Sub-Adults in the Bioarchaeological Record

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Introduction and Overview

Context and Terminology

Recently, the interest in sub-adults in the archaeological record has increased in response to a greater appreciation of their contribution to anthropological study; especially in the area of gender studies (see Baxter 2005). Beginning with Mead in 1955, several ethnographic studies have been carried out in the anthropological school of "culture and personality" (Baxter 2005:4). However, it has only been recently that archaeologists have seriously begun to reconsider the topics of childhood in archaeology and the "unknowable" status of children in antiquity (Baxter 2005:9). This reconsideration has been facilitated by improvements in methods of age determination as well as emerging technologies and methodologies for sex determination of sub-adult skeletal remains.

This article is in response to the growing interest in the archaeological sub-adult record and attempts to bring together recent literature on the theories and methodologies currently employed in the study of sub-adult human skeletal remains.1 The focus of this literature review is on the theories and methodologies used in the analysis and interpretation of pathological conditions in sub-adult skeletal remains, emphasizing the importance of accuracy when coming to conclusions and conservatism in conclusions where accuracy cannot be obtained.

Sub-Adults in the Archaeological Record

The ratio of adults to sub-adults in the archaeological record is often biased in favour of adults. Scheuer and Black (2004:18) note that this bias in a demographic profile is due to "the under-representation of the immature component of a skeletal sample". Sub-adults account for approximately 50 percent of a population (Kamp 2001:9), a fact that indicates how significant this bias is in much of the literature on ancient populations. This under-representation is likely due to a combination of factors including the poor preservation of infant skeletons, research designs that do not include sub-adults and the subsequent low retrieval rates of sub-adult skeletal material at excavation, cultural factors that influence burial locations, as well as socio-economic factors (Kamp 2001:9; Roberts and Manchester 2005:178; Scheuer and Black 2004:18-19). Several other authors (e.g., Blondiaux et al. 2002; Kamp 2001; Pfeiffer and Crowder 2004) have drawn attention to the paucity of sub-adult remains and the lack of data on those collections that do exist. Pfeiffer and Crowder (2004:24), in their analysis of an infant skeleton with rickets due to vitamin D deficiency, point out that a photograph and an inventory of this infant skeleton were published previously in the literature, yet no mention was made of the abnormal nature of its bones. As Pfeiffer and Crowder (2004:23) indicate, "it was in the context of a broader documentation that the infant skeleton described here was noted."

The study of adult skeletons can often provide insight into the health of sub-adults through the study of childhood stress indicators on adults who had survived childhood stress events (Kamp 2001:9). However, this is in no way an adequate substitute for accurate and in-depth analysis of sub-adult skeletal remains. Sub-adults represent, as Kamp (2001) emphasizes, a critical aspect of the archaeological record that can provide insight not only into childhood activities, but also into the general state of the population as a whole. In order for the study of sub-adult remains to be useful and valid, however, it is essential that the proper methodological approaches and theoretical frameworks be used. Archaeological data and data from historical or modern populations must be scrupulously analyzed and made available to researchers for comparison, and analysts must be cautious in the theoretical and practical application of their interpretations of the skeletal data. Lewis and Roberts (1997:584) emphasize this last point, stating that authors need to be conservative with their interpretations and understand the methods used.

Methodology in the Analysis of Sub-Adult Skeletal Remains

Age Determination

Accurate age determination of sub-adults is necessary to examine not only pathological conditions in individual cases and within populations, but also to examine how specific cultural practices like infanticide or infant sacrifice compare to death by natural causes (Smith and Avishai 2005:84). Studies have shown that in modern populations the greatest frequency of deaths are in the perinatal period (including up to one month of age) and are generally the result of birth defects or trauma (Smith and Avishai 2005:86). However, in order to examine the causes of infant deaths in the archaeological record, it is necessary to determine an accurate age at death. The methods most frequently used, which mainly consider gross morphological aspects of skeletal and dental materials, do not always prove accurate on their own for several reasons, and are best used in conjunction with one another. In addition, skeletal samples of sub-adults of documented age are extremely rare, while samples of undocumented age proliferate (Tocheri and Molto 2002:357), leaving few comparative samples. Of the samples that are available, it is important to consider, as noted by Perry (2006:90), that growth and development are influenced by population specific factors such as sexual, environmental, and genetic variability, which would affect the interpretation of age in skeletal material.

