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The bioarchaeology of infant feeding

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Introduction

Bioarchaeology, by its very simplest definition, is the study of human skeletal remains from the archaeological context. This approach is the only direct way to assess the experiences of people in the past. The bioarchaeological study of infants and children has been a relatively recent phenomenon in the past 15 years or so, largely precipitated by the work of Mary Lewis and others in the field (Gowland 2006; Lewis 2007, 2018; Halcrow and Tayles 2008). It is now acknowledged that infants and children are very sensitive barometers of living conditions in the past (Halcrow and Tayles 2008; Lewis 2018) and that the early stage of life is critical for later life health experiences (Gowland and Halcrow 2020). Bioarchaeological studies of the human condition during the earliest years of life have primarily focused on two areas of inquiry: 1) Disease and pathological conditions recorded in skeletal remains as evidence for health status/physiological stress; and 2) dietary patterns revealed by chemical analyses of skeletal tissues as evidence of infant feeding practices.

Infant and child dietary studies are important in bioarchaeology as they are informative of subsistence changes, infant and child feeding practices and care, food choice, and differential access to foods as a result of social factors (Stuart-Macadam and Dettwyler 1995; Lewis 2007; Larsen 2015; Halcrow 2020). Questions of the health of infants weaned at different ages and the nutritional quality of weaning and early childhood diets are important issues to consider. Infant and child diet and the weaning process have significant implications for morbidity, mortality, and fertility in past societies (Stuart-Macadam and Dettwyler 1995; Lewis 2007). There is also a synergistic relationship between diet and infection, with poor diet making a person more susceptible to infection, and infections leading to poor nutrient absorption (Scrimshaw and SanGiovanni 1997).

There has been a significant focus in bioarchaeological research on weaning. Here we define weaning as a process of introducing non-milk products into an infant’s diet over a more or less extended period of time. Many bioarchaeological studies refer to weaning as a complete cessation of breastfeeding. They acknowledge that this definition is limited because it treats weaning as a single event and “masks the complicated, variable, and often protracted process through which infant diets are transformed from breast milk to other foods through the introduction of non-breast milk food” (Herring et al. 1998: 425).

The study of infant weaning is informative of the central anthropological questions of relationships between the origins of agriculture, increased sedentism, changing human fertility and/or birth
Halcrow, Miller, Pechenkina, Dong, and Fan

intervals, and demographic change (Halcrow et al. 2018), many of which are topics central to the anthropology of reproduction. One underlying assumption in bioarchaeology is that infants who are weaned earlier allow women to get pregnant again sooner and, therefore, speed up overall population growth by decreasing the time between pregnancies (see also Kramer, Veile, and Henry, and Crittenden and Herlosky in this volume). Identifying how long an infant is exclusively milk-fed, the age when an individual was weaned off of milk, and the corresponding weaning foods are questions of interest to many bioarchaeological researchers as these processes and practices are indicative of larger cultural phenomena and are believed to have wide-ranging potential effects on child growth and development, and short- and long-term health status. The use of stable isotope analyses, particularly the fine-grained dietary reconstruction of early life through incremental dentin segments, presents an opportunity for us to ask these kinds of questions to extend knowledge on the relationships between diet, weaning, health, human biology, and culture.

Looking into the past, bioarchaeology contributes an understanding of the evolutionary processes and the role of environmental stressors, such as diet, nutrition, and health disparities on processes such as breastfeeding, pregnancy, fertility, and reproduction, all integral to the study of the anthropology of reproduction (Tomori et al. 2018). The bioarchaeology of infant feeding takes a biocultural approach that investigates the physical manifestations of social life and reproductive behaviors as mediated through infant feeding practices, and parenting and care in relation to aspects of identity including age and gender. Infant feeding is clearly something that is entangled in many parts of society. The biocultural nature of the practice of infant feeding is historically and locally contingent and therefore an integration of approaches from the fields of medical anthropology (reproductive anthropology) and bioarchaeology is important for a holistic approach to this topic (see Tomori et al. in this volume). This work directly contributes to some of the central research questions within the anthropology of reproduction.

