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Gender across Generations: Childhood Food Practices as Socialization Processes in Ancient China

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ABSTRACT Food is a biological imperative as well as a core material that humans use in socializing ourselves, and the things we choose to consume are infused with cultural meanings. Children, especially very young children, have little agency in subsistence decisions, and therefore the foods that caretakers feed to children may hold profound information about cultural value systems and reveal social processes and idealized identities. Here we focus on relationships between food, sex, and gender in early life by studying the childhood diets of 57 Eastern Zhou period individuals from the Central Plains region of China (771–221 BCE). Using stable isotope analysis of incremental dentin samples, we create detailed dietary histories of childhood years. From very early in life, the average $\delta^{15}N$ value for boys is notably higher than the average for girls, indicating slightly more protein consumption for most males, and this continues across childhood. Foods such as meat and millet were highly valued in ancient China and, whether intentional or not, become associated with aspects of sex and gender through preferential feeding to male children. These isotopic data reveal a key aspect of the socializing processes of children across generational interactions with caretakers, with food communicating information about social worth and gender, which becomes embodied in the developing child.

Keywords: stable isotope; childhood; China

Diet and nutrition are key components to health experiences over the lifetime and have significant effects on growth and development during early life and continued effects into adulthood (Gamble and Bentley 2022; Gluckman et al. 2007; Lewis 2018). Beginning from birth, nutritious and safe food is critical for all organisms (including liquids/drinks as "food"). However, humans approach food not only as a biological imperative but also as a medium that conveys sociocultural information (Appadurai 1981). The choices caretakers make about the foods given to infants and children are implicitly biocultural as they have significant biological and social meanings and effects. For example, infant feeding strategies

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(milk feeding vs. formula feeding, weaning timing, complementary food choices, etc.) are all culturally mediated practices that can have biological consequences for the developing infant (Miller 2018; Palmquist 2017). Consequently, anthropologists and health scientists have a long-standing interest in studying human diets and nutrition, both to improve health conditions in living populations as well as to understand the cultural values we attach to cuisines. Here we utilize stable isotope analysis of tooth dentin and bone collagen samples to study diets of ancient Eastern Zhou individuals from the Central Plains of China (Fig. 1) over their lifetimes, with particular attention to childhood diets and the roles specific foods may have played in gendering individuals in early life.

Food and Gender

Food is a primary substance used in the socialization and enculturation of individuals and communities, as food practices are intertwined with culturally specific understandings of age, gender, wealth, religion, politics, and more (Appadurai 1981; Douglas 2008; Hastorf 2017; Meigs 1987; Sterckx 2005, 2011; Weismantel 1988). Cultural identities are inextricably tied to foodways; indeed, a common way communities identify "us versus them" is through comparisons of subsistence and cuisine (Appadurai 1981; Douglas 1984; Franklin 2001; Gaytán 2008; Harris 1985; Hesse 1990). Food practices and beliefs about what is or is not edible, who consumes particular foods (when, how much, how often, in what context), and other values that foods are imbued with

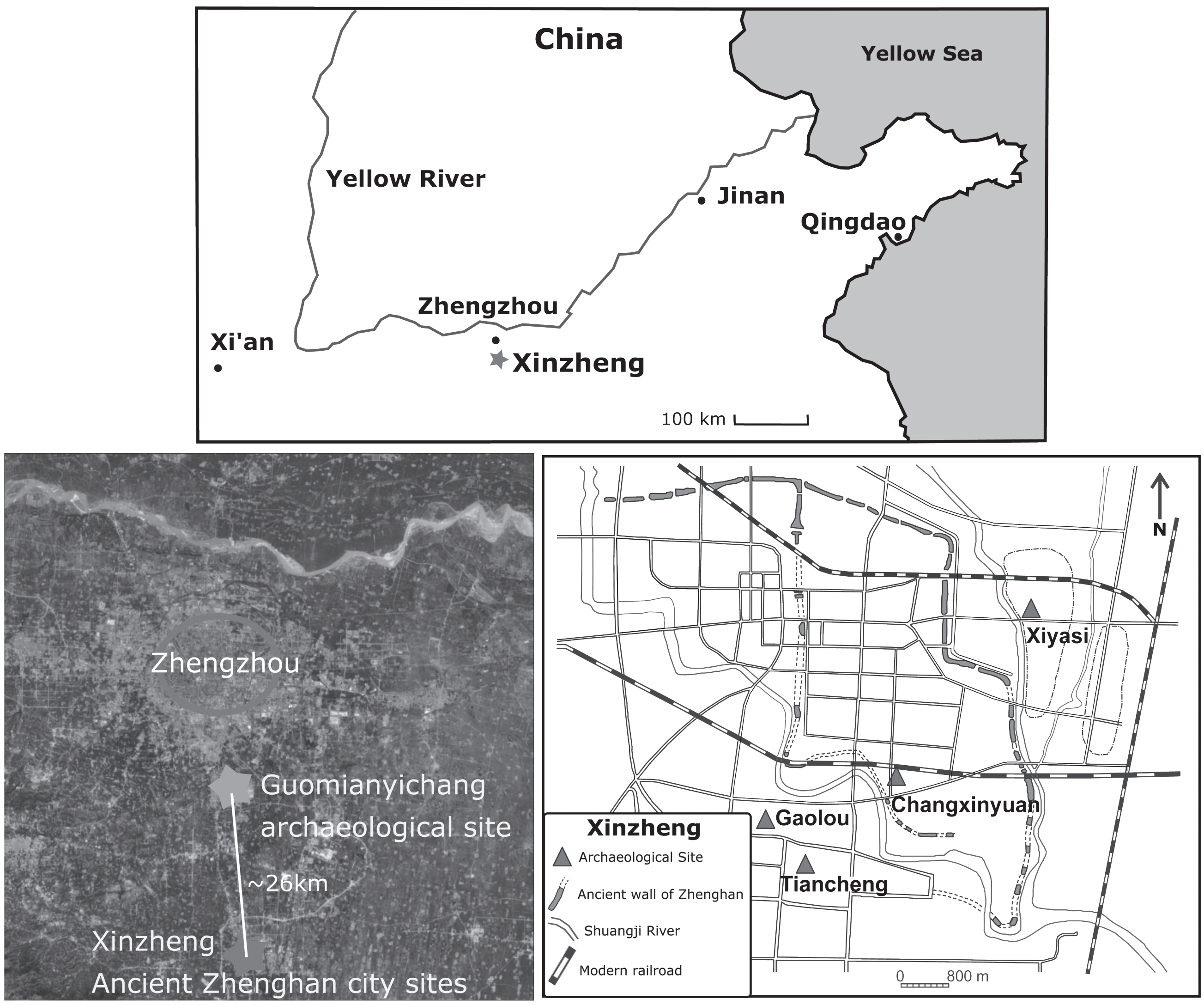

Figure 1. Maps showing locations of Eastern Zhou archeological sites. Lower right map shows the archaeological sites of Changxinyuan, Gaolou, Tiancheng, and Xiyasi (part of the ancient Zhenghan city). Lower left map shows relative location of archaeological site Guomianyichang, approximately 26 km north of Xinzheng/ancient Zhenghan city sites.

(such as what qualifies as “healthful” foods) are all learned behaviors that are routinely practiced and embedded in our social interactions (Bourdieu 1977; Lévi-Strauss 1966; Meigs 1987; Rozin et al. 1997; Sterckx 2011). Caretaker/familial relationships are foundational to that socialization process via food; caretakers are responsible for ensuring adequate food intake for the young, and what qualifies as adequate/proper meals for young people is culturally defined. From how infants are fed (breastfeeding, animal-milk feeding, formula feeding, etc.), to who makes the choices about weaning foods and what those are (and why), to later childhood diets and beyond, these are all small acts that normalize and idealize particular ways of being and convey significant amounts of social-cultural knowledge through their action and embodiment (Bourdieu 1977; Butler 1999; Farnell 2000; Mauss 1973; Meigs 1987; Mennell 1985; Taylor 1999).

Within the field of bioarchaeology, “sex” is often a key variable in research design and is usually presented as a binary expression (male/female) of biological factors (such as chromosomes, genes, gonads, hormones, etc.), with skeletal morphology being the primary lens of analysis, and this is not without problems or critique of assigning a binary gender construction to estimated biological sex (Agarwal and Wesp 2017; Fausto-Sterling 1993, 2012; Geller 2017; Richardson 2013; Sofaer 2006; Zuckerman and Crandall 2019; Zuckerman et al. 2023). Bioarchaeologists typically disambiguate “sex” from “gender” through the framework of viewing gender as a cultural construction; gender encapsulates socialized (learned) ways of being, embodied and performed (how to behave, speak, carry one’s self, emote, etc.), which includes culturally specific understandings of characteristics and behaviors that make one socially appropriate and identifiable according to shared understandings of gender norms (Butler 1999; Geller 2017). One’s gender may or may not correspond to notions of an individual’s sex, though historians have noted that a sex-gender conflation existed in ancient China (Hinsch 2013, 2018; Nyitray 2021).

Both external and internal conditions shape understandings of gender, and these are historically contingent and change over time and space (Bourdieu 1977; Butler 1999; Farnell 2000; Taylor 1999). Gender/gendering (gender expression, gendered embodiment) is a continuous process of both external (communal/societal/institutional) as well as internal (personal/psychological) interpretation and performance of normative behaviors, expectations, beliefs, actions, and so on, such that society genders us and we are gendering ourselves through countless thoughts and acts (Butler 1999; Joyce 2000). Scholars have noted the insidious nature of gendering processes, which are often implicit, are nondiscursive, and normalize particular ways of being in the world as completely “natural,” which is achieved through countless choices and acts, usually without reflexive critical thought (Bourdieu 1977; Bouveresse 1999; Butler 1999; Farnell 2000; Mauss 1973). Gender in particular is communicated through embodied performance (*hexis*; Bourdieu 1977), which makes studying these parts of humanity particularly challenging for scholars of the past. However, there are material things that are central to our socialization, and in this case, we investigate food as a primary medium for the communication of cultural values (see Geller 2017 on gender and the *materially discursive*).

Food is embodied material culture, “that is, a special kind of material culture created specifically for immediate destruction, but destruction through the transformative process of ingestion into the human body . . . hence, it has an unusually close relationship to the person and to both the inculcation and the symbolization of concepts of identity” (Dietler 2007:222). While numerous materials reveal and communicate aspects of personal and shared identities and ideologies (clothing, for example), food is one of the few things humans imbibe and whose components, both chemical elements and symbolic meanings, can become a part of the person. People have long looked to food, drinks, and other substances we consume as constructive, neutral, or destructive elements in creating particular types of people (healthy, sickly, strong, weak, virtuous, corrupt, moral, pious, deviant, etc.), and this was certainly part of belief systems in ancient China (Sterckx 2011). These food valuations are learned and passed across generations, which is not to say they remain static but in fact can be places where culture is demonstrably changing over time and can be studied through material traces in the archaeological record (Dietler and Hayden 2001; Hastorf 2017). Food can symbolize normative, aspirational, and inimical values, which in turn can be incorporated and embodied by the consumer.