Before examining the methods used in determining age in sub-adult skeletons, it is necessary to define "age". Scheuer and Black (2004:3) distinguish between biological age and chronological age. Biological age is defined simply as how far along the development continuum an individual has progressed, whereas chronological age refers to the specific amount of time (days, months, years) that a person had lived prior to death (Scheuer and Black 2004:3). These two ages do not always agree and in archaeological populations, it is impossible to determine the chronological age of an individual. Perry (2006:92) also indicates that focusing on evidence of maturation is a "more fruitful" exercise than focusing on chronological age. Therefore, biological age is used in the analysis of skeletal remains.

Biological age is generally determined though the use of skeletal and/or dental indicators. Both Baker et al. (2005) and Scheuer and Black (2004) recommend that both methods be used where possible. However, the available material is often limited and therefore tends to favour one method over the other. There have been recent studies (e.g., Humphrey and Scheuer 2006; Liversidge and Molleson 2004; Smith and Avishai 2005; Tocheri and Molto 2002) published on various other indicators of prenatal, perinatal and post-natal age in sub-adults that are valuable in terms of a multi-methodological approach to age determination. These studies will be discussed following an examination of the traditional methods used in determining age.

Scheuer and Black (2004:12) note that there is a difference in terms of an individual's size and their biological maturity/age. In terms of using size to determine biological age, generally, "size appears to be more affected by adverse circumstances than is maturity but the majority of studies have recorded diaphyseal measurements of the major long bones" as this method is faster and easier than assessing skeletal maturity (Baker et al. 2005:157; Scheuer and Black 2004:12). The assessment of skeletal maturity is often done through analysis of the ossification centres. Three aspects are generally considered: the appearance of ossification centres, the morphology and size of ossification centres, and the fusion of ossification centres (Scheuer and Black 2004:14-16). Scheuer and Black (2004:12-13) note that while age determination based on epiphyseal union is often used, this practice is generally problematic since epiphyses are rarely preserved or excavated, and there is a high incidence of intra- and inter-observer error using this method where epiphyses are present.

In terms of the interpretation of prenatal remains, age estimation methods include histological and radiological analysis. In modern samples used for comparison or in forensic applications, a common method of examination is the use of Alizarin Stain. The stain is injected into the cartilage or bone of an embryo or foetus, allowing more accurate observation of morphological structure (Scheuer and Black 2004: 8-10). Prenatal age can be determined through a 23-stage model using external and internal morphological criteria, which are independent of size. This is expressed in greatest length, which is the length of the foetus, minus the legs (Scheuer and Black 2004:4-5). In skeletal remains, however, it can still be extremely difficult to distinguish between prenatal, perinatal and neonatal infants, with previous studies neglecting to distinguish between these stages at all and grouping them together in analysis (Smith and Avishai 2005:87). In addition, Smith and Avishai (2005:87) note that with 20 percent low birth weight within a population, infant statistics should be biased toward foetal remains using the standard aging techniques (mainly, bone length).

There are several problems with using skeletal criteria for determining age. Several authors (e.g., Baker et al. 2005:157; Perry 2006:90; Tocheri and Molto 2002:357) have indicated that post-cranial material must be analyzed using population-specific skeletal growth profiles, and therefore requires knowledge of which population or sample the skeletal material is derived from. This is often impossible to determine unless the researcher can be certain that all people living in a particular area were of the same ethnicity and socio-economic class. Since population-specific development standards are practically non-existent (see Tocheri and Molto 2002:357,), this type of study is quite difficult.