Social bioarchaeology and infant feeding

The focus on interpretive approaches of weaning stress and questions of agricultural transitions restricts an exploration of identity and agency, central to understanding a myriad of social aspects of past populations. Research that investigates infant weaning and diet can be informative for central questions of social identity, and a life course approach is a tool to understand dietary practices through consideration of aspects of identity such as age, gender, and status, and the impacts that these have on individuals over the lifetime (Gowland 2006; Inglis and Halcrow 2018; Miller et al. 2018). This allows us to assess the expression of social life mediated through infant feeding practices and care in relation to identity, such as age and gender identity.

In bioarchaeology, our interpretations of infant feeding and health are made in concert with contextual information including environmental (subsistence) evidence, historical records on diet and feeding, care and family relationships, and/or artifacts such as infant feeding vessels. Our work in the bioarchaeology of feeding can be extended through the consideration of social anthropological, ethnographic, evolutionary, and historical literature that shows the widespread existence of alloparenting, and allo-breastfeeding (Hrdy 2009; Konner 2010; Palmquist 2020; see Tomori et al. in this volume). The exploration of alloparenting (see Crittenden and Herlosky in this volume), or the mere acknowledgment that it exists, is needed in bioarchaeology.

Bioarchaeological studies of infant feeding

Although most of the research on infant feeding has been undertaken using isotope studies of bones and teeth (reviewed below), some of the methods that we use to infer infant feeding
The bioarchaeology of infant feeding

in the past are indirect, such as an assessment of physiological stress, nutritional disease, oral pathology, and dental wear (Halcrow et al. 2018; Brickley et al. 2017; Snoddy et al. 2018). Non-specific stress indicators are those skeletal indicators of physiological disruption, such as dental enamel defects, that have a number of potential etiologies, and are therefore not diagnostic of a specific health issue. Katzenberg et al. (1996) has warned against overly simplistic interpretations of correlations found between dental enamel defect peak frequencies and weaning stress, emphasizing that stress indicators have multiple etiologies. Despite this, there are numerous studies that interpret their results of these indicators as “weaning stress” (e.g., Moggi-Cecchi et al. 1994; Berbesque and Hoover 2018). Furthermore, research has shown that some teeth may be more likely to exhibit these indicators of physiological disruption during the formation times of between two and four years of age due to the nature of enamel layer formation (Hillson and Bond 1997). Given that most of the anterior permanent teeth (incisors, canines) that are used for the analyses of linear enamel hypoplasia form between two and four years, the higher prevalence of these dental enamel defects represented at that time is likely the result of this sampling bias, rather than a reflection of more physiological stress occurring at these times. This research often interprets the timing of the development of dental enamel defects in relation to an estimate of when the weaning process ends. It is unlikely for physiological stress to be elevated around the complete cessation of the weaning process, which generally occurs gradually over a long time period, and any psychological stress from any abrupt changes in feeding would likely be minimal and would be socially and culturally specific (Fouts 2004).

Instances of metabolic disease (such as vitamin D deficiency) have been related to the feeding of infants nutritionally incomplete milk products and nutritionally poor weaning foods, or famine periods (Snoddy et al. 2016; Brickley et al. 2017). Another metabolic disease caused by nutrient deficiency that is visible on the skeleton is scurvy caused by vitamin C deficiency. The appearance of this condition has been found at different periods in different parts of the world and linked to poor weaning foods and famine periods during infancy and childhood (Geber and Murphy 2012; Klaus 2014; Snoddy et al. 2017; Sun et al. 2019).

Studies of dentition are being used by bioarchaeologists to assess weaning foods and the timing of weaning. Although oral health is not necessarily a direct reflection of diet, it may be informative of infant feeding types and the cariogenicity of weaning food (e.g., bottle feeding can cause rampant caries), and deciduous (baby) teeth have been suggested to be more sensitive to carious decay (Bonsall et al. 2015). Recently the analyses of macroscopic levels of dental wear have been used in bioarchaeology to assess weaning and childhood diet (e.g., Mahoney et al. 2016; Mays 2016).

