliable. There are three columns for recording age: 1) summary age; 2) dental age for children; and 3) age range.

Summary age: The investigator is asked to designate a single year (i.e., 37) as the age-at-death. This is the best estimate that the investigator can make. In its simplest form without additional information, this age is nothing more than the midpoint of the designated age range. Age is given in years using decimals to designate tenths of years (conversion of months). Individuals aged greater than 60 years, and for whom no further estimate is possible, are coded as 99. Summary age is recorded as a four (4) digit numeric field with one decimal place (e.g., 00.6 or 35.5).

Dental age: A dental age for children is required for the growth analysis. In many cases the dental age and the summary age are the same; however, this category uses only dental development, whereas the summary age may stem from other sources of information. Dental age is recorded as a four (4) digit numeric field with one decimal place (e.g., 03.4).

Age range: It is preferable to use standardized age ranges (i.e., 50–54 years), but the data to be coded were already collected and age ranges differ between investigators. On this variable we could not expect true concordance after the fact. The investigator provided the age range in years for that individual. For categories such as subadult or old adult, the investigator defined this category by providing an age range in years. If such ranges are being determined for this project, then standard five-year intervals (i.e., 30–34 years) are employed. Age range is recorded as two numeric fields with two characters in each. The first represents the minimum age (e.g., 30) and the second the maximum age (e.g., 45).

Date of birth: Where known, the date of birth or decade (by using the midpoint, i.e., 1915) is recorded. Date of birth is a single field with four (4) numeric characters.

Continental Ancestry

Each skeleton is assigned to one of these populations of origin: 1) Native American; 2) European; 3) African; 4) Asian; 5) Mixed, any mixture of the above. This code is based on the site context or from the historic literature. Although there are various degrees of mixture in some of the groups, we cannot reliably estimate the mixture for an individual skeleton; 6) Unknown. Continental ancestry is a single character numeric field.

Social Status

An individual's position in a social hierarchy (i.e., social status) can influence access to both luxury items and/or necessities of life (e.g., adequate housing, nutrition, etc.). Thus, social status can have considerable influence on such biological characteristics as height, as well as determining resistance to disease (e.g., impairment of the immune system), physical work load (e.g., seen as increase in degenerative joint disease), and so on.

For some of the skeletal populations, there is clear evidence of social/economic distinctions evident from either the historical records or grave goods (i.e., differential access to luxury or scarce items). Each individual receives a three digit code. The first designates the stratification category of the society, the second indicates the number of strata, while the third indicates that person's place within the society.

Social Stratification Codes. 1) Denotes undifferentiated societies, reflecting the lack of significant differences in social stratification observable in the grave goods, and in archaeological or historical evidence. If there is any doubt whether the presence of grave goods had any status meaning, these individuals or groups are placed here; 2) A ranked society is one in which there are social differences with groups or individuals having clear differential access to luxury or exotic goods. Membership in this category may be determined from either grave goods or historical records, including archaeological interpretation; 3) A class stratified society is one in which there are social differences with groups or individuals having clear differential access to wealth and/or subsistence resources. Assignment to this category may be determined from either grave goods or historical records, including archaeological interpretation.

Number of Social Stratification Code. The number of distinct social strata in the culture is designated by number. An undifferentiated society is coded as 1, a three strata society as 3, and so on.

Individual Position Codes. 1) The person occupies the highest rank in a ranked society or is a member of an undifferentiated society; 2) The person occupies the second from the highest rank in a stratified society; 3) The person occupies the third from the highest rank in a stratified society; 4) The person occupies the fourth from the highest rank in a stratified society; and so on.

Social Stratification Coding. The coding of social stratification uses a three digit numeric code with the first designating the presence or kind of stratification in the society, the second the number of social strata, and the third the position of the individual in the social ranking. For example, a person in an undifferentiated society is coded as 111. A person in an historic class society could be coded as 331 (a class society, three classes, person belongs to highest class). If all that can be determined is that the society is ranked with only tendencies for high or low social status, then the code might be 222 for a ranked society, two levels, with the person belonging to the lower social status.