Recent studies, however, have proposed additional methods to use in determining age from the skeletal record. These methods involve basiocciput osteometrics (see Fazekas and Kósa 1978; Redfield 1970; Tocheri and Molto 2002) and closure of the foramen of Huschke (Humphrey and Scheuer 2006). Tocheri and Molto (2002:356) indicate that the basiocciput is relatively resistant to taphonomic processes and, compared to other bones, is unlikely to be found broken, which would allow for relative consistency in its use. Basiocciput osteometrics provide an accurate age range determination, however the range is wide (Tocheri and Molto 2002:360). It was determined that this method is most applicable in assisting in the placement of "infants into the younger or older ranges of the age estimates derived from other skeletal and dental evidence" (Tocheri and Molto 2002:362). Humphrey and Scheuer (2006) came to similar conclusions in their study on the use of the foramen of Huschke in age determination. They suggest that, due to the wide range of development, only certain generalizations can be made (Humphrey and Scheuer 2006:58-9). Thus, this method is valuable in its ability to contribute to accurate age determination in conjunction with other estimates.

Compared to skeletal methods of age determination, dental methods are generally considered more accurate (see Perry 2006:90). It is useful to study dental collections because there is very little variation between historical and modern populations, with the modern populations providing a large comparative sample (Liversidge and Molleson 2004:178). Recent research by Heuzé (2006) suggests that intra-population variation is equal to or greater than inter-population variation when dental age assessments are made using comparative samples. This research indicates that there is no increase in the quality of age assessment by using population specific data and that data from various geographical regions can be used together in constructing a comparative sample (Heuzé 2006). An inter-population sample would not require knowledge of the population of origin of the sub-adult skeletal specimen in question, which may be unknown.

The factors most often used in dental age determination methods involve tooth eruption/emergence and tooth mineralization, the latter being the more accurate of the two (Baker et al. 2005:157; Scheuer and Black 2004:16-17). Recently, Liversidge and Molleson (2004:174) suggested that previous dental growth studies lacked clearly defined stages of crown and root development. They found that, in early childhood, deciduous teeth grow faster and are more accurate in predicting age than permanent teeth (Liversidge and Molleson 2004). Smith and Avishai (2005:84) propose that the neonatal line, which is a dental indicator of stress in newborns, can distinguish between death in the first week of life and death in the three weeks following. This is important because most of the deaths in the first year of life occur in the first month (Smith and Avishai 2005:84). Like Liversidge and Molleson (2004), in their article on crown and root development, Smith and Avishai (2005:87) found that since there was no difference in the relation of crown-height to neonatal line between historic and modern populations, this method is a valid approach for precise aging and determination of post-natal survival.

As demonstrated above, the traditional methods for age determination in archaeological populations are prone to error when only one method, in particular long bone measurements, is used alone. Dental methods are more accurate when specific aspects of formation are analyzed, as opposed only using eruption as an indicator of age. The most accurate approach to obtaining the precise age necessary for analyzing population and individual morbidity and mortality is a multi-faceted one, where several methods are used together in an attempt to eliminate both methodological and observer errors.

Sex Determination

Of those who study sub-adult skeletal remains, many would agree that "undoubtedly the largest single problem in the analysis of immature skeletal remains is the difficulty of sexing juveniles with any degree of reliability" (Scheuer and Black 2004:19). Scheuer and Black (2004:19-21) go on to note that all methods of sex determination in sub-adults require further study or are simply ineffective. These methods include analysis of the sciatic notch and comparison of the rate of skeletal development with the rate of dental development, where in the former method, the analysis of sex differences of the sciatic notch was only found to be accurate in sexing black females (Walsh-Haney et al.1999:18-19). The latter method indicates that if the rate of skeletal development and dental development are close, the individual is likely male (Walsh-Haney et al. 1999:19). These methods are included in those that Scheuer and Black (2004), mentioned above, consider generally ineffective or at the least in need of further study.

A recent study by Cardoso (2006) indicates that sexual dimorphism of the teeth of sub-adults may be used to indicate the probability of sex. He notes that various morphological and metric methods have been tested but fail to be significantly accurate (Cardoso 2006). Cardoso's method employs the use of logistic regression to develop sex determination formulae using combinations of measurements from different permanent teeth (Cardoso 2006). His method provides control for variation, something that previous methods do not control for (Cardoso 2006). It must be stressed, however, that this method provides a probability of sex (just over 80 percent) and not a certainty, and is therefore best used in combination with other methods (Cardoso 2006).