Recent work on ancient biomolecule analyses of archaeological infant feeding vessels from prehistoric Europe has shown the earliest direct evidence for the use of ruminant milk for the feeding of children (Dunne et al. 2019). Work to extend this research beyond the identification of the incorporation of non-human milk into past infant and child diets should include a consideration of the health effects of this feeding practice with the potential for increased pathogens from dirty vessels and contaminated animal milk, and the incomplete nutrients in animal milk for feeding human infants, and an isotopic investigation of the time that infants were fed with ruminant milk (Halcrow 2019).

Stable isotope approaches for studying breastfeeding, weaning, and childhood diet

Paleodietsary reconstructions based on the stable isotope analysis of bone and tooth samples are predicated on the assumption that “you are what you eat”; however, there are multiple caveats
Molecules from the foods we eat become the tissues of our body and we can use chemical analyses to recover the traces of specific food groups from the skeletal remains of past people. Archaeologists commonly analyze bone collagen (see Figure 34.1) for stable isotopes of carbon ($\delta^{13}$C) and nitrogen ($\delta^{15}$N), and are increasingly incorporating tooth dentin collagen (see Figure 34.2) in studies of ancient human diets (Ambrose 1993; Eerkens et al. 2011).

Human bone remodels over an individual’s lifetime and is continuously incorporating dietary compounds; studies indicate that bone chemistry reflects the average diet from at least the final decade of life (Fahy et al. 2017). In contrast, human teeth form during discrete periods of early life and do not remodel, so they record specific periods of diet from prenatal to early adulthood depending on the tooth examined (Beaumont et al. 2013). New methods of analyzing individual teeth using an incremental sampling approach have opened avenues for examining early life experiences related to diet, breastfeeding, weaning, and stress with a fine-grained time resolution (Burt and Garvie-Lok 2013). By segmenting a tooth from the crown to the root into small sections, each section represents a specific period of growth from months to
The bioarchaeology of infant feeding

Teeth and bone comprise organic and inorganic portions, which record different aspects of the human diet. The organic component is primarily collagen. The biosynthesis of collagen preferentially incorporates amino acids directly from the diet. Therefore, collagen isotope values are skewed towards dietary protein sources (Ambrose and Norr 1993; Tieszen and Fagre 1993). Despite this, most archaeological isotopic studies have focused on collagen analysis because the assessment of collagen preservation is straightforward (DeNiro 1985; van Klinken 1999). This chapter will focus on the carbon and nitrogen stable isotope data recovered from collagen (from both tooth dentin and bone), where the majority of bioarchaeological research has been conducted to date.

**Stable isotope analysis: Carbon and nitrogen**

Carbon stable isotope values (δ\(^{13}\)C) primarily reflect the plant and animal foods that a person consumed (DeNiro and Epstein 1978). Plants utilize different photosynthetic pathways (commonly called C\(_3\), C\(_4\), and CAM plants), resulting in significantly different carbon isotope values between these groups (Farquhar et al. 1989). Most of the plants that humans consume are C\(_3\) plants (e.g., wheat, potatoes, legumes, and most other vegetables and fruits), few are C\(_4\) plants (e.g., maize, millet, sugar cane, sorghum), and even fewer are CAM (e.g., cacti), and δ\(^{13}\)C can be used to differentiate these foods (Vogel and van der Merwe 1977). This dietary carbon is incor-

Figure 34.2 Example of method used to serial section a canine tooth longitudinally and resulting δ\(^{15}\)N and δ\(^{13}\)C isotope data from dentin serial sections of a canine tooth. Isotopic data is from one individual from Zhenghan City, China (Xiyasi M139). Midpoint age estimation of each dentinal isotopic sample for the archaeological Zhenghan example follows Beaumont and Montgomery (2015).
Halcrow, Miller, Pechenkina, Dong, and Fan

porated into bodily tissues, and skeletal collagen values are about +5‰ compared to dietary δ13C values (Van Der Merwe and Vogel 1978; Sullivan and Krueger 1981). Further, research has documented about +1‰ difference between a nursing infant’s δ13C and its mother, so carbon isotope values have also been used to identify breastfeeding and weaning patterns (Fuller et al. 2006).