Growth and Heights

Maximum Diaphyseal Length. Height for dental age is an excellent indicator of nutrition and overall health of children. Maximum diaphyseal lengths of the femora (left is first, then right, if left is unavailable) are used to calculate growth statuses of juveniles using ages determined from dental development. Only the diaphyseal length (no epiphyses) is recorded here. This field contains three numeric characters for the measurement in millimeters.

Femur Length. Adult height is an excellent indicator of nutrition and health during childhood. The variable recorded is the maximum length of the left femur (right if left is unavailable). If necessary, femur length was estimated from other bones using regression formulae. The field contains three numeric characters and the lengths are recorded in millimeters.

Adult Height. The various formulae for calculating stature from the maximum length of the femora or other bones are available in Krogman and Iscan (1986; American Whites and Blacks page 308, Mongoloids page 310, and Indigenes of Central Mexico pages 319–320) and Sciulli et al. (1990: 275–280, Native Americans). The recorder calculated the heights. Heights are recorded in a four character numeric field in millimeters.

Robusticity

Femur. Robusticity provides information on body weight, past diet, current physiological health, work and activity patterns, and degree of mobility. The total subperiosteal area (TA) of the adult femur is most responsive to the combined effects of mechanical demand/physical activity and body weight, but activity is likely most important in behavioral interpretation. The anteroposterior (AP) and mediolateral

(ML) diameters of the adult left femoral midshaft (right if the left is unavailable) is recorded in order to calculate TA. The formula for this calculation is (from Fresia et al. 1990):

$$TA = \pi \, (Tap/2)(Tml/2)$$

where

Tap = anteroposterior diameter at midshaft, and

Tml = mediolateral diameter at midshaft.

Human populations vary widely in body size and, consequently, in femoral size. Therefore, it is absolutely essential that the measurement of TA be standardized when comparing populations. This can be done easily by dividing TA by femoral length to the third power in the following manner (Ruff et al. 1993):

$$TA_{standardized} = [\pi \, (Tap/2)(Tml/2)]/\text{max. length cubed.}$$

The anteroposterior (AP) and mediolateral (ML) diameters of the femur midshaft are recorded in millimeters in two fields each of two numeric characters.

Humerus. Robusticity data for the adult humerus is provided by the maximum length and the circumference of the midshaft. These two measurements in millimeters are entered into two fields, the length with three numeric characters and the circumference with two numeric characters.

Enamel Hypoplasias

Enamel hypoplasias are excellent measures of childhood nutritional and morbidity stress, which complement growth rates and adult stature for reconstructing past health. Although they cannot be remodeled, they can be removed by wear and caries. Hypoplasias are reported only on the maxillary incisors and either the mandibular or maxillary canines for both deciduous and permanent teeth. The hypoplasias recorded are only linear grooves that can be clearly seen with the unaided eye under good illumination.

Hypoplasias are recorded for 1) deciduous maxillary central incisor; 2) deciduous canine (maxillary or mandibular); 3) permanent maxillary central incisor; and 4) permanent canine (either maxillary or mandibular). There is one column for each of these teeth. Only systemic hypoplasias are recorded, and the left teeth are used, but rights are reported if lefts are not available. The four teeth are scored as follows: 0 Not observable (no suitable teeth, incomplete development, or too worn, etc.); 1 No hypoplasia; 2 One hypoplasia; 3 Two or more hypoplasias.

Dental Disease

Dental Caries. Caries results from a disease process, and without intervention it results in complete destruction and loss of the affected tooth. In most groups, dental caries is the primary cause of abscessing and loss of teeth. However, there are some groups where rapid wear leads to abscessing and tooth loss, while in others, periodontal disease is the primary cause. The data are recorded for the permanent dentition only, as follows: 1) The total number of permanent teeth observed; 2) The total number of permanent teeth lost before death (antemortem); 3) The total number of teeth with lesions or restorations (i.e., fillings).

The data reported here are used to calculate individual (percent of carious teeth per mouth) and population (percent of total carious teeth per group) statistics on caries prevalence. There are three fields, each with two numeric characters.