The area of molecular genetic research proves far more promising in that it "has been evolving quickly in recent years and can now provide viable alternatives to the morphometric and chemical sexing of adults and, more importantly, sub-adults" (Hildebrandt 2003:22). Several studies have been carried out involving genetic sex determination, including Saunders and Yang (1999) and Hildebrandt (2003). Saunders and Yang (1999) examine the role of DNA (deoxyribonucleic acid) in determining the sex of an individual in forensic identification using polymerase chain reaction (PCR) and the role of amelogenin gene codes. They indicate that further study is needed in DNA research and that it is not frequently used due to the high cost, its time-consuming nature, and the risk of sample contamination (Saunders and Yang 1999:53). However, the PCR technique has been applied to the archaeological record with confidence in the sex determination of a two-year-old girl from Lisieux, France (see Blondiaux et al. 2002:210).

Recently, Curtis Hildebrandt (2003) attempted to assess the feasibility of skeletal sex determination from DNA, using skeletal samples from ancient Egypt. Hildebrandt (2003) tested four systems for identifying genetic sex including, SRY (sex-determining region Y), amelogenin loci, the alphoid repeats and Y-STRs (Y-chromosome short tandem repeats). These methods prove to be rather quick and easy in accurately identifying sex in modern populations and Hildebrandt (2003:18) proposes that these methods could apply to ancient populations and problematic modern samples. He found that it is "possible to obtain amplifiable DNA for sex determination loci from bone samples that range in age from approximately 100 years old to just under 2000 years old" (Hildebrandt 2003:58). However, Hildebrandt (2003:59) proposes that further testing be undertaken, as there may have been possible sample contamination by handlers or analysts (particularly males) in his study. It is essential that samples of aDNA (ancient DNA) be analyzed in a clean laboratory. However, the problem of contamination is difficult to avoid, as there is always the possibility of aDNA contamination from handlers of the material.

Research on aDNA provides a more accurate method of sexing sub-adult individuals than the previously proposed methods based on morphological indicators. Despite criticism of this method (see Saunders and Yang 1999) in terms of lack of study, high cost, and low availability, new research is showing that aDNA can be used in the analysis of ancient skeletal remains. While the skeleton can often be deceiving, with male skeletons showing feminine traits and vice versa, aDNA has the potential to provide an unbiased indication of skeletal sex at any age, once methods are refined and laboratory errors reduced or eliminated. In addition, RNA (ribonucleic acid) or DNA could potentially be used to identify viral infections (Roberts and Manchester 2005:181) and can already be used to determine general categories of ethnicity (Hildebrandt 2003:24).

Other Methodological and Theoretical Constraints

There is a strong need to ascertain what is 'normal' in the developing skeleton, as it does not often correspond to the morphology of the adult skeleton (Lewis and Roberts 1997:584). Ribot and Roberts (1996:71) point out the difficulty in distinguishing between pathological change and normal processes and between different pathological conditions, especially if they are mild. In a follow up to that study, Lewis and Roberts (1997:584) note that there is a problem in studying the distribution of periostitis because it is indistinguishable from rapid appositional growth, which is normal.

Along with the problem of distinguishing normal from abnormal is the problem of inter- and intra-observer errors (Lewis and Roberts1997:583; Scheuer and Black 2004:13). Stress indicators are often underestimated through errors in observation and method of recording, and there is a question of the reliability of stress indicators. Ribot and Roberts (1996:78) have found that there is a lack of correlation between lesions and stress episodes. Generally, the non-specific stress indicators used include enamel hypoplasias, porosity (skull or vault lesions), Harris lines, and subperiosteal new bone formation. Wood et al. (1992:344) suggest that the "observed frequency of pathological conditions should overestimate the true prevalence of the conditions of the general population". Therefore, when considering the implication of interpreting pathological conditions in the skeletal record, one must be exceptionally wary of coming to any conclusions about the prevalence of these conditions. To illustrate this point, Stodder (1997:376), in her study of linear enamel hypoplasias on Latte Period populations in Guam, remarks that while hypoplasias are related to age at death in the Guam sample, there is no indication of whether infections are caused by anaemia/ hypoplasias or whether stress-causing anaemia/hypoplasias cause an increased susceptibility to infection and, therefore, early mortality.