Nitrogen stable isotope values (δ15N) track an individual’s position in the food chain and can aid in distinguishing vegetarian-based diets from those with more animal protein, in addition to detecting consumption of marine resources (DeNiro and Epstein 1981). Nitrogen values increase by +3 to 5 ‰ as a consumer rises through a food chain, resulting in animal tissues having higher δ15N values than their diet (Minagawa and Wada 1984; Schoeninger and DeNiro 1984). Nursing also adds a step to the food chain: Infant animals consuming milk are at a slightly higher trophic level than their mother (or their allomother) for the duration of time that they are exclusively consuming milk (Fogel et al. 1989; Fuller et al. 2006). Studies of modern mother–infant pairs have confirmed offsets between this dyad: Nursing infants’ collagen δ15N values are typically +1 to 4‰ higher than their mother’s values, with studies showing breast milk δ15N being −0.6‰ to +5‰ higher than mother’s diet (Fuller et al. 2006; Luca et al. 2012; Herrscher et al. 2017). During the weaning process, typically, the δ15N values of the growing infant decline by 1 to 4‰ as milk is removed from the diet (Fuller et al. 2006; Luca et al. 2012; Herrscher et al. 2017).

Using isotopic data to study infant feeding practices in the past: Bone collagen

More than three decades ago, archaeologists started exploring how stable isotope analysis of bone collagen could be used to study the diets of individuals who died in infancy and childhood (Katzenberg et al. 1993; Tuross and Fogel 1994; White and Schwarcz 1994; Schurr 1997; Herring et al. 1998). These studies examined individuals from cemetery populations who died at different ages (from infants to the elderly), thereby capturing dietary isotopic data from the final years before death, and compared these values across the different age groups (Figure 34.1). This work generally documented that infants who died within the first few months of life often had nitrogen isotope values similar to the adult population suggesting that they either hadn’t had milk signal incorporated into their bone collagen yet or were not breastfed at all, while infants and young children who died after reaching a few months old had δ15N values that were higher than the adult mean (Katzenberg et al. 1993; Tuross and Fogel 1994; Herring et al. 1998). Further, they noted that δ15N typically declined between the ages of two and six years, and those patterns were interpreted as evidence for weaning age/cessation of milk consumption (Katzenberg et al. 1993; Tuross and Fogel 1994; White and Schwarcz 1994; Herring et al. 1998).

Isotopic studies of bone collagen from individuals who died during youth have revealed various patterns across the populations under study. Some of these have noted the diversity of weaning ages within the same mortuary population, suggestive of different caretaker relationships with their infants (Katzenberg et al. 1993; Herring et al. 1998; Pearson et al. 2010). Others have used a comparative approach, examining communities with different subsistence strategies and/or long-term diachronic changes in a particular region/cultural area (Tsutaya and Yoneda 2013; Britton et al. 2018; Schurr 2018). A few recent reviews have compiled data to investigate large-scale patterns (Tsutaya and Yoneda 2013, 2015; Reynard and Tuross 2015). Cumulatively, the bone collagen data studied to date across human populations suggest that there is variability in infant feeding practices, but that generally infants are breastfed exclusively for less than one year, with increasing amounts of supplementary foods incorporated over time, and breastmilk is usually isotopically absent from the diet between ages two and four years, indicating milk is no
The bioarchaeology of infant feeding

longer a significant dietary component (Tsutaya and Yoneda 2013; Reynard and Tuross 2015; Schurr 2018).

Recent work has noted limitations of the earlier data (Reynard and Tuross 2015; Tsutaya and Yoneda 2015; Beaumont et al. 2018). Specifically, bone collagen research has a bias of sampling non-survivors who may have had different life experiences than those who survived into adulthood. A common practice has been to use adult mean $\delta^{15}N$ and $\delta^{13}C$ values (and often narrowed to the average value of women from that population) to calibrate the juveniles against, which carries many assumptions (Reynard and Tuross 2015). This assumes diets are homogenous, including between pregnant and nonpregnant women, and over the lifetime (i.e., children will be weaned onto a diet the same as their mothers). There are many under-studied aspects of isotopic systems that may influence the isotopic values and the interpretation of these recorded in different tissues (see Reynard and Tuross 2015).