Abscess. Abscesses can result from progressive caries or from tooth wear rapid enough to exceed the dentin's ability to fill the pulp chamber. In some cases the cause is not obvious (the loss is spontaneous). There is evidence that abscesses can be life threatening or, at the very least, diminish resistance to disease and, even more than caries, affect dietary intake. Abscesses are recognized by a clear drainage passage leading from the tooth root(s) to the external surface of either maxilla or mandible. The data are recorded in two fields: 1) two numeric characters for the total number of sockets examined; and 2) one numeric character for the total number of abscesses.

Anemia

Anemia (as indicated by cribra orbitalia and porotic hyperostosis) can be caused by a variety of factors, including an iron-deficient diet, disease, and parasites. Scoring these conditions can be very complicated, but the information contained in the various skeletal expressions can be obtained by a simple scoring system. Cribra orbitalia and porotic hyperostosis are scored separately. To score as present or absent, at least one parietal and one orbit must be observable. Scattered fine pitting of parietals and occipital, sometimes called porotic pitting, is not scored as positive. There are two fields, each with one numeric character.

Cribra Orbitalia is scored as: 0 No orbits to be observed; 1 Absent on at least one observable orbit; 2 Presence of a lesion; 3 Gross lesions with excessive expansion and large area of exposed diploe, which is the form associated with sickle-cell disease and other severe forms of anemia.

Porotic Hyperostosis is scored as: 0 No parietals to be observed; 1 Absent on at least one observable parietal; 2 Presence of a lesion; 3 Gross lesions with excessive cranial expansion and huge areas of exposed diploe, which is the form associated with sickle-cell disease and other severe forms of anemia.

Auditory Exostosis

It has been demonstrated that auditory exostoses (i.e., growth of extra bone occluding the ear canal) are associated with swimming in cold water. These growths do impair hearing and are recorded as follows: 0 At least one auditory meatus not present for observation; 1 Auditory meatus exhibits no exostosis; 2 Exostosis present in one or both ears.

Infection / Periosteal Reactions

Infections of the bone (primarily by ubiquitous *Staphylococcus* or *Streptococcus* organisms) can be quite serious and debilitating because they are very difficult for the body's defense mechanisms to combat. All such infections result in pain and swelling (with possible disfigurement), and interfere with normal activities. In addition, the infections are a burden on the individual's defense mechanism, which can result in reduced resistance to other disease processes.

Infectious lesions are complex to score because they can be isolated and minor, localized but chronic and debilitating, or the result of systemic disease. The skeletal sequelae of infection can exhibit the characteristics of active ongoing infection or the healing scars of past disease. Some periosteal reactions can result from trauma (bruising of the bone's periosteum), and these may be difficult to distinguish from infection. However, as most periosteal reactions are due to infection, they are scored as such unless the recorder has some reason to think otherwise. In order to ensure consistency of reporting, only major lesions of the major long bones are employed in the development of the index. Active and healed lesions are not differentiated. We focus almost exclusively on the tibia, which is the most common site for infectious lesions. There are two sets of scores, with the first being for the tibiae and the second for the remainder of the skeleton. Each of the fields contain one (1) numeric character.

Tibial Scores: 0 No tibia(e) present for scoring; 1 No infectious lesions of the tibia(e) with at least one tibia available for observation; 2 Slight, small discrete patch(es) of periosteal reaction involving less than one-quarter of the tibia(e) surface on one or both tibiae; 3 Moderate periosteal reaction involving less than one-half of the tibia(e) surface on one or both tibiae; 4 Severe periosteal reaction involving more than one-half of the tibia(e) surface (osteomyelitis is scored here).

Remaining Skeleton: 0 No periosteal reaction on any other bone than the tibiae; 1 Periosteal reaction on any other bone(s) than the tibiae not caused by trauma; 2 Evidence of systemic infection involving any of the bones (including the tibiae) of the skeleton. This would include specific diseases, such as (but not limited to) tuberculosis and syphilis.