There are, however, cases where non-specific stress indicators are not present and other factors, such as retarded growth, indicate that stress was present. Bennike et al. (2005:737) define growth retardation as a developmental adaptation or adjustment (with the purpose of increasing survival), resulting from decreased nutritional requirements or due to a decreased availability of nutrients. Pfeiffer and Crowder (2004:25) suggest that without evidence of growth arrest (i.e., Harris lines), the stress causing growth retardation might have been slow and persistent. In their study, the cause of growth retardation was likely the result of a case of vitamin D deficiency rickets that was due to diet, or a metabolic problem of inadequate renal function, causing the inability to use vitamin D (Pfeiffer and Crowder 2004:28).

The Osteological Paradox

As pointed out by Wood et al. (1992:344), "there is one, and perhaps only one, irrefutable fact about the cases making up a skeletal series: they are dead." Wood et al. (1992:344), in their article "The Osteological Paradox", argue that "all samples of the dead are inherently unrepresentative of the original living population at risk of death, even a skeletal collection that is a perfect random sample of all those who died." They point out two main conceptual problems: (1) selective mortality – not all individuals at risk of death from a particular cause will die from it, and (2) hidden heterogeneity in risks – there is varied susceptibility to disease or death within a population (Wood et al. 1992:344). In addition, it is impossible to know the epidemiological rates of exposure to illness or death. References to "health", an individual biological characteristic, must be based on population-level statistics (Wood et al. 1992: 344-5). It is also interesting to examine the idea that perhaps the "healthy" skeletons were in fact the ones who were least able to resist illness, dying before bone reaction could occur, and that the skeletons who present with inactive lesions are, in fact, the survivors of a particular illness (Wood et al. 1992:352).

The paper by Wood et al. (1992) received mixed reactions. Several authors (e.g., Byers 1994; Cohen 1994; Goodman 1993) challenged the notion of the Osteological Paradox. However, whether or not Wood et al (1992) were correct, the notion of the Osteological Paradox is prevalent in recent literature. For example, Lewis and Roberts (1997:582) indicate in their analysis of the interpretation of stress indicators, that the majority of children probably died from acute infections and accidental death, which would not be expected to affect their dental or skeletal patterns. The Osteological Paradox should be taken into account especially in the study of cemetery populations. Many cemeteries, like the Næstved cemetery in Denmark, cater to certain portions of the population, in this case, those individuals who were suffering from leprosy (Bennike et al. 2005). These skeletons, therefore, could not possibly be considered as representative of the society from which they are drawn (Bennike et al. 2005:744). This study also draws attention to the necessity of being aware of the historical context from which a sample is derived before the patterns of morbidity and mortality of a past society can be reconstructed (Bennike et al. 2005:744).