One significant issue that will continue to limit our interpretations is the issue of accurate skeletal age-at-death estimation, and accurately aging the tissue under study (knowing the rates of formation and turnover for the specific tissues) (Reynard and Tuross 2015; Tsutaya and Yoneda 2015).

Using isotopic data to study infant feeding practices in the past: Dentin collagen

About two decades ago, bioarchaeologists began investigating teeth as a source of early life dietary evidence. The use of teeth allows us to examine individuals who survived into adulthood, potentially avoiding the issue, as noted above, of survivorship bias in bone collagen studies (Wright and Schwarcz 1998; Fuller et al. 2003).

Technological changes have allowed us to analyze smaller samples, allowing sub-sampling of individual teeth to be pushed even further (Figure 34.2) (Eerkens et al. 2011; Beaumont et al. 2013). Studies have shown patterned changes in $\delta^{13}C$ and $\delta^{15}N$ in serial dentin samples and linked these to breastfeeding and weaning practices on a finer timescale than bone collagen samples have allowed (Fuller et al. 2003; Beaumont et al. 2013). The ability to capture refined dietary chronologies from dentin collagen allows researchers to study intrapopulation variation and/or individual life-course approaches, examining the relationships between infant feeding and childhood diet with variables such as sex and gender, wealth, health, and social inequality (Eerkens and Bartelink 2013; Henderson et al. 2014; Beaumont and Montgomery 2016; Fernández-Crespo et al. 2018; King et al. 2018). These issues are all highly relevant to the anthropology of reproduction (Tomori et al. 2018).

One promising aspect is the use of $\delta^{15}N$ data to consider the role of physiological stress and the health status of individuals in the past (Beaumont and Montgomery 2016; King et al. 2018). Undernourished bodies may resort to catabolizing their own tissues to meet energetic demands. This internal amino acid recycling further enriches the nitrogen isotope pool from which new tissues are formed and results in individuals under these kinds of stress having higher $\delta^{15}N$ values, essentially showing an increased trophic level shift (Katzenberg and Lovell 1999). Isotopic data from deciduous teeth forming in utero may record evidence for maternal stress, while early forming permanent teeth may capture the stress of the developing infant (Beaumont and Montgomery 2016; King et al. 2017).

Recent work has highlighted issues of using bone collagen to assess childhood diets in comparison with using dental tissues (Beaumont et al. 2018; King et al. 2017). Studies comparing $\delta^{13}C$ and $\delta^{15}N$ values of bone collagen from a cross-section of a mortuary population, and incremental dentin collagen from a subset of that same mortuary population, have demonstrated that the serial dentin sampling approach is more informative of infant feeding.
practices (Beaumont et al. 2018; King et al. 2017). For example, in an Anglo-Saxon sample, Beaumont and colleagues (2018) found that dentin samples were better for capturing breastfeeding and weaning patterns than bone from the same young individuals. They suggest that during periods of physiological stress teeth will continue to capture isotopic data from the diet (and stress) while bone may stop growing, and therefore teeth may be a better tissue to investigate dietary practices and health events during development (Beaumont et al. 2018). Ideally, both bone and dentin collagen approaches would be integrated to provide the most information possible and capture the largest amount of variation in order to study patterns across different cross-sections of any society, and across the life course (King et al. 2017; Miller et al. 2018).

Case study: Infant feeding in Eastern Zhou China

Here we present an exploration of infant breastfeeding, weaning, and childhood diet with stable isotopic analyses of incremental dentin segments from an urban population living during the Bronze Age Eastern Zhou Dynasty (771–221 BCE) in the Central Plains of China (see Figure 34.3). We present sex-based differences in infant feeding and the importance of the consideration of aspects of social identity (in this case, gender) and cultural factors in the interpretation of infant feeding in the past.