Degenerative Joint Disease

Degenerative joint disease provides considerable information concerning activity patterns because chronic stress on the joints eventually damages the cartilaginous surfaces and, when sufficiently advanced, also the bone surface beneath. Within a given population, those individuals engaged in regularly occurring activities that produce chronic joint stress (e.g., rowing, running, etc.) will develop patterns (i.e., specific joints affected, such as knees or elbows) of degenerative joint disease differing from that in the general population. In addition to differences in the pattern of joints affected, variation in the age at which the damage appears can be informative.

Degenerative diseases can be difficult to score consistently and yet can be very informative even when recorded with great simplicity. There are eight (8) fields, each with one numeric character: 1) shoulder and elbow; 2) hip and knee; 3) cervical; 4) thoracic; 5) lumbar vertebrae; 6) temporomandibular joint; 7) wrist; and 8) hand. The most severe manifestation from either the right or left side is scored.

Shoulder and Elbow are scored as one unit, and if either joint is affected (score the most severely affected joint), it is scored as follows: 0 Joints not available for observation; 1 Joints show no sign of degenerative disease; 2 Initial osteophyte or deterioration of the joint surfaces; 3 Major osteophyte formation and / or destruction of the joint surface, such as eburnation; 4 Immobilization of the joint due only to degenerative disease; 5 Systemic degenerative disease (e.g., rheumatoid arthritis, alkaptonuria, etc.).

Hip and Knee are scored as one unit, and if either joint is affected (score the most severely affected joint), it is scored as follows: 0 Joints not available for observation; 1 Joints show no sign of degenerative disease; 2 Initial osteophyte or deterioration of the joint surfaces; 3 Major osteophyte formation and / or destruction of the joint surface, such as eburnation; 4 Immobilization of the joint; 5 Systemic degenerative disease.

Vertebrae are scored by type: cervical, thoracic, and lumbar. If four or more thoracic vertebrae are present, they are scored, and if two or more cervical or lumbar are present, they are scored. Only the bodies of the vertebrae are scored for the most severe expression:

Cervical: 0 Not observable; 1 No lesions on at least two observable vertebrae; 2 Initial osteophyte formation along rim of the vertebral body(-ies); 3 Extensive osteophyte formation along rim of the vertebrae; 4 Two or more vertebrae fused together.

Thoracic: 0 Not observable; 1 No lesions on at least four observable vertebrae; 2 Initial osteophyte formation along rim of the vertebral body(-ies); 3 Extensive osteophyte formation along rim of the vertebrae; 4 Two or more vertebrae fused together (keeping in mind that kyphosis from tuberculosis would be scored under infectious disease and not here).

Lumbar: 0 Not observable; 1 No lesions on at least two observable vertebrae; 2 Initial osteophyte formation along rim of the vertebral body(-ies); 3 Extensive osteophyte formation along rim of the vertebrae; 4 Two or more vertebrae fused together.

Temporomandibular Joint. Deterioration of the temporomandibular joint (TMJ) can lead to difficulties in chewing, intense pain, and a large, poorly understood array of psychosomatic diseases. Only extreme deterioration is recorded. This is recognized at the level that degenerative disease would be recorded on any other joint, including osteophytes, eburnation, and joint surface deterioration: 0 TMJ not observable; 1 No deterioration; 2 Joint deterioration.

Wrist. Radio-ulnar joint: 0 Bones not observable or not recorded; 1 No degenerative disease of the joint; 2 Degenerative disease of the joint.

Bones of the hand. 0 Bones not observable or not recorded; 1 No degenerative disease of the joint; 2 Degenerative disease of the joint.

Trauma

Trauma provides information about many aspects of society and the relationship of the people to the environment. Different activity patterns and terrains produce different patterns of trauma. For example, walking on rocks tends to produce higher frequencies of fractured ankles, while in less rugged terrain, lower arm fractures tend to predominate. In addition, both intra- and interpopulational violence can be documented by specific types and patterns of trauma, such as parry fractures of the lower arm or depressed fractures of the cranium. The scoring of trauma focuses on the major bones of the limbs and the skull: humerus, radius, ulna, femur, tibia, fibula, and skull. Unless there can be shown to be premortem or perimortem traumata (e.g., saw marks of an amputation or axe wound), they are scored only when there is some evidence of healing. Any form of surgery would be recorded as trauma. It is critical that postmortem modifications or damage not be recorded.