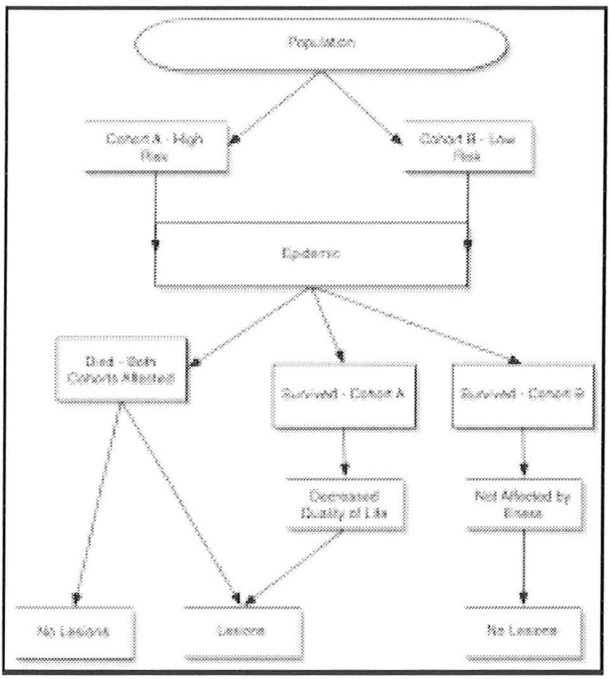

Figure 1: The Effects of a hypothetical epidemic on a population

While not addressed specifically in Wood et al. 1992, the effects of childhood illness on adults can be representative of various social aspects of a population. Kamp (2001:10) discusses the issue of how "adults who have been severely stressed as children may have lower fertility, capacity for work, or adult health" (see also Goodman and Armelagos 1989:227). Figure 1 demonstrates the Osteological

Paradox as well as the effects on the surviving portion of a population that has been affected by an infectious epidemic. This chart shows two cohorts of the population. Cohort A is considered 'high risk' in terms of morbidity and mortality (i.e., the underprivileged sector) and Cohort B represents those of a higher socio-economic status who are considered to be at 'lower risk.' When hit by an epidemic, both sectors will be affected. Those in Cohort B will be better able to resist the insult, with many people not affected at all by the epidemic; however, in Cohort A, the majority of the people are affected and while some survive, they are left with the 'after-effects' of the illness, and likely a decreased quality of life. In terms of the skeletal record, there will be those without lesions from both Cohorts. Without considering the Osteological Paradox, all those without lesions would appear to have been the 'healthiest'. However, in Cohort A, those without lesions represent the ones who succumbed to the illness at the time of the epidemic. In cohort B, those without lesions represent those who were not affected at all by the epidemic. It would be inaccurate to consider that 2/3 of this population was 'healthy' while 1/3 (those with lesions) were 'ill'. This example demonstrates the necessity of, at the very least, considering the Osteological Paradox when examining the effects of illness on a population.

The following issue is one that needs to be taken into consideration along with the Osteological Paradox in the analysis and interpretation of skeletal remains. Exempting accidental deaths, it is exceptionally rare for a person to die "healthy". Whether or not lesions are present on a skeleton, there was a cause of death. Therefore, the accuracy of any type of speculation on population morbidity is extremely difficult using only the skeletal record, especially when looking at very ancient populations. Even if all skeletons of all the people who died within, for example, a one hundred year period were present, they all are dead and all died of something, whether or not the cause could be determined from analysis of the skeleton. Even if the skeletons appear "healthy", the cause of death (unless the result of accident or trauma) would have been from "ill-health" (i.e., heart attack, stroke, diabetes, various cancers, as well as other less common illnesses). The study of the sub-adult record becomes extremely important in this aspect in that, if bioarchaeologists can compare the proportion of individuals who survived into adulthood to those who did not, speculation of mortality and "implied morbidity" is then possible, even if all the particular causes of death cannot be determined from the skeletal record.

Overcoming Methodological and Theoretical Problems

The Differential Diagnosis

Several recent studies (e.g. Blondiaux et al. 2002; Brickley and Ives 2006; Buckley 2000) have attempted to offset many of the methodological and interpretive problems by providing a series of differential diagnoses in their analyses of sub-adult skeletal pathologies. In many cases, the cause of skeletal reactions to illness can be deduced. However, the argument is strengthened when authors are able to demonstrate why the specific pathologies are unlikely to be representative of other illnesses with similar skeletal indicators. Differential diagnosis is especially important when dealing with non-specific lesions, such as porotic lesions. For example, Brickley and Ives (2006) discuss a case of abnormal skeletal lesions, indicative of scurvy, present on the bones of six infants from St. Martin's Cemetery in England. While the lesions were indicative of scurvy, they present a differential diagnosis comparing scurvy and two other possible diagnoses: anaemia and rickets. Through this comparison, they are able to distinguish scurvy from anaemia and rickets based on the pattern and distribution of bone changes (Brickley and Ives 2006:170).