Life during the Eastern Zhou Dynasty

The emergence of stratified and patriarchal Chinese cultures from the relatively egalitarian Neolithic to the hierarchical Bronze Age Dynasties and later highly stratified Qin and Han Dynasties laid the early foundations for marked class and gender inequalities seen today (Yu and Sarri 1997). Dong et al. (2017) identified male–female dietary and health inequalities in adults, symptomatic of the rise of patriarchal society during the Eastern Zhou Dynasty, in contrast with earlier Neolithic periods in the Central Plains of China (Pechenkina et al. 2005; Pechenkina and Oxenham 2013). Using stable isotope analysis of human and animal bones, they found a dietary shift from indigenous millets to newly introduced cereals during the Eastern Zhou Dynasty, especially among adult females who consumed more of these new cereals and less animal protein compared with their male peers (Dong et al. 2017). The rise of sex-based dietary differences during this time was accompanied by other markers of biological and social inequality, including higher rates of skeletal stress and growth disruption in females, and greater wealth of male burials (Dong et al. 2017; Pechenkina et al. 2017).

The Eastern Zhou Dynasty witnessed significant cultural change as population densities increased, political factions went to war, intellectuals such as Confucius and Mencius were sharing their philosophies, and societal norms were changing (von Falkenhausen 2006; Feng 2013). The Eastern Zhou period is divided into the Spring and Autumn phase (771–476 BCE) and the Warring States phase (475–221 BCE), and terminates when Qin Shihuang conquered and unified ancient China (von Falkenhausen 2006; Feng 2013). With such dynamic cultural change happening over the course of these 500 years, scholars have wondered how these shifting circumstances affected people across the Central Plains of China. During the Eastern Zhou period, the ancient city of Zhenghan (鄭韓故城) was a vibrant urban community and recent excavations have uncovered the tombs of city residents (Henan Provincial Institute of Cultural Relics and Archaeology 2012). Here we present the isotopic data from 23 individuals from the Eastern Zhou period sites of Xiyasi (西亚斯) and Changxinyuan (畅馨苑) located in ancient Zhenghan city, under the modern-day city of Xinzheng in Henan Province, China (see Pechenkina 2012...
The bioarchaeology of infant feeding

and Pechenkina et al. 2017 for detailed information on the skeletal collections). To fully understand how increased inequality has affected society over the long term, we can assess health and nutrition across the individual’s life course. Characterizing infant and childhood dietary practices through serial dentin collagen isotope samples in conjunction with bone collagen isotopic data allows us to track dietary practices over an individual’s lifetime.

Figure 34.3 Maps showing the location of the archaeological sites of Xiyasi and Changxinyuan, located under the modern-day city of Xinzheng, Henan Province, China.
Materials and methods

An early forming tooth (permanent first molar or canine) was selected from 23 adults from the Xiyasi and Changxinyuan mortuary assemblages (Xiyasi: Seven females, eight males; Changxinyuan: Four females, four males; Figure 34.3). We used an incremental dentin sampling approach to create 283 individual dentin segments for isotopic analysis. Collagen preparation followed published protocols (Beaumont and Montgomery 2015) and all dentin samples were analyzed at the Stable Isotope Laboratory of Shenzhen Huake Precision Testing Inc. in China on a Flash 2000 Elemental Analyzer coupled to a Delta V Advantage Isotope Ratio Mass Spectrometer (see Miller et al. 2020 for analytical details and all data). Corresponding bone collagen samples from these individuals were analyzed by Dong et al. (2017) and Miller et al. (2020), and methods elaborated therein. All collagen isotopic data presented here had C:N ratios between 2.9 and 3.6, the accepted range for collagen (DeNiro 1985).