Childhood is a critical period where one is figuring out how to be in the world (Lancy et al. 2010), and learning gendered behavior is certainly a large part of this social developmental process (Montgomery 2010). It is through inter- and intragenerational interactions that particular ways of being are normalized over time. This socializing/learning of gender norms occurs both externally (through dialogue, through material culture) but also internally (psychologically/personally), recursively functioning as “boying the boy and girling the girl” (Butler 1999; Joyce 2000). It is these processes that begin in life as external that individuals then take up and carry on, or modify or reject over the course of their lifetime (Butler 1999). Food can act as a medium imbued with values related to gender, where cultural ideas about what a particular gender eats (or should eat) is passed on, re-enacted over time, normalized, and embodied. Children often lack the agency of choice when it comes to subsistence, with families typically exerting this power over young individuals (Lancy 2012). Therefore, through these acts of caretakers choosing food for infants and children, they are also implicitly communicating ideals and values through meals, which in turn create the literal body of the child.

One of the earliest adult interventions in childhood feeding is the process of weaning a child off of (breast) milk using supplementary foods. This process is highly variable in its timing and tempo (Macadam and Dettwyler 1995; Tomori et al. 2018). The weaning process has long interested anthropologists and health scientists due to the complex biosocial relationship formed between a mother/allomother and an infant, as well as the potential short- and long-term consequences for the health of the pair, particularly the developing child (Lewis 2007; Macadam and Dettwyler 1995; Tomori et al. 2018; Tomori et al. 2022). Beliefs and behaviors about when to begin weaning a child, how long that process should last, what supplementary foods should be given to an infant, or what foods should be actively avoided are primarily culturally dictated practices. Although infants typically need dietary supplementation beginning around age six months as metabolic needs outpace milk's nutritional content, the addition of new foods into a child's diet around this period are primarily cultural/personal choices (Dettwyler 1987; Fouts 2004; Halcrow et al. 2018; Macadam and Dettwyler 1995). It is assumed that over the course of human history, mothers (embedded in their larger social spheres) have primarily been making these decisions about when to wean their baby and the appropriate ways to do so. The length of time a child is weaned has often been related to ideas of parental investment, and the foods that children begin eating as they transition to a nonmilk diet may be especially revealing about deeply held cultural valuations ascribed to specific foodstuffs.

While much of the anthropological work to understand human food practices in relation to culture and social identities is on living populations, we have historical and archaeological evidence for gendered diets in the past, including revelations made through the use of stable isotope analysis (Miller 2016; Miller et al. 2018; Reitsema and Vercellotti 2012; Soncin et al. 2021; White 2005). Our bodies reflect the chemistry of the foods we eat and the water we drink, with some caveats (Lee-Thorp 2008). Stable isotope analysis of bodily tissues is one technique bioarchaeologists frequently use for dietary reconstructions and can inform us of the plants and animals consumed during specific periods of life, depending on the tissue studied (Miller et al. 2018; Sealy et al. 1995). Carbon stable isotope data ($\delta^{13}C$) primarily tell us about the plant foods people ate as well as animal sources (DeNiro and Epstein 1978; Schoeninger and DeNiro 1982). Carbon isotope data are particularly useful in places where diets can include both C_3 and C_4 plants, such as central China, where the traditional domesticated crop millet is a C_4 plant, while primary C_3 crops include rice, wheat, soy, and more (Farquhar et al. 1989). Nitrogen stable isotope data ($\delta^{15}N$) can be used to understand food webs and trophic positions, with increasing nitrogen values as one rises through the food chain (i.e., $\delta^{15}N$ values can aid in distinguishing vegans from carnivores) (DeNiro and Epstein 1981; Minagawa and Wada 1984).

Analyzing different tissues from the same individual (i.e., bone and tooth) allows us to study dietary patterns from different periods of life, as well as different time scales of dietary averaging (Beaumont et al. 2018; Reynard and Tuross 2015; Tsutaya and Yoneda 2015). Bone is constantly remodeled over the lifetime while teeth are formed during youth and do not remodel. We can now subsample the dentin of a single tooth using an incremental/serial approach to create a detailed chronology of isotopic signatures across the developmental window of that tooth (Burt and Garvie-Lok 2013; Eerkens et al. 2011). For this study, targeted sampling of a permanent first molar provides dietary evidence spanning from around birth to 10 years of age, while sampling a permanent canine informs us of dietary patterns roughly from the ages of one to 14 years (AlQahtani et al. 2010; Hillson 2005). In contrast, bone chemistry reflects the average diet from at least the final decade before death (Ambrose and Norr 1993; Fahy et al. 2017). By studying a bone and tooth sample from individuals who died as adults, we can examine dietary patterns over the life course in conjunction with various biosocial variables such as sex and age (Miller et al. 2018). Therefore, we approach the body as a material record of dietary practices during life and use the chemical signatures locked in bodily tissues to try and understand the biosocial roles that foods played in animating that life (Sofaer 2006; White 2005).

Life in Eastern Zhou Period China

The Eastern Zhou period (Spring and Autumn period 771–476 BCE and Warring States period 475–221 BCE) is a pivotal era of Chinese history as numerous political, technological, and ideological changes were under way. This is a time of political instability, with many states frequently in conflict and at war, terminating with the final Zhou ruler deposed and the unification of early China by Qin Shihuang (Feng 2013; Liu and Chen 2012; von Falkenhausen 2006). Philosophers such as Confucius, Mencius, and Mozi lived during the Eastern Zhou period, and their ideologies were recorded and canonized over time, cementing cultural philosophies, including idealized behaviors and normative social roles, which in turn were being shaped in response to earlier Chinese history, as well as becoming archetypes for future generations to model/modify (Feng 2013; Hinsch 2003; Liu and Chen 2012; Sterckx 2005; von Falkenhausen 2006). Texts that relate to this period of Chinese history are themselves revised products. For example, many of the writings attributed to Confucius were assembled by disciples in the Han Dynasty period (206 BCE–220 CE). Consequently, these texts reflect later compilers selecting particular rules, lessons, and fables that uphold the highest standards of moral order to inspire people to live up to, as well as reflecting aspects of class, gender, clan, and so on (Hinsch 2013). By the Han Dynasty period, society was patriarchal, and these texts are primarily devoted to the experiences of men, and elite men at that, with far fewer passages dedicated to women's experiences, which in and of itself suggests a lower value afforded to women and their diminished power within these societies (Hinsch 2013, 2018).

Gender roles appear to be increasingly codified during this time, with most political and public-facing power concentrated in the hands of men, including control of wealth, land, inheritance, and so on. In contrast, women's roles emphasized the family and domestic sphere, with great weight placed upon women for producing children, particularly a male heir (Hinsch 2013, 2018; Nyitray 2021). The well-known phrase "men plow, women weave" (*nangeng nüzhi*) is thought to have its roots in even earlier times in China and articulates a gendered division of labor while also symbolizing the larger culturally sanctioned gendered separations that existed along many axes of daily life (Hinsch 2013). Historians have argued that these bifurcations between men and women's roles evolved over time and that earlier generations (such as the Shang and Western Zhou Dynasties) laid the foundation for an ideological shift to occur during the Eastern Zhou period, one that created a more stark contrast in idealized gender relations and whose philosophies related male–female duality of perceived biological sex to individual and familial morality and virtue, as well as good governance and political stability (Hinsch 2013, 2018).

While women are underrepresented in ancient texts, the passages that do relate to women often focus on the domestic sphere and filial piety, as Hinsch (2013) summarizes: "(a) woman should ideally hide herself within the recesses of the home, sacrifice her desires so she could cater to her husband and his kin, and obey her spouse and senior in-laws. Conversely, a man was free to leave the home and enter the wider world, pursue personal interests apart from his family, and exercise authority over his wife. Separation of the sexes had become a justification for wide-ranging masculine privilege" (Hinsch 2013:25). Wealthy families had the economic means to segregate parts of their daily lives and socialize primarily in homosocial spheres (men out in the world with men, women cloistered at home with other women and children), but this was certainly not the case for most common people whose daily interactions would have likely been structured but potentially less gender-divided out of practical necessity (Hinsch 2013). Though much more is known about life during these times for the ruling and elite classes, certain aspects of gender roles, particularly related to the roles of girls as daughters, and women as wives and mothers responsible for producing and caring for children, were likely shared across many social dimensions, including class and clan groups (Hinsch 2018).

The Liji, also known as the Book of Rites, provides further insights into the Eastern Zhou sex–gender binary, which clearly began in childhood with children treated differently based on their perceived sex (external genitalia and associated reproductive capabilities) and gendered accordingly:

> 子能食食，教以右手。能言，男唯女俞。男鞶革，女鞶絲. When the child was able to take their own food, they were taught to use the right hand. When they were able to speak, a boy (was taught to) respond with respect; a girl, submissively and gentle. The former was fitted with a handbag of leather; the latter, with one of silk. 六年教之數與方名。七年男女不同席，不共食。八年出入門戶及即席飲食，必後長者，始教之讓。九年教之數日。 At six years, they were taught the numbers and the names of the cardinal points; at the age of seven, boys and girls did not occupy the same mat nor eat together; at eight, when going out or coming in at a gate or door, and going to their mats to eat and drink, they were required to follow their elders: the teaching of yielding to others now begun; at nine, they were taught how to number the days. 十年出就外傅，居宿於外，學書計，衣不帛襦褲，禮帥初，朝夕學幼儀，請肄簡諒。At ten, (the boy) went to a master outside, and stayed with him (even) over the night. He learned the classical books and calculation; he did not wear his jacket or trousers of silk; in the courteous manners he followed his early lessons; morning and evening he followed the etiquette of respecting

> the elders; he would ask to be exercised in (reading) the tablets, and learn to be honest. 女子十年不出，姆教婉娩聽從，執麻枲，治絲繭，織紝組紃，學女事以共衣服，觀於祭祀，納酒漿、籩豆、菹醢，禮相助奠。A girl at the age of ten ceased to go out (from the women's apartments). Her governess taught her the arts of pleasing speech and manners, to be docile and obedient, to handle the flax fibers, to deal with the cocoons, to weave silks and to learn (all) woman's work, how to furnish garments, to watch the sacrifices, to supply the liquors and sauces, to fill the various stands and dishes with pickles and brine, and to assist in setting forth the appurtenances for the ceremonies. 十有五年而笄，二十而嫁；有故，二十三年而嫁。聘則為妻，奔則為妾。凡女拜尚右手。At fifteen, she assumed the hair-pin; at twenty, she was married, or, if there were occasion (for the delay), at twenty-three. If there were the betrothal rites, she became a wife; and if she went without these, a concubine. In all salutations of females, the upper place was given to the right hand. (Liji, Nei Ze, 76–82; translation by authors)

Here we see a clear sex–gender binary from a young age with a number of specific ages called out as chronological markers of particular life events depending on the gender of the individual, and clear demarcation of gendered work begins from a young age. All of this points to deeply embedded notions of a gender binary and an implicit hierarchy where males are given greater power in the public domain, while female power is limited to the domestic sphere (Hinsch 2013, 2018).