In a study on the differential diagnosis of pathologic lesions in sub-adults from a pre-European burial mound in Tonga, Polynesia, Buckley (2000) examines several possible causes. These include various infectious diseases, metabolic diseases, trauma, Caffey's disease, and iron-deficiency anaemia. Despite her in-depth analysis of the skeletal material and the examination of several differential diagnoses, Buckley (2000:503) concludes a specific diagnosis is not possible. In the analysis of the sub-adult skeletal record, and the adult record as well, it is desirable to remain without a diagnosis while employing the proper methodology and thorough interpretation of results than to assign a diagnosis based on inconclusive data.

The Importance of Analyzing Sub-adults in the Archaeological Record

The analysis of only the adult portion of a population neglects the fact that children contribute significantly to a society and its culture (Baxter 2005; Kamp 2001:24). Goodman and Armelagos (1989:227) stress that illness and stress during childhood can have lasting effects on the functional capacity of an individual as well as their future resistance to disease. There is often a strong link between maternal health and infant health (Goodman and Armelagos 1989:237); therefore, if infants are unhealthy within a population, it is likely their mothers represent an unhealthy portion of the adult population and vice versa. Chemical analysis of enamel, dentine, and bone can also provide a record of diet or feeding practices (Perry 2006:94).

In addition to providing insight into the degree of morbidity within a population (see Kamp 2001:10), the analysis of sub-adult skeletons is often quite revealing of the social conditions in which the individuals lived (see Baxter 2005). It is possible to determine socio-economic aspects of a society (Baxter 2005; Brickley and Ives 2006:164, 171; Stodder 1997:363-4) as well as cultural aspects, such as weaning (Dupras et al. 2001), infanticide (Kamp 2001:21; Pfeiffer and Crowder 2004:23), and childhood violence such as child warfare (Perry 2006:95) from the analysis of sub-adult remains.

In certain cases, such as examining the frequency and age distribution of Harris line formation, it is advantageous to analyze the sub-adult population, rather than the adult population. In adults, there is unpredictable and frequent remodelling of Harris lines, which makes them difficult to assess (Lewis and Roberts 1997:582).

Conclusions

The analysis of the sub-adult bioarchaeological record can provide a wealth of information, not only on the sub-adults themselves, but also on the population as a whole. In the past, certain factors such as poor preservation, a lack of recognition of sub-adult bones and a lack of suitable comparative materials have prevented many authors from including sub-adults in their studies. Recently, interest in the sub-adult portions of populations has increased not only in the field of bioarchaeology, but throughout the discipline of anthropology. This appears to be following the trend apparent in

the social science disciplines, of breaking the historical silence of minorities and otherwise under-represented portions of populations, commonly women and children. However, despite the growing interest in the inclusion of sub-adults in the study of archaeological societies, it must be stressed that this inclusion requires a more meticulous collection, analysis, and interpretation than is normally involved when studying the adult members of a society.
Methodological problems, particularly with aging and sexing sub-adult skeletons, pose barriers that need to be overcome. The more analyses done on comparative populations of known individual data, the more accurate age or sex determinations will become. The rapidly advancing field of molecular genetic research promises more accurate methods of sex determination as well as prospects for identifying specific infections in skeletal material. In terms of the interpretation of skeletal data and its application to an ancient population, it is necessary to take into consideration certain theoretical concepts, such as the Osteological Paradox and the importance of producing a differential diagnosis.

Despite the obstacles in the analysis and interpretation of the sub-adult skeletal record, it is clear that this is something that is no longer being ignored and therefore requires accurate and comprehensive research. Future exploration into the theoretical and methodological approaches discussed in this article will provide greater accuracy in the analysis and interpretation of the sub-adult skeletal record and will likely increase the inclusion of sub-adults in bioarchaeological research.

Notes

[1] In this article, the term "sub-adult" refers to individuals who had not reached biological maturity at the time of death. For purposes of continuity with an original text, the term "juvenile" will be used interchangeably with "sub-adult" as per the cited author's usage of the term.

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