Results and discussion

The dentin samples reveal breastfeeding and weaning patterns in addition to showing dynamic dietary changes for individuals throughout childhood. Figure 34.4 shows the δ¹⁵N data for each individual over the early years of their life. We see that the earliest sample for each individual (most are dentin segments that formed around the age of one year) is the segment with the highest δ¹⁵N value, followed by a characteristic decline of 2 to 3‰ in δ¹⁵N over the next couple of years. This indicates all individuals consumed breastmilk during early infancy, and that over time milk was slowly removed from the diet as the child was weaned and complementary

![Figure 34.4](image_url)

Figure 34.4  δ¹⁵N values from serial dentin samples for each Zhenghan individual. Females are shaded circles and males are open circles. Loess curves are also plotted for each sex over time showing the trends between boys (dashed line) and girls (solid line) δ¹⁵N. The patterned decline in δ¹⁵N values over the first years of life indicates the weaning process. Note that the average δ¹⁵N values for boys are higher than those for girls, suggesting boys may have consumed a bit more protein than girls during childhood. Final adulthood diet values are plotted to the far right on the figure to show the dietary shifts between childhood and the final decade before death; the average value for men is slightly higher than women, indicating differential consumption of meat continued through adulthood.
foods were consumed in greater proportions; these isotopic data suggest individuals completed weaning between ages two-and-a-half and four years. This range of ages for the removal of milk suggests significant variability in nursing and feeding behaviors among the mothers living in this Eastern Zhou urban community.

After this initial dietary change from a milk-based to non-milk diet, there is relative stability in $\delta^{15}N$ values for most individuals over the rest of their childhood, and relatively little evidence for significant change in $\delta^{15}N$ from late childhood through adulthood (the final dentin $\delta^{15}N$ values for each person are quite close to the bone collagen value representing the average diet for their final decade before death). We plotted a loess curve (moving average) for each sex which shows the patterning of $\delta^{15}N$ over time between boys and girls (Figure 34.4). In general, $\delta^{15}N$ values are not significantly different between boys and girls, but values for boys are continuously slightly higher than their female peers. This may hint that girls were eating a little less meat than boys, but more urban Eastern Zhou individuals need to be studied to see if this pattern holds. In adulthood, most men consumed more protein than women (on average, males had significantly higher bone collagen $\delta^{15}N$ values), so perhaps this gendered dietary protein trend begins in childhood and amplifies in adolescence and adulthood (Dong et al. 2017; Miller et al. 2020).

In stark contrast to the relative stability of $\delta^{15}N$ across childhood, we see very dynamic changes to $\delta^{13}C$ values for almost every individual studied (see Figure 34.5). Most show fluctuations of 2 to 4‰ in $\delta^{13}C$ values during childhood indicating children are eating varying amounts of $C_3$ and $C_4$ foods over these early years of life. Foxtail and broomcorn millets were the local domesticates that dominated the diets of Central Plains inhabitants for millennia and millets are one of the few $C_4$ crops that humans consume (Zhao 2011; Dong et al. 2017). Archaeobotanical studies of Eastern Zhou sites from this area of the Central Plain have shown that millets, espe-

![Figure 34.5](image-url)

**Figure 34.5** $\delta^{13}C$ values from serial dentin samples for each Zhenghan individual. Females are shaded circles and males are dark gray. Loess curves are plotted for each sex over time showing the trends between boys (dashed line) and girls (solid line) $\delta^{13}C$. Final adulthood diet values are plotted to the far right on the figure to show the dietary shifts between childhood and the final decade before death. As indicated on the left side of the figure, lower (more negative) carbon values indicate diets with more $C_3$ foods (wheat, soy, etc.) while higher carbon values indicate diets with more $C_4$ foods (millets). On average, all children consumed more $C_3$ foods (wheat and soybean) during their childhood than they did in adulthood. Additionally, we see that during childhood, boys consumed more millets ($C_4$) than girls, which continued into adulthood.
cially foxtail millet, remained the dominant plant food during this era, with wheat and soybean (C₃ plants) being the second and third most common findings (Cohen 2011; Zhao 2011). Importantly, wheat was domesticated far to the west and introduced to this area during the late Neolithic; however, it was relatively slow to gain importance in the cuisines of the Central Plains of China (Liu et al. 2014; Deng et al. 2020). The isotopic data demonstrate that children from Zhenghan city were eating across C₄ and C₃ food groups, but almost all individuals had δ¹³C values during childhood that were lower than their later adulthood bone collagen δ¹³C value. This means that children regularly consumed more C₃ foods than adults, suggesting that particular foods such as wheat and soybean were selected as foods to give children. Additionally, from the loess curves (Figure 34.5) we can see that on average, Zhenghan females had significantly lower δ¹³C values than males during childhood. While all people consumed more C₃ plants during early life, girls consumed more of these than boys, who were consuming slightly more millet (C₄). Here we are seeing how gender roles were intertwined with food practices for the people living in this urban Eastern Zhou community. During childhood, the traditional food of millet was actively given to boys more than to girls, and in adulthood, men consumed significantly more millet than women. Families were gendering their children (and themselves) through their daily food practices. It is likely that women were responsible for preparing meals and feeding children, and therefore mothers were actively choosing to give more of certain foods to their children based on the perceived cultural values of these foods in relation to notions of sex and gender (Linduff and Sun 2004; Hinsch 2018).