We acknowledge that the layering and intersections of various experiential variables (age, gender, social status, ethnicity, etc.) means that while we may focus on one of these, in this case gender, we recognize these axes rarely operate independently and singularly; therefore, our interpretations may be clouded by individual factors we cannot comprehend, qualify, or quantify at this time. Recently, feminist and queer critiques of understandings of gender in China's history have pushed researchers not only to expand studies to include women in the past but also to study masculinity, as well as to view gender beyond a dichotomous perspective (Chiang 2012; Hinsch 2013, 2018; Louie 2002; Nyitray 2021). It is certain that different ideas and norms for gendered behavior existed for individuals of different social classes, ethnic groups, and so on in ancient China (Hinsch 2013, 2018; Ko 2007; Nyitray 2021). This research starts to touch upon those intersections of gender with other experiential identities through the presentation of selective individual case studies.

Evidence of Eastern Zhou Cuisines

Archaeological and historical evidence indicate the importance of particular plants and animals in the diets of Eastern Zhou peoples (Dong et al. 2017; Lee et al. 2007). Millet is the locally domesticated crop and dominated diets for millennia (Cohen 2011; Lee et al. 2007; Liu et al. 2009; Zhao 2011), while grains such as rice (domesticated from the south) and wheat (introduced from the west) appear less frequently in archaeological assemblages in this region during this time (Chen 2016; Deng et al. 2019; Fuller et al. 2009; Guo and Jin 2019; Jiang and Liu 2006; Zhou and Garvie-Lok 2015). Historical texts reference specific foods, and the contexts of these references can provide hints as to the valuation and cultural meanings ascribed to some of these foodstuffs. For example, in many historical texts such as the Analects of Confucius, the Liji, and the Huang Di Nei Jing, millet is repeatedly mentioned and is qualified as the traditional, highly desired grain. In contrast, wheat and soybean were considered "coarse" foods and therefore less valued, both symbolically as well as monetarily, with higher prices recorded for millet during the later Han Dynasty. Soybean and wheat were also known as reliable foodstuffs for feeding the poor and were even used to feed soldiers during military campaigns (Yu 2016). Grains such as millet, rice, and wheat were also turned into alcoholic beverages, and these wines are often mentioned in historical texts in relation to elite men's sociopolitical interactions, as well as rituals honoring ancestors (Chang 1977; Liu and Reid 2020; Liu et al. 2020; Sterckx 2005, 2011; Yu 2016). Importantly, millet is isotopically distinct from most other plants that humans consume because it is a C_4 plant, with $\delta^{13}C$ values ranging from –14‰ to –8‰. In contrast, C_3 plants, such as rice, wheat, barley, and soybeans, have $\delta^{13}C$ values around –23‰ (An et al. 2015; DeNiro and Epstein 1978; Farquhar et al. 1989; Kohn 2010; O'Leary 1988; Wang et al. 2018).

Meat was also given high value both economically and socially, particularly holding significant power for honoring ancestors and performing rites (see Knapp 2019; Liji Wang Zhi 31; Sterckx 2019). Meat was also thought to have been infrequently consumed by the majority of people, particularly beef and lamb, which were highly prized and very expensive. Rather, these were meats of the upper classes, while pork and chicken, in particular, were more likely the occasional meat protein sources for commoners and poorer folks (Chang 1977; Yu 2016). Nitrogen isotope values can provide information about protein consumption, with stepwise enrichment of +3–5‰ in $\delta^{15}N$ as one rises through the food chain (DeNiro and Schoeninger 1983; Minagawa and Wada 1984; Schoeninger and

DeNiro 1984). Isotopic analysis of a small number of zooarchaeological samples (pig, dog, cattle, sheep) from two Eastern Zhou sites in ancient Zhenghan city (Changxinyuan and Tianli) indicate animals raised on diverse resources (Dong et al. 2017; Miller et al. 2020). The $\delta^{13}C$ values ranged from −18.6‰ to −6.8‰, and $\delta^{15}N$ values ranging from 2.4‰ to 10.7‰. Recent bioarchaeological research using stable isotope analysis has documented dietary differences between nobles and commoners, with nobles/high-status individuals having the highest nitrogen values, indicating greater meat consumption and often consuming greater amounts of millet (or rice), which were also highly valued (Wei et al. 2021; Zhou 2020; Zhou et al. 2021).

Previous bioarchaeological research on life for people living during the Eastern Zhou period has shown links between diet, sex, gender, and increasing social inequalities (Dong et al. 2017; Miller et al. 2020). Specifically, bioarchaeological evidence has shown dietary differences between males and females during adulthood, with males consuming more of the traditional and highly valued grain of millet, as well as more meat, while females consumed more of the relatively newly introduced cereals, wheat and soy (Dong et al. 2017; Miller et al. 2020). A recent study of 23 individuals from ancient urban Zhenghan city (Xiyasi, 西亚斯, and Chanxingyuan, 畅馨苑; Fig. 1) using incremental dentin samples suggested that aspects of these dietary patterns began during childhood, with boys consuming more C_4 foods (millets) than girls, starting in youth, but overall, individuals consumed more C_3 foods (wheat, soy, rice, etc.) during childhood in comparison to their later adulthood diets (Miller et al. 2020).

Here we focus on the stable isotopic data from 34 newly studied Eastern Zhou individuals in addition to drawing on the previously published data from 23 other urban Zhenghan Eastern Zhou people (Miller et al. 2020) in order to illuminate childhood dietary patterns with particular attention to understanding dynamic relationships between food, sex, and gender. These dietary data from Eastern Zhou period individuals are from three newly studied archaeological sites from Henan Province on the Central Plains of China (Fig. 1): Gaolou (郜楼), Tiancheng (天成), and Guomianyichang (国棉一厂). Two of the sites, Tiancheng and Gaolou, are from ancient urban Zhenghan city, located under present-day Xinzheng. The third site, Guomianyichang, is located about 26 km to the north of ancient Zhenghan city, in the modern Longhu town, near Zhengzhou. Guomianyichang is located near the ancient city of Huayang, which was a military outpost, though the relationship between those two sites is still unclear. Archaeological research on these sites and associated excavated materials is ongoing (see Supplemental Information for more information).

Materials and Methods

Skeletal samples (both a tooth and a bone sample) from 34 Eastern Zhou period individuals from three archaeological sites (Gaolou, Tiancheng, and Guomianyichang) were analyzed using isotopic methods. We studied nine individuals from Gaolou (five females, four males) and nine individuals from Tiancheng (five females, four males). Due to preservation issues, we are missing bone collagen isotopic data for three individuals from Tiancheng. From Guomianyichang, 16 individuals were studied (six females, seven males, three unknown skeletal sex). Ongoing analyses of archaeological materials, including further human osteological analyses, prevent complete assessment of the nature of these cemeteries. No radiocarbon dates have been analyzed from these locales, but artifacts and stratigraphy indicate all burials presented here are from the Eastern Zhou era, and in some cases, this can be refined further to either the Spring and Autumn period or the Warring States period (see Supplemental Information). Some burials are believed to have been disturbed and looted in the past and therefore we are cautious in the use of mortuary treatment and associated grave goods, as these may not accurately reflect the original burial treatment and are also known to reflect the actions of the living and not necessarily the status of the deceased.

Individuals were selected for isotopic analysis based on preservation of skeletal elements to estimate sex and age, as well as presence of a permanent canine or first molar with minimal wear. Skeletal sex and age were estimated using standard osteological observations of the pelvis and skull (Brooks and Suchey 1990; Buikstra and Ubelaker 1994). Almost all were adults at the time of death, so these individuals are survivors, in that most did not die as youths. Individuals were grouped in broad age categories of "juvenile" (estimated age of death as less than 18 years; $n = 2$), "young" (estimated age at death from 18 to 29 years; $n = 10$), "middle" (estimated age at death between 30 and 49; $n = 8$), or "older" (estimated age at death 50+; $n = 8$). Six individuals were more challenging to narrow their estimated age at death, so five are listed with two potential age categories, and one is noted as an adult (over 18 years at age of death). Of the 34 new individuals studied, 16 were estimated to be females, 15 were estimated to be males, and three were of unknown skeletal sex. A permanent first molar or canine tooth was preferentially selected to capture the early years of diet (however, one individual's childhood diet is represented by a second molar, Guomianyichang M109). Teeth were gently cleaned and silicone molds were created prior to destructive analysis. Bone samples were preferentially taken from elements that were already broken.

Tooth dentin segments were prepared for isotopic analysis following previously published protocols (Beaumont and Montgomery 2015; King et al. 2018; Sealy et al. 1995; Sealy et al. 2014). For dental samples, enamel was removed using a handheld rotary tool and preserved for future analyses. The remaining dentin tissue was placed in labeled beakers with dilute HCl (0.5 M) until the tissue demineralized sufficiently to be sliced with a scalpel. Any adhering cementum and/or secondary or tertiary dentin was removed when noted. Tooth samples were carefully sliced into ~1 mm increments beginning from the occlusal surface of the crown and proceeding to the root tip, using a clean scalpel and metric ruler. Individual dentin slices were placed into labeled microcentrifuge tubes with 0.5 M HCl until further demineralized. Samples were rinsed repeatedly with pure water to neutrality, and then dilute HCl of 0.001 M (pH 3 solution) was added to samples before gelatinizing them for 24 hours in a 75°C oven. Samples were then agitated to mix and frozen prior to freeze-drying. Bone samples followed a similar protocol. Cortical surfaces were first cleaned and then bone was crushed and sieved, with the 0.25 mm to 1 mm fraction used for collagen extraction. Bone samples were demineralized in 0.2 M HCl (replaced as needed until demineralization was complete) and then rinsed with purified water to neutrality. Samples were then treated with 0.125 M NaOH for 20 hours and then rinsed to neutrality. Dilute 0.001 M HCl was added to each sample before placing them in a 70°C oven for 48 hours. Samples were then frozen and freeze dried.