There are seven (7) fields, each with one numeric character: 1) arm; 2) leg; 3) nasal bones; 4) face; 5) skull vault; 6) hands; 7) weapon wounds.

Arm: humerus, radius and ulna. If any bone shows trauma, it is scored as follows: 0 No long bones observable (must have humerus and at least one bone of the forearm to be scored); 1 Not fractured; 2 Healed fracture with acceptable alignment; 3 Healed and poorly aligned; 4 Healed with fusion of the joint; 5 Healed fracture with alignment unknown.

Leg: femur, tibia, and fibula. If any bone shows trauma it is scored as follows: 0 No long bones observable (must have femur and tibia or fibula); 1 No fracture or other trauma; 2 Healed fracture with acceptable alignment; 3 Healed and poorly aligned with some loss of locomotion; 4 Healed with extreme loss of locomotion, such as loss of limb or complete fusion of the joint in the lower limb; 5 Healed with alignment unknown.

Nasal and Nasal Process: 0 No bones to be observed; 1 No fracture; 2 Healed fracture.

Face Other Than Nasal: 0 No bones to be observed; 1 No fracture; 2 Healed fracture.

Skull Vault: 0 No bones to be observed; 1 No fracture; 2 Healed fracture.

Hand Fractures: 0 No bones to be observed or not recorded; 1 No fracture; 2 Healed fracture(s).

Weapon Wounds to Any Part of the Body and Head: 1 No weapon wounds; 2 Weapon wound(s).

REFERENCES

Bush, J. W., M. M. Chen, and D. L. Patrick. "Social Indicators for Health Based on Function Status and Prognosis," *Proceedings American Statistical Association* Soc.Stats.Section (1972): 71.

Cadman, David, Charles Goldsmith, George W. Torrance, et al. "Development of a Health Status Index for Ontario Children. Final Report to Ontario Ministry of Health." Research Grant DM648 (1986): (00633).

Coale, Ansley J., and Paul Demeny. *Regional Model Life Tables and Stable Populations.* New York: Academic Press, 1983.

Cook, Noble David. *Demographic Collapse: Indian Peru, 1520–1620.* Cambridge: Cambridge University Press, 1981.

Dobyns, Henry F. *Their Numbers Became Thinned: Native American Population Dynamics in Eastern North America.* Knoxville: University of Tennessee Press, 1983.

Drummond, Michael F., Greg L. Stoddart, and George W. Torrance. *Methods for the Economic Evaluation of Health Care Programmes.* New York: Oxford University Press, 1987.

Erickson, Pennifer, E. Allen Kendall, John P. Anderson, et al. "Using Composite Health Status Measures to Assess the Nation's Health." *Medical Care* 27 Supplement (1989): 66–76.

Feeney, David, William Furlong, George W. Torrance, et al. "A Comprehensive Multi-Attribute System for Classifying the Health Status of Survivors of Childhood Cancer." *Journal of Clinical Oncology* 10 (1992): 923–928.

Feeney, David, Roberta Labelle, and George W. Torrance. "Integrating Economic Evaluations and Quality of Life Assessments." In *Quality of Life Assessments in Clinical Trials,* ed. B. Spilker, 71–83. New York: Raven Press, 1990.

Frank, Peter, Marthe Gold, and Pennifer Erickson. "Do Utility-Based Measures of Health-Related Quality of Life Predict Future Health Status? Longitudinal Evidence from a Nationally Representative Cohort." 1992 (Unpub).

Fresia, Anne, C. B. Ruff, and Larsen, C. S. "Temporal Decline in Bilateral Asymmetry of the Upper Limb on the Georgia Coast." In *The Archaeology of Santa Catalina de Guale: 2. Biocultural Interpretations of a Population in Transition,* ed. C. S. Larson. Anthropological Papers of the American Museum of Natural History No. 68, pp. 121–132. Washington, D. C.: 1990.

Glasson, William H. *Federal Military Pensions in the United States.* New York: Oxford University Press, 1918.

Haddad, Lawrence J., and Howarth E. Bouis. "The Impact of Nutritional Status on Agricultural Productivity: Wage Evidence from the Philippines." *Oxford Bulletin of Economics and Statistics* 53 (1991): 45–68.