Although isotopic studies have highlighted the central importance of millet in the cuisines of adults living in early China (Cai and Qiu 1984; Pechenkina et al. 2005; Zhang et al. 2010; Guo et al. 2011; Zhou and Garvie-Lok 2015), the findings presented here contribute to a previously overlooked aspect of feeding practices—the role of wheat and soy in early north-central China’s cuisines for children. Archaeobotanical and zooarchaeological data can provide information about potential taxa that were consumed in the past, but who is doing the eating of these foods is often elusive. Our study of dietary patterns in this urban Eastern Zhou community indicates that children were breastfed in infancy and, for most, the weaning process ended between ages two-and-a-half and four years. The complementary foods that children were eating during the weaning process and into later childhood included significant amounts of C₃ foods such as wheat and soy, so we are potentially seeing the importance of these “new” crops as foods that were specifically selected for feeding the youth. This work also revealed that children were being fed diets that were slightly different from adults around them, and even further, girls and boys ate slightly different meals, which reflected cultural beliefs of nourishing normative male and female bodies. Directly assessing dietary histories through these kinds of isotopic studies sheds significant light on the lived experiences of the people who were partaking in these meals, where aspects of social life were mediated and expressed through the foods one ate (Hastorf 2017). Future studies of Eastern Zhou dietary patterns will compare across sites to see if these gendered eating behaviors existed in other communities.

**Conclusion**

Assessment of infant feeding and weaning is central for archaeological questions about major cultural changes and adaptations including shifts in subsistence, demographic implications related to fertility, and for bioarchaeological questions regarding individual and population health. There has been somewhat of a preoccupation in bioarchaeology with the assessment of so-called “weaning stress” through skeletal indicators. Although important for assessment of major social, subsistence, and health transitions, population-level interpretations of weaning and
weaning stress have the tendency to overlook individual life histories and the social aspects of care and diet. New isotopic techniques employing incremental dentin sampling are beginning to look at individual life histories of weaning from a more socially grounded context. These isotopic studies are an important tool for revealing the roles that foods play in human social life, and are useful for teasing apart the relationship between social identities and care, and the intersections of physiological stress and diet in early life. Our case study showed that by examining individual life histories of diet across infancy, childhood, adolescence, and adulthood, we can start to answer questions about the intersection of age and gender-based differences in infant feeding and care during a dynamic time in Bronze Age China. Through the exploration of individual life histories, we can begin to look at the early life beginnings of gender bias in infant care, which has had significant health repercussions on females in terms of evidence for stress and disease of their skeletons. Drawing on aspects of social identity (e.g., age and gender) in relation to infant feeding, care, reproduction, and health in the past interrogates the central questions of the anthropology of reproduction. Future work drawing together the fields of social anthropology of reproduction and bioarchaeology will be beneficial to advance a more holistic understanding of the historical and local social determinants of infant feeding practices in relation to aspects of identity.

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Halcrow, Miller, Pechenkina, Dong, and Fan


The bioarchaeology of infant feeding