Freeze-dried collagen samples were weighed into tin capsules for isotopic analysis at the Joint International Research Laboratory for Environmental and Social Archaeology at Shandong University, Qingdao, China, using a Flash 2000 HY elemental analyzer coupled to a Delta V Advantage IRMS. Samples were analyzed in conjunction with calibration standards, including USGS40 (L-glutamic acid, $\delta^{13}C = -26.39‰ \pm 0.04‰$, $\delta^{15}N = -4.52‰ \pm 0.06‰$), USGS62 (caffeine, $\delta^{13}C = -14.79‰ \pm 0.04‰$, $\delta^{15}N = +20.17‰ \pm 0.06‰$), USGS41a (L-glutamic acid, $\delta^{13}C = +36.55‰ \pm 0.08‰$, $\delta^{15}N = +47.55‰ \pm 0.15‰$), and internal standard of EMA B2155 (casein). The lab reports precision of ± 0.1‰ for $\delta^{13}C$ and ± 0.2‰ for $\delta^{15}N$. Collagen quality was assessed by %C, %N, and atomic C:N, with all samples reported here having C:N values between 3.1 and 3.6 (DeNiro 1985; Guiry and Szpak 2021; Schwarcz and Nahal 2021).

A general developmental timeline for each tooth was used to facilitate interindividual comparisons as well as allowing for comparisons of dentin isotopic data across studies. With M1, we assumed the developmental range began at birth (0 years) and completed at 10 years, while for canines, we placed the maximums at six months (0.5 years) to 14 years. Age estimations of each segment were calculated using the Beaumont and Montgomery (2015) method, which relies on a simple, linear relationship between the total time a tooth was growing (for example, 10 years for a first molar) and the number of segmented samples extracted by a researcher. The result is an estimated median age point for each incremental sample and which provides a standardized approach that allows comparison to previous studies (Miller et al. 2020). However, dentin is not deposited in horizontal layers throughout the tooth structure, meaning that the slices created through the protocol will inevitably capture overlapping periods of dentin development, and therefore, associated time frames for each segment should be considered an estimated average with potentially fuzzy boundaries rather than absolutes (Beaumont et al. 2013; Tsutaya 2020).

Results

The incremental dentin samples from Eastern Zhou individuals from Gaolou, Tiancheng, and Guomianyichang ($n = 34$ individuals with $n = 393$ paired $\delta^{13}C$ and $\delta^{15}N$ values, Supplemental Tables 1 and 2) show a wide range of $\delta^{13}C$ values, from −19.8‰ to −7.6‰, and $\delta^{15}N$ values range from 6.2‰ to 14.3‰. Examining the individual dietary profiles (Figs. 2–4), many individuals show characteristic declines in $\delta^{15}N$ in the first years of life, indicating the process of removing breast milk from the diet (weaning), as well as changes to $\delta^{13}C$ values across childhood years related to differential consumption of C_3 and C_4 plants. These same individuals ($n = 34$) have bone collagen values that range from −15.7‰ to −8.8‰ and $\delta^{15}N$ values from 6.1‰ to 10.5‰ (Figs. 2–4, Supplemental Table 1). The dentin profiles of individuals from the Eastern Zhou ancient Zhenghan city archaeological sites of Xiyasi and Changxinyuan are replotted in Supplemental Figures 1 and 2, and their data are included in subsequent analyses of Eastern Zhou dietary patterns (for all original Xiasyi and Changxinyuan data, see Miller et al. 2020).

Figures 5 and 6 plot the incremental dentin isotopic profiles from all of the Eastern Zhou individuals we have studied to date (Gaolou, Tiancheng, and Guomianyichang in this study and Xiyasi and Changxinyuan data from Miller et al. 2020) and use a loess curve to show the moving average for $\delta^{15}N$ and $\delta^{13}C$

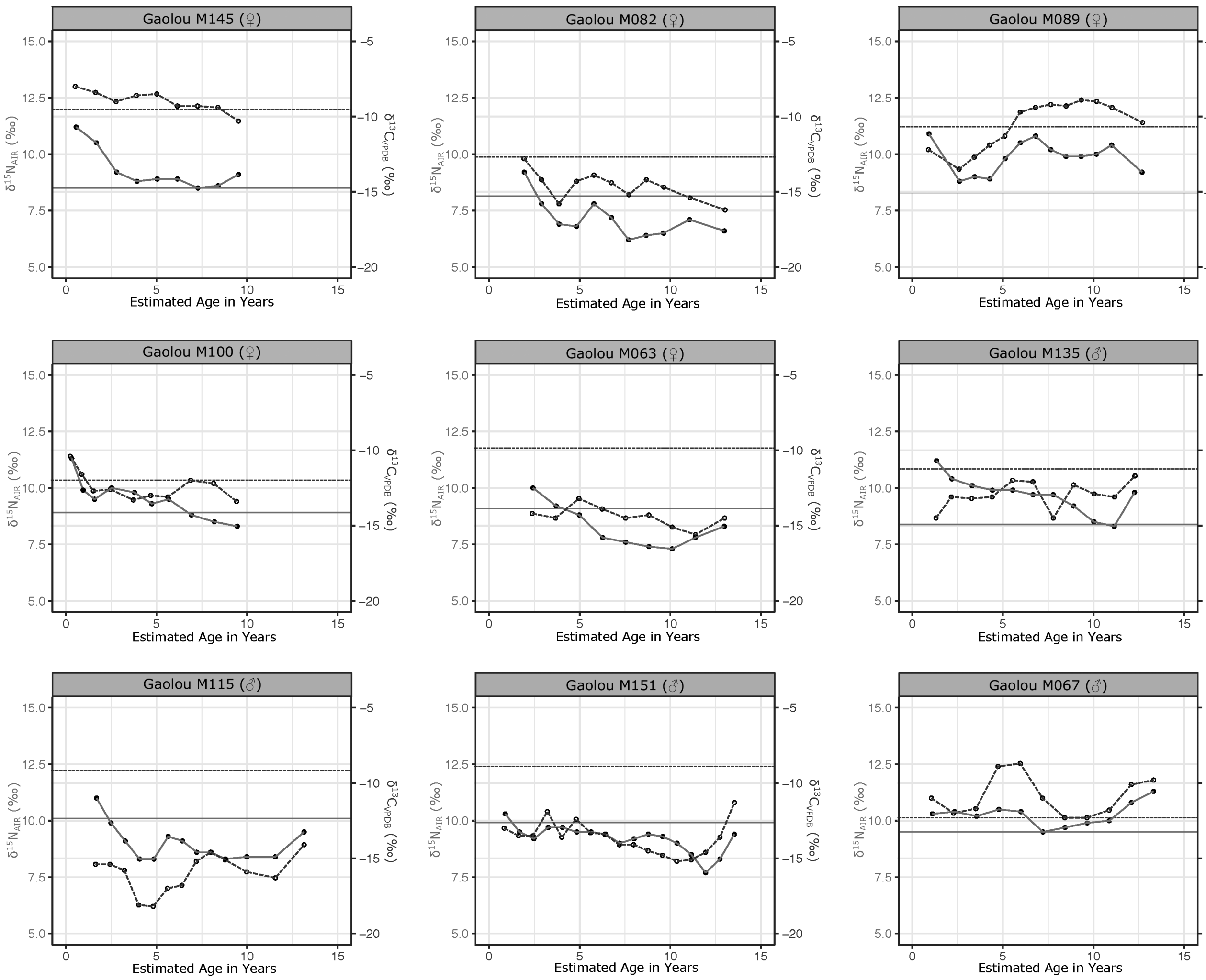

Figure 2. Isotopic profiles for individuals from Gaolou ($n = 9$; $n = 5$ females; $n = 4$ males). δ^{15}N values (solid plotted line with circles shows dentin collagen values and horizontal line is bone collagen value) and δ^{13}C values (dashed plotted line with circles shows dentin collagen values and dashed horizontal line is bone collagen value) are presented.

across the childhood years in conjunction with estimated skeletal sex ($n = 54$; 27 females, 27 males). Overall, we see a high degree of isotopic heterogeneity, with large ranges observed in nitrogen, but especially in carbon isotope values, suggestive of differential dietary practices between children, as well as revealing an expansive diversity in the foods that were considered acceptable to feed growing children. A patterned difference is observed across childhood in the dentin δ^{15}N values (Fig. 5), where the male average is consistently slightly higher than the female average, indicating slightly more protein consumption (or proteins from a higher trophic position). The offset suggests a meaningful difference in dietary practices. Additionally, for most of childhood, females have slightly lower average dentin δ^{13}C values, indicating more C_3 foods in their diets compared to their male peers (Fig. 6).

We estimated the weaning ages for a total of 47 Eastern Zhou individuals (28 individuals from this study plus data from 19 individuals studied in Miller et al. 2020) who have the earliest dentin segments present in their profiles (Table 1; Supplemental Table 1). To estimate weaning ages, we looked for declines in δ^{15}N by 1‰ to 4‰, with potential concurrent changes to δ^{13}C values across the earliest forming dentin, and that are associated with the removal of milk from the diet (Burt and Amin 2014; Eerkens et al. 2011). Individuals ($n = 10$) who are missing the early forming dentin tissue or those with isotopic data that do not fit the expected drop in δ^{15}N were excluded from weaning age estimations. Across the 47 individuals examined, the average weaning age is estimated at 2.9 years of age, with no statistically significant difference (Wilcoxon rank sum test $p = 0.759$) in weaning age

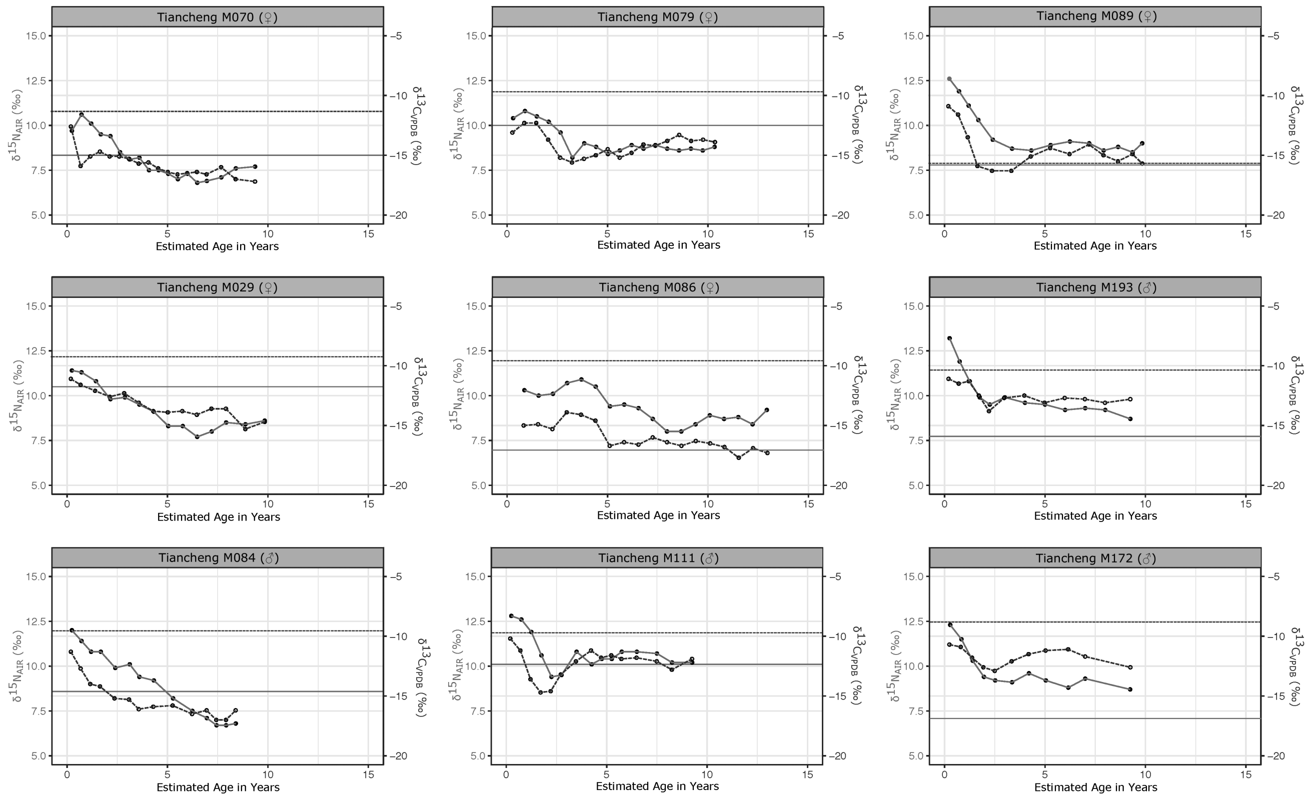

Figure 3. Isotopic profiles for individuals from Tiancheng ($n = 9$; $n = 5$ females; $n = 4$ males). δ^{15}N values (solid plotted line with circles shows dentin collagen values and horizontal line is bone collagen value) and δ^{13}C values (dashed plotted line with circles shows dentin collagen values and dashed horizontal line is bone collagen value) are presented.

estimates between females ($n = 20$, average = 3.0 years) and males ($n = 24$, average = 2.9 years). These ages are estimates in that the dentin samples capture overlapping periods of development due to the way dentin tissue grows as well as the sampling procedure, and coupled with the fact that every individual's developmental timeline will vary (i.e., timing of tooth growth). Therefore, these estimates should be treated as fuzzy averages rather than absolutes.

Diets in the first few years of life are a complex combination of a mother's (or allomother's) diet (via milk) and the weaning foods consumed. Since the isotopic data indicate the average age of weaning was three years, we used the age of five years as the cutoff for comparing means (δ^{15}N; δ^{13}C) between females and males, which should represent diets that do not include the influence of milk (mother's diet) and only reflect the diet of the individual (Tables 2 and 3; Supplemental Table 1). There is a statistically significant difference in childhood diets post five years between males (mean δ^{15}N = 8.5‰; mean δ^{13}C = –13.3‰) and females (mean δ^{15}N = 7.8‰; mean δ^{13}C = –14.0‰) for both elements. All δ^{15}N values were pooled (not averaged by individual) and appear bimodally distributed for both males and females, with males' distribution shifted slightly higher on δ^{15}N values (Wilcoxon rank sum test, $p = 1.21e\text{-}07$). All δ^{13}C values post age five years were compared between males and females (values pooled, not averaged by individual), and males were normally distributed but females were not (Wilcoxon rank sum test, $p = 0.0018$). We further compared the means of dentin samples of females and males between ages five and 10 years, which is the overlapping developmental period first molars and canines capture. The 27 males (represented by 139 dentin samples) had a mean δ^{15}N = 8.5‰, which is statistically significantly different from the 27 females (represented by 144 dentin samples) who had a mean δ^{15}N = 7.8‰ (Wilcoxon rank sum test, $p = 3.086e\text{-}5$). The female mean δ^{13}C (27 females, $n = 144$ samples) of –13.9‰ is statistically significantly different from the male mean δ^{13}C (27 males, $n = 139$ samples) of –13.2‰ (Wilcoxon rank sum test, $p = 0.006$). This suggests there are meaningful differences in diets between boys and girls. On average, females have lower average δ^{15}N and δ^{13}C values than males during childhood (postweaning).

Bone collagen values are compared for these same Eastern Zhou individuals to examine possible dietary

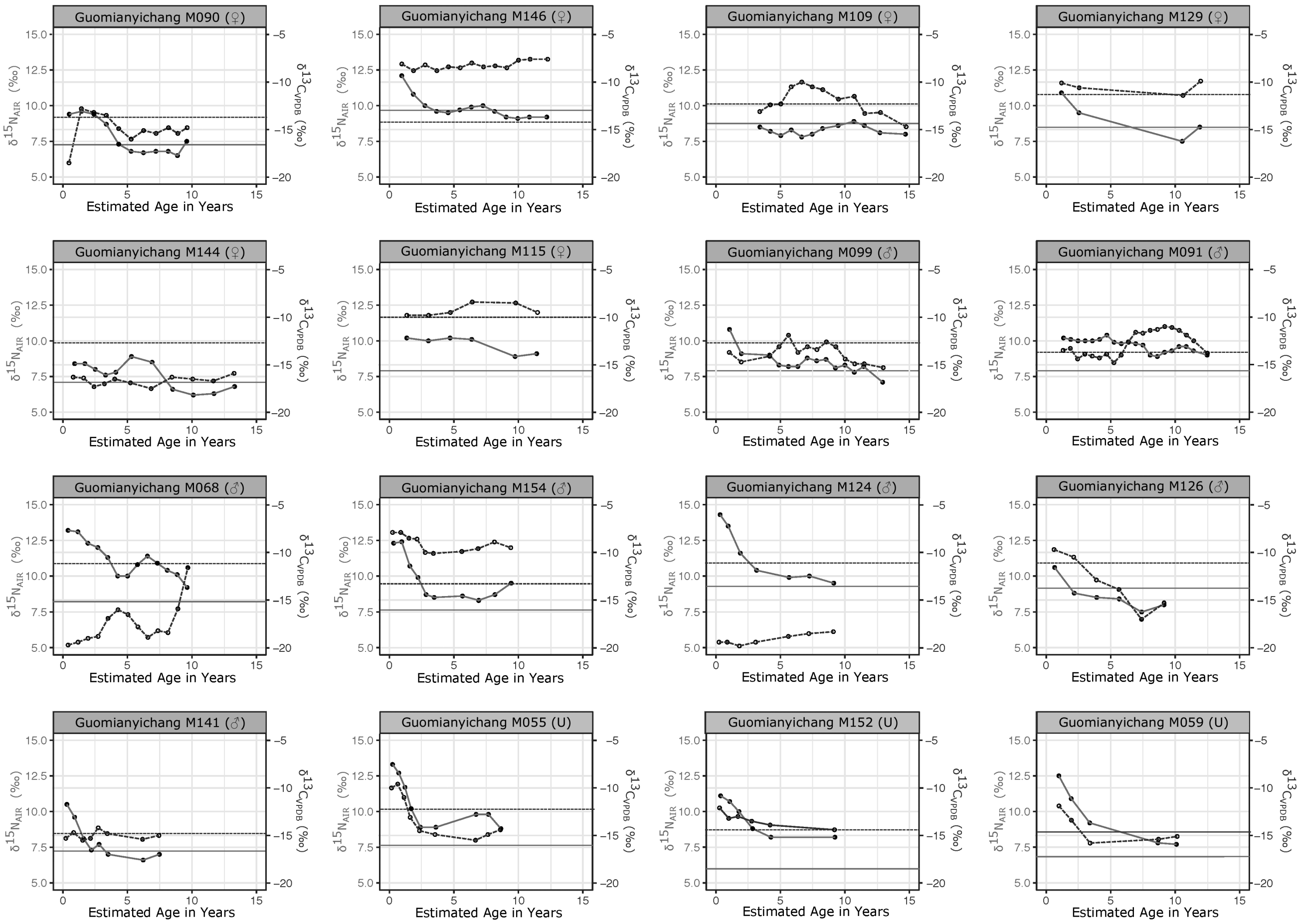

Figure 4. Isotopic profiles for individuals from Guomianyichang ($n = 16$; $n = 6$ females; $n = 7$ males; $n = 3$ unknown skeletal sex). δ^{15}N values (solid plotted line with circles shows dentin collagen values and horizontal line is bone collagen value) and δ^{13}C values (dashed plotted line with circles shows dentin collagen values and dashed horizontal line is bone collagen value) are presented.

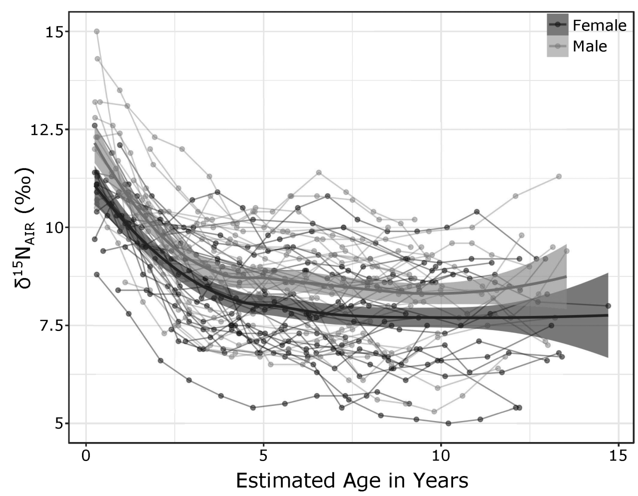

Figure 5. δ^{15}N dentin profiles for each Eastern Zhou individual studied across the Gaolou, Tiancheng, and Guomianyichang sites as well as the δ^{15}N dentin profiles of individuals from Xiyasi and Changxinyuan (Miller et al. 2020). Female and male dentin profiles are plotted. A loess curve was plotted for males and females, and it shows that on average, male children had slightly higher δ^{15}N values than their female peers across infancy and childhood.

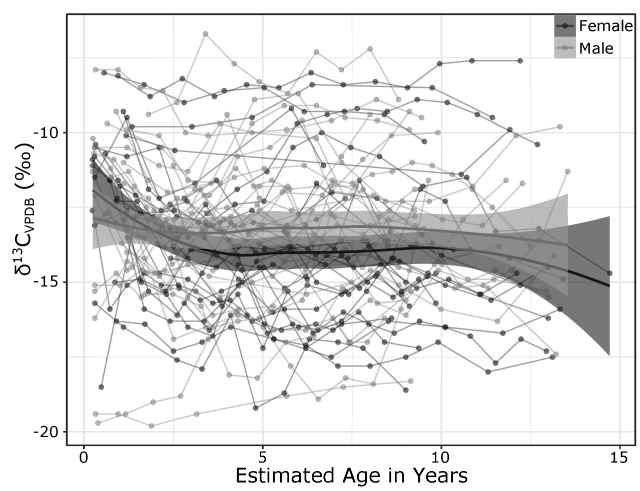

Figure 6. δ^{13}C dentin profiles for each Eastern Zhou period individual studied across the Gaolou, Tiancheng, and Guomianyichang sites as well as the δ^{13}C dentin profiles of individuals from Xiyasi and Changxinyuan (Miller et al. 2020). Female and male dentin profiles are plotted. A loess curve was plotted for males and females, and for much of the childhood period, females had slightly lower δ^{13}C values compared to their male peers.

differences in later life (Tables 4 and 5; Supplemental Table 1). There are no statistically significant differences between the average $\delta^{15}N$ (Wilcoxon rank sum test, $p = 0.762$) and $\delta^{13}C$ (Wilcoxon rank sum test, $p = 0.079$) bone collagen values of females and males. Interestingly, the degree of difference between the childhood dentin and later life bone collagen $\delta^{15}N$ values decreases between females and males, while the average $\delta^{13}C$ values become more divergent in adulthood.

Table 1. Eastern Zhou Estimated Age of Weaning

Eastern Zhou	Count (*n*)	Median (years)	Mean (years)	SD (years)
Overall	47	2.8	2.9	0.6
Males	24	2.7	2.9	0.7
Females	20	3	3	0.7
Unknown	3	2.8	2.9	0.5

Table 2. Summary of $\delta^{15}N$ Dentin Values Post Age Five Years

Sex	Number of Dentin Samples	Median $\delta^{15}N$ (‰)	Mean $\delta^{15}N$ (‰)	SD (‰)
Female ($n = 27$)	168	7.9	7.8	1.2
Male ($n = 27$)	159	8.6	8.5	1.3

Table 3. Summary of $\delta^{13}C$ Dentin Values Post Age Five Years

Sex	Number of Dentin Samples	Median $\delta^{13}C$ (‰)	Mean $\delta^{13}C$ (‰)	SD (‰)
Female ($n = 27$)	168	–14.5	–14	2.8
Male ($n = 27$)	159	–13.2	–13.3	2.5

Table 4. Summary of Bone Collagen $\delta^{15}N$ for These Eastern Zhou Individuals

Sex	Number of Dentin Samples	Median $\delta^{15}N$ (‰)	Mean $\delta^{15}N$ (‰)	SD (‰)
Female	27	8	8.1	1.1
Male	27	7.9	8.2	1.1
Unknown	3		6.9	

Table 5. Summary of Bone Collagen $\delta^{13}C$ for These Eastern Zhou Individuals

Sex	Number of Dentin Samples	Median $\delta^{13}C$ (‰)	Mean $\delta^{13}C$ (‰)	SD (‰)
Female	27	–11.4	–12	2
Male	27	–10.9	–11	1.8
Unknown	3		–13.8	

Discussion

Feeding children as gendering practices: Childhood diets

Overall, the dentin isotopic values for Gaolou, Tiancheng, and Guomianyichang individuals show a very wide range, from diets composed primarily of C_3 plants to diets heavily reliant on C_4 plants, and numerous mixtures between these extremes. There was also differential consumption of proteins (relatively more or less and/or proteins from different trophic positions) (Figs. 2–4). We see that dietary variation occurs both within the same person's diet over the course of childhood, in comparison with their later bone collagen values, and between individuals. This high degree of diversity in the isotopic values during childhood indicates that people living in this region had access to many different kinds of plant and animal resources and that a large spectrum of items were considered foods that were appropriate to feed growing children.

Surprisingly, when we aggregate all of the incremental dentin values for Eastern Zhou individuals we have studied from this region so far (Fig. 5), we observe a small but consistent offset in the average $\delta^{15}N$ values between males and females across infancy and childhood. In general, females have lower $\delta^{15}N$ values when compared with males. Stable nitrogen isotope values primarily reflect the proteinaceous foods of the diet, and differences between individuals may be evidence of more or less protein consumed or different types of proteins consumed (i.e., plant proteins vs. animal derived proteins). That individuals we assessed as biologically male show, on average, higher $\delta^{15}N$ values across their childhood years compared with the individuals assessed as biologically female reveals that males were fed a bit more meat, or proteins from higher trophic levels, when they were children. In contrast, the females we studied generally received a bit less meat in their diets or instead consumed lower trophic proteins (potentially more plant-derived proteins) as youths. Patriarchal Eastern Zhou society valued males more than females, and meat was also highly prized. We propose that caretakers fed male children more meat than female children, and whether intentionally or not, meat became tied to the creation of male bodies and embodiment of male gender roles, including conveying notions of social worth.

Furthermore, the $\delta^{15}N$ offset occurs across the entire period of dentin development represented, beginning in the very earliest period of life. Across childhood but especially during the first years of life, it was likely mothers who were the primary caretakers making choices about the feeding habits of their children and setting their dietary trajectories (though certainly mothers' beliefs were embedded within culturally learned, normative frameworks). The earliest dentin segments capture the first couple years of life, when most infants were still consuming significant amounts of breast milk (see discussion of weaning, below). The fact that an offset between males and females begins so early in life presents the possibility that the diets of lactating women may have even altered based on perceptions of their child. If male children were preferred, women who produced male heirs may have themselves benefited by being able to consume more meat in their own meals. This temporary access to a more coveted food item, meat, could cause a slight increase in the δ^{15}N of their breast milk, which in turn would be consumed by their developing infant and resulted in the downstream effect, separating the δ^{15}N dentin values observed between females and males during the earliest period of infancy. The persistence of the offset across all of the childhood years represented (and statistically significant difference in δ^{15}N between boys and girls after age five years) indicates that, in general, male children were likely fed a little bit more meat than their sisters and other girls throughout this developmental period and that this was an ongoing embodied gendering practice across childhood.

We also considered if there may have been any differences in childhood nitrogen isotope patterning within and between sites; perhaps meat consumption was related to factors such as geography (urban vs. nonurban communities), economic power, or access to particular foodstuffs. Comparing within and between sites, we see that the higher male offset in δ^{15}N persists (Fig. 7). This suggests that notions that children deemed to be "boys" (highly desired male offspring) should be fed more meat in their diets because of their higher social value may have been widespread within Central Plains Eastern Zhou culture. There are a few individuals who do not follow these patterns (a few females with high δ^{15}N values, a few males with low δ^{15}N values) who likely indicate how diet is also entangled in aspects of wealth, status, access, and other factors. It is in these dietary isotopic data sets that we can begin to access personalized and lived aspects of gender for Eastern Zhou people, discerning how food practices were entangled in gender norms and embodied gender expression, with specific foods fed to certain individuals, which, over time, shapes that person into the embodiment of those cultural ideals.

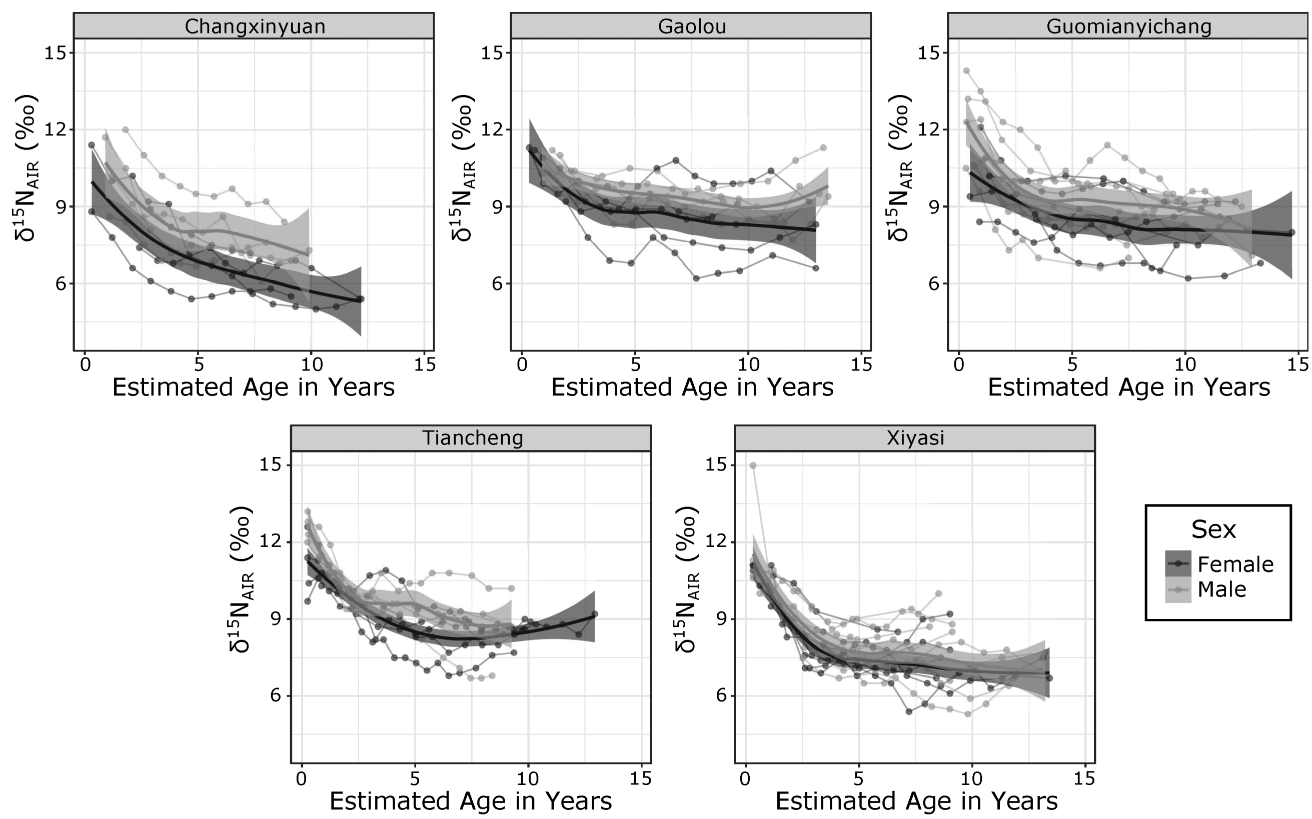

Figure 7. δ^{15}N isotopic data profiles by site and by skeletal sex showing the same patterning of a higher average δ^{15}N value for males than for females across all sites.

Although we believe this patterned offset in $\delta^{15}N$ values for the dentin collagen samples was driven by cultural forces, we cannot rule out the possibility of a sex-based biological explanation. Physiological stress can change how the body utilizes energetic resources, which can alter tissue nitrogen stable isotope values (D'Ortenzio et al. 2015; Fuller et al. 2003; Fuller et al. 2006; Katzenberg and Lovell 1999; Williams et al. 2011). Elevated $\delta^{15}N$ values observed in hair or dentition samples have been interpreted as potential evidence for stress in past populations (D'Ortenzio et al. 2015; King et al. 2018; Miller et al. 2020), but these are usually short-term changes to a few individuals, and protracted stress across an entire group has (to our knowledge) only been observed by Beaumont and Montgomery (2016) in their study of victims of the Great Irish Famine. We believe it is unlikely that as a group, male children are experiencing heightened stress relative to their female peers, particularly in the patriarchal Eastern Zhou society with known male–female hierarchies. If not related to stress, perhaps boys metabolize and incorporate dietary protein differently during childhood compared to females? However, most research using this isotopic methodology to study childhood diets from other regions of the world finds little difference in isotope results used for assessing diets between males and females during childhood. Further, when dietary differences between females and males have been found, they have been explained as evidence for cultural behaviors, such as social differentiation via food practices, not as a biological phenomenon (Eerkens and Bartelink 2013; Ganiatsou et al. 2022). A few individuals we studied exhibit opposing covariance in nitrogen and carbon values (such as nitrogen declining but carbon values increasing; for example, see Guomianyichang M068). These patterns have been considered potential evidence of physiological stress (Beaumont and Montgomery 2016; Garland et al. 2018; King et al. 2018) but can also occur when a child is weaned onto a diet that is different from the milk they were previously consuming (i.e., mother's diet). If an infant was weaned using foods that have more positive $\delta^{13}C$ values (such a millets) than what the lactating female had been consuming (captured in the milk), we would see nitrogen values continuing to decline (removal of milk from diet) while carbon values increased (consumption of foods like millets with higher $\delta^{13}C$ values). Both of these hypotheses should be considered in individuals whose values exhibit covariance, and other stress indicators (via paleopathological analyses) may also assist in these interpretations. Future studies may help to clarify if there are any underlying physiological reasons that might cause such noted differences in nitrogen isotope values between growing children.

When we aggregate the dentin $\delta^{13}C$ isotope profiles for all Eastern Zhou individuals, we find that the average is slightly lower for females than it is for males across most of childhood, and the means between the sexes are statistically different when we look at the values after age five years (see loess curves in Fig. 6). This indicates that overall, female children were consuming a bit more C_3-type foods while males were consuming a bit more C_4-type foods. If C_4 foods, such as millets, were afforded a higher value (as indicated in historical texts), then the difference in childhood carbon isotope values may demonstrate the preferential feeding of millets to boys and with slightly less of these foods (or drinks) given to girls. However, the patterns in these data appear more complex when we examine the values within and between archaeological sites (Fig. 8).

We previously found (Miller et al. 2020) that during childhood, females from Xiyasi and Changxinyuan generally consumed more C_3 foods than males, who consumed more C_4 foods (millets), and this pattern is also seen in the newly examined individuals from Tiancheng. However, the opposite pattern is found for those buried at the sites of Gaolou and Guomianyichang; the average $\delta^{13}C$ value for males is lower than females, indicating females buried at those sites ate more millets during childhood than the males. The few individuals with the very highest $\delta^{13}C$ values across childhood and the very lowest $\delta^{13}C$ values across childhood also all come from Gaolou and Guomianyichang (with one exception of a male from Changxinyuan who also has quite high $\delta^{13}C$ values in childhood), and therefore the individuals who were interred in these cemeteries encompass the largest $\delta^{13}C$ range in childhood diets. When we examine the evidence at the individual level, we see indications of relationships between isotope values, markers of grave wealth/status/class, and life histories (see "Dietary patterns over the lifetime: Individual examples"). Here we may be seeing interacting effects of regional food practices and access to specific resources, in conjunction with experiences such as gender and class.

Weaning patterns

All Gaolou, Tiancheng, and Guomianyichang individuals studied with early life dentin segments show evidence for breastfeeding and weaning in their isotopic values. Our weaning age estimations for 47 of the Eastern Zhou individuals show that by around age three years of age, milk is no longer a detectable dietary component for most, and there is no significant difference in the estimated weaning ages between females and males. The earliest age we detected weaning termination was around 1.6 years (Gaolou, M100,

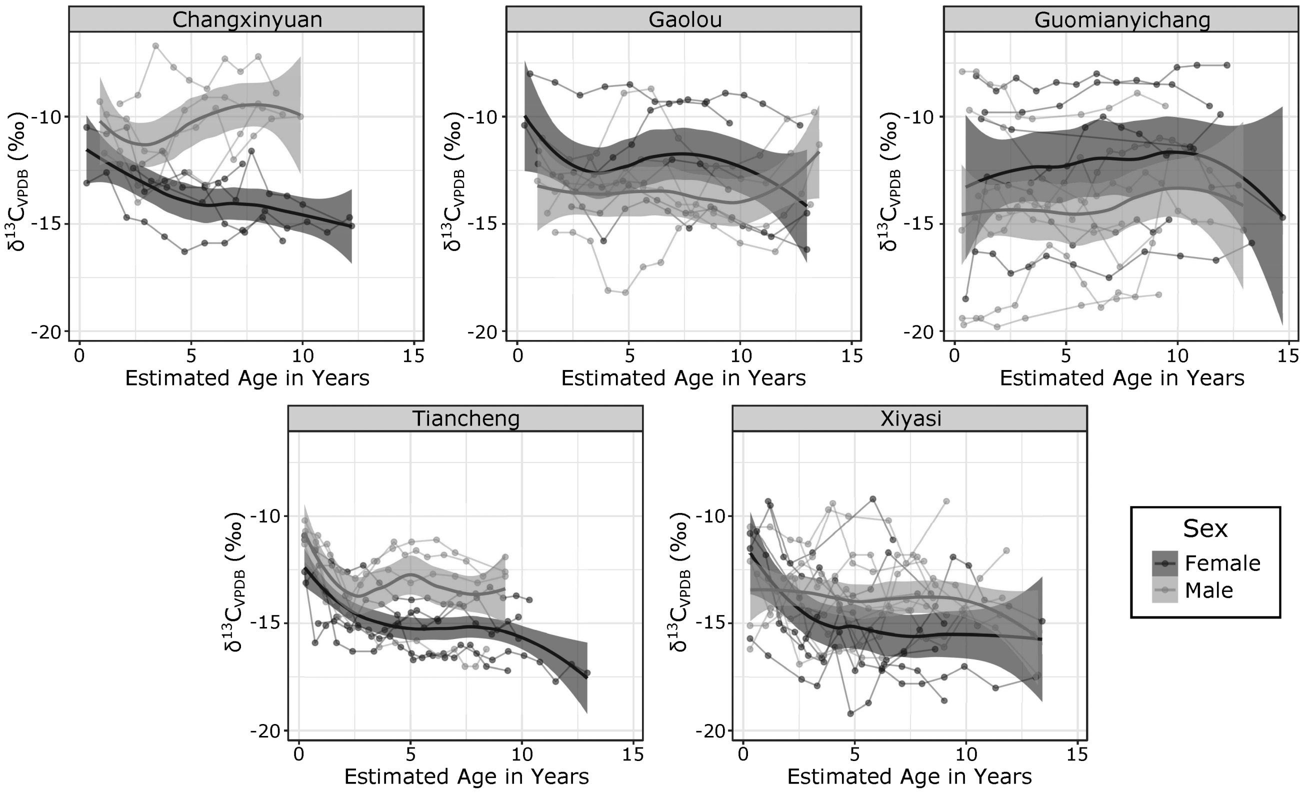

Figure 8. δ^{13}C isotopic data profiles by site do not show a standardized pattern between the sexes, suggesting this aspect of diet is not driven by gender alone but likely has many complicating factors such as location/region, class/wealth, and more.

female; Supplemental Tables 1 and 2) while the latest age we estimated weaning completion was around 4.3 years (Guomianyichang, M090, female; Supplemental Tables 1 and 2). Therefore, there is variability in the length of the weaning process, with most children completing weaning between ages 2.5 and 3.5 years.

Historical texts provide information about the relationship between specific chronological and social ages, and they suggest that the age of three years was an important marker in a child's life. For example, in the Liji, a Warring States and Han period document advising of social norms and ceremonial rituals, we learn, "食子者，三年而出，見於公宮則劬。大夫之子有食母，士之妻自養其子. The nurse of the ruler's boy quit the palace after three years, and the ruler meets her, and rewarded her for her toilsome work. The son of a Great Officer had a nurse. The wife of an ordinary officer nourished her child herself" (Liji, Nei Ze, 74). This passage tells us a few very important things: (1) children were nursed (breastfed), (2) in almost all cases a baby's mother was the one nursing the infant but ruling and upper-class elite families had access to wet nurses, and (3) children were nursed and closely cared for in this way for the first three years of life. Further evidence of the importance of the age of three is found in the Analects of Confucius through a discussion of proper mourning rites, where it is said deceased parents should be mourned for three years as that is the same amount of time that they intensely cared for their child at the beginning of their life (Chen [Confucius] 2017:215; see also Miller et al. 2020). These isotopic findings, in conjunction with historical references, support the importance of the social age of three years in ancient Eastern Zhou culture.

There is a large amount of variation in childhood diets (between individuals and within the same individual's childhood years), revealed through the wide spread of nitrogen and carbon isotope values observed across the dentin data sets. This shows there was a high degree of variability in supplemental foods during weaning and the diets subsequently consumed across childhood. When we look more closely at the carbon isotopic profiles from the earliest years of life, we see that during the first two to three years of life, the male δ^{13}C values are actually lower than the females. However, the loess curve representing the male average δ^{13}C values over time (average is the solid blue line and blue shaded band is the confidence interval of the mean; see Fig. 6) is almost flat across all of childhood, suggesting little change overall in the average male consumption of C_3 and C_4 plant-based foods (and animals consuming those resources). In contrast, the female

$\delta^{13}C$ average line shows a drop of about 2‰ across the first few years of life before leveling out slightly below the male line. This is the same period of time we believe most individuals were still consuming some breast milk as they were slowly being weaned. Consequently, these data from the earliest years of life partially reflect a mother's diet while she was breastfeeding as well as revealing the isotopic values of the dominant weaning foods. We suggest that the patterns in the $\delta^{13}C$ averages indicate that infant girls' diets were supplemented with more C_3 foods (daughters given more meals with wheat, soy, rice, barley, etc.), while infant boys were generally weaned onto diets with slightly more C_4 foods (millets). Mothers' diets likely contained more C_4 foods than the diets that they weaned their daughters onto, hence the ~2‰ decline as they were weaned off of millet-enriched milk and onto diets with more C_3 solid foods. Sons were weaned onto diets that more closely resemble their mother's diets (a bit more millet), hence the relatively flat loess curve for male $\delta^{13}C$ across childhood.

Dietary patterns over the lifetime: Gender and age

For the Eastern Zhou people studied ($n = 56$), we calculated that on average, dietary $\delta^{13}C$ increased by 1.9‰ between childhood and adulthood (comparing average $\delta^{13}C$ post age five to bone collagen $\delta^{13}C$; Tables 2–5; Supplemental Table 1), meaning most individuals consumed slightly more C_3 resources in childhood and then more C_4 resources in adulthood. When divided by skeletal sex, we see that on average, female values ($n = 27$) increased between childhood and adulthood by 1.7‰, while male values ($n = 27$) increased by 2.1‰. Of 27 females, only seven had values in adulthood that were lower than their childhood values (i.e., their diets included more C_3 foods as they aged), and further three of those individuals had change of less than 1‰ (so a relatively insignificant dietary change for those women). Of the 27 males, five had values in adulthood that were meaningfully lower than their childhood values (change was greater than 1‰), suggesting a shift to more C_3 foods as they aged. These patterns show that most people's diets changed slightly over their life course, and for the majority, that meant consuming a greater amount of C_4-type foods, presumably millets, in adulthood compared to during their childhood years. This dietary influx of millet during adulthood may relate to better access to preferred foods for older individuals, as well as the consumption of millet-based alcoholic beverages (Liu 2021).

The Liji provides multiple narratives on age-related dietary habits, such as passage 11 of the Nei Ze, which discusses the proper conduct for a recently married young couple who live with the husband's parents: " 父母在，朝夕恒食，子婦佐餕，既食恒餕，父沒母存，冢子御食，群子婦佐餕如初，旨甘柔滑，孺子餕. While the parents are both alive, at their regular meals, morning and evening the sons and their wives will serve them, and what is left after they will themselves eat. When the father is dead, and the mother still alive, the eldest son should accompany her at meals, and other sons and the wives will serve, and do with what is left as in the former case. The children should have the sweet, soft, and unctuous things that are left" (Liji, Nei Ze, 11). This passage reveals information about the familial structure as well as how food is distributed within a household. The parents of the eldest son (parents-in-law from the wife's perspective) hold the highest regard in the family, they are fed first, and what they do not eat is then left to the married couple, and after that children (those of the younger married couple) are fed the remaining foods. The Liji text can be interpreted as a guide for how people (of particular classes and means) should ideally comport themselves, and it presented guiding structures and principles for proper cultural behavior to maintain order in the family, clan, and state. Here we see how food-related behaviors are part of upholding the social power structure. If as one ages, they get to select the better (preferred/more valued/tastier) portions of a meal, then we could see how consumption of particular foods such as millet could be mediated by multiple aspects of life experience, including sex/gender, age, and status.

Interestingly, within the 56 individuals we can calculate dietary change between their dentin and bone collagen samples, we find almost no change observed for $\delta^{15}N$. When we divide the sampled individuals by sex, we see that female $\delta^{15}N$ values generally increase between childhood and adulthood, by an average of 0.3‰, while male values actually decrease by an average of 0.2‰. Neither of these shifts are considered isotopically meaningful, in that they are not indicative of a major dietary change (Pestle et al. 2014), though the slightly higher rate of change for females may indicate some benefit for particular women who had better access to meat in adulthood compared with childhood, while boys and men already generally had better access to meat compared with females and maintained that over their lifetime. Interestingly, the Liji again points to the intersections of multiple life variables and highlights how aging adults should be given privileged access to certain food if they are elderly: "王制: 五十異粻，六十宿肉，七十貳膳，八十常珍；九十，飲食不離寢、膳飲從於游可也. For those of fifty, the grain was (fine and) different (from that used by younger men). For those of sixty, flesh was kept in store. For those of seventy, there were two fine dishes every meal. For those of eighty, there was a constant supply of delicacies. For those of ninety, food and drink were never out of their chambers. Wherever they wandered (to another place), it was required that savory meat and drink should follow them" (Liji, Wang Zhi, 56). Here we see how nicer grain and meat were considered particularly important foods for people as they aged, with the elderly ideally always having easy access to a tasty meal, especially meat; this hypothesis could be tested in future bioarchaeological research focused on age-related dietary changes in adulthood.

Dietary patterns over the lifetime: Individual examples

Two of the females we studied from Gaolou have exceptionally high $\delta^{13}C$ values in childhood and that are retained into adulthood based on their bone collagen values, and both of these women also had markers of wealth in their burials. Individual M089 had both an inner and outer coffin (considered a more expensive grave), while M145 was buried with many pieces of pottery and a coffin decorated with cinnabar, and perhaps their (interpreted) higher status may have given them greater access to the desirable grain, millet, across their lifetimes. However, the relationships between gender and wealth likely have interacting effects over the life course. For example, M082 was a female from Gaolou who also had a wealthier burial featuring inner and outer coffins, pottery, cowry shell, and cinnabar, but she has much lower $\delta^{13}C$ values across childhood showing significant C_3 food consumption. Her bone collagen value is over 3‰ higher than her final dentin sample, indicating she experienced a dietary change to consuming more C_4 foods in adulthood, which may have been tied to a change in wealth/status later in life. Similarly, Gaolou M115, a male, had the lowest $\delta^{13}C$ values across his early childhood years within the whole Gaolou sample: the average $\delta^{13}C$ across all his dentin samples = −16‰, with the very final dentin segment $\delta^{13}C$ = −14.1‰, but his later life bone collagen $\delta^{13}C$ = −9.1‰, shows a very dramatic dietary shift between childhood and adulthood. Perhaps his social standing and wealth improved as an adult, he was buried with shell and cinnabar, and the later life shift to a diet rich in the desired grain, millet, could have also been a benefit if his social status improved. It is certain that gender was only one of many potential axes that diet was interacting with, and wealth and status would have played a major role in the foods people could afford to eat as well as what was considered appropriate and desirable cuisine. Unfortunately, assessing large-scale relationships between mortuary treatment and diet over the lifetime is challenging due to grave disturbances and plundering in earlier times, limiting our ability to accurately assess all individuals' treatment at death (see Materials section).

The same patterning of average $\delta^{13}C$ for males being lower than females during childhood is also seen in the Guomianyichang sample. Guomianyichang may have been affiliated with a nearby military site and may not have had consistent access to the same food resources as Zhenghan city (Yang et al. in press). For example, individual M124 from Guomianyichang was an older aged male from the Spring and Autumn period, and his childhood carbon isotope values are the lowest of any Eastern Zhou male we have studied to date: average $\delta^{13}C$ across all his dentin samples = −19.1‰, with the very final dentin segment $\delta^{13}C$ = −18.3‰, but his later life bone collagen $\delta^{13}C$ = −11‰, showing a significant dietary shift between childhood and adulthood. He appeared to be buried without a tomb structure but had five pottery items interred with him. Perhaps M124's social status increased over his lifetime and in his older age he was able to dine on more millet? Interestingly, another male from Guomianyichang, M068, also had very low $\delta^{13}C$ values across most of his dentin samples, with an average $\delta^{13}C$ = −18‰ between birth and around age nine years. His final dentin sample, aged around nine to 10 years, shows a large change in $\delta^{13}C$ to −11.6‰, and this dietary shift may have held through his later life as his bone collagen $\delta^{13}C$ value is −11.4‰. In contrast, M146 was a young adult woman who lived during the Warring States period and upon death was buried in a single coffin, with one piece of pottery. Her childhood dentin $\delta^{13}C$ values were very high (average = −8.2‰), indicating a diet dominated by millets, but her final bone collagen value, −14.2‰, shows a significant dietary shift occurred for her and that she consumed much more C_3-type foods as an adult. It might be possible that some of the individuals who were buried at Guomianyichang were not born and raised in this area but instead moved here in association with the military post, and therefore their diets may have shifted if there were regional differences in the cuisines or access to particular ingredients. Therefore, gender may be an important factor in childhood dietary practices, but additional variables such as wealth or region/location may have played a larger role or dictated different dietary customs for individuals or specific communities.

Conclusions

The unique relationships that humans have with the things that we eat make food-related data sets (botanical and faunal remains, stable isotope data, dental calculus data, iconographic representations, etc.) a rich medium to explore layers of the human experience that are inaccessible from other material remains in archaeological contexts. Technological advances are allowing for finer resolution of information that was previously out of reach, and attention to particular materials, such as dietary evidence from food studies, which is known to be laden with meaning (including environmental information, economic values, ideological uses, understandings of sex, gender, age, health, wellness, etc.), offers us a window to aspects of humanity that are personal, are relatable, and can deepen our understanding of the shared and divergent parts of what it has meant to be human in particular times and places. Isotopic analysis of skeletal tissues provides a rare opportunity to get to know the life history of a specific person from the past, and advances such as incremental segmentation of tooth dentin provide detailed pictures of specific periods of ancient lives. Here we have shown that dentin samples can reveal information about particular foods fed to children and the ways that communities thought about and imbued those foods with values. The observed patterning in the isotopic data reported here is pointing to something that goes beyond the simplistic act of eating; repeated processes of feeding children slightly different meals, such as differing amounts of meat or other protein-rich foods, appears to reflect socially constructed food-value systems intersecting with gender roles, which are enacted by caretakers using food (intentionally or not) as a material medium that both symbolically conveys gendered meaning as well as literally creating a gendered body that is chemically differentiated through consumption of these meals over time.

All humans become part of their culture and communities through socialization into myriad roles and shared understandings of normalized/naturalized ways of being. The Warring States period philosopher