Hershcovitz, Israel, Bruce M. Rothschild, Bruce Latimer, Oliver Dutour, Georges Leonetti, Charles M. Greenwald, Christine Rothschild, and Lyman M. Jellema. "Recognition of Sickle Cell Anemia in Skeletal Remains of Children." *American Journal of Physical Anthropology* 104 (1997): 213–226.

Kaplan, Robert M., and James W. Bush. "Health-Related Quality of Life Measurement for Evaluation Research and Policy Analysis." *Health Psychology* 1 (1982): 61–80.

Keeney, R. L., and H. Raiffa. *Decisions with Multiple Objectives: Preferences and Value Tradeoffs.* New York: J. Wiley & Sons, 1976.

Krogman, Wilton M., and Mehmet Y. Iscan. *The Human Skeleton in Forensic Medicine.* Springfield, Ill.: Charles C. Thomas, 1986.

Lohr, Kathleen N. "Advances in Health Status Assessment: Overview of the Conference." *Medical Care* 27 Supplement (1989): 1–11.

Lovejoy, C. Owen, Richard S. Meindl, Robert P. Mensforth, et al. "Multifactorial Determination of Skeletal Age at Death: A Method and Blind Tests of Its Accuracy." *American Journal of Physical Anthropology* 68 (1985): 1–14.

Maresh, M. M. "Linear Growth of Long Bones of Extremities from Infancy Through Adolescence." *A.M.A. American Journal of Diseases of Children* 89 (1955): 725–742.

Pollit, E., K. Gorman, P. L. Engle, et al. "Nutrition in Early Life and the Fulfillment of Intellectual Potential." *Journal of Nutrition* 125 Supplement 4S (1995): 1111S–1118S.

Preston, Samuel H., and Michael R. Haines. *Fatal Years: Child Mortality in Late Nineteenth-Century America.* Princeton N.J.: Princeton University Press, 1991.

Rondinelli, Robert D. "Practical Aspects of Impairment Rating and Disability Determination." In *Physical Medicine and Rehabilitation,* ed. Randall L. Braddom, 109–124. Philadelphia: Saunders, 2000.

Ruff, Christopher B., E. Trinkaus, A. Walker, and C. S. Larsen. "Postcranial Robusticity in *Homo.* I: Temporal Trends and Mechanical Interpretation." *American Journal of Physical Anthropology* 91 (1990): 21–53.

Schultz, M. "The Initial Stages of Systematic Bone Disease." In *Histology of Ancient Human Bone,* ed. G. Grupe and A. N. Garland, 185–203. Berlin: Springer Verlag, 1993.

Sciulli, Paul W., K. N. Schneider, and M. C. Mahaney. "Stature Estimation in Prehistoric Native Americans of Ohio." *American Journal of Physical Anthropology* 83 (1990): 275–280.

Sokoloff, Kenneth L., and Georgia C. Villaflor. "The Early Achievement of Modern Stature in America." *Social Science History* 6 (Fall 1982): 453–481.

Stannard, David E. *Before the Horror.* Honolulu: University of Hawaii Press, 1989.

Steckel, Richard H. "A Dreadful Childhood: The Excess Mortality of American Slaves." *Social Science History* 10 (1986a): 427–465.

"A Peculiar Population: The Nutrition, Health, and Mortality of American Slaves from Childhood to Maturity." *Journal of Economic History* 46 (1986b): 721–741.

"The Health and Mortality of Women and Children, 1850–1860." *Journal of Economic History* 48 (1988): 333–345.

Steckel, Richard H., and Roderick Floud, eds. *Health and Welfare during Industrialization.* Chicago: University of Chicago Press, 1997.

Torrance, George W., M. H. Boyle, and S. P. Horwood. "Application of Multi-Attribute Utility Theory to Measure Social Preferences for Health States." *Operations Research* 30 (1982): 1043–1069.

Torrance, George W., and David Feeney. "Utilities and Quality-Adjusted Life Year." *International Journal of Technology Assessment in Health Care* 5 (1989): 559–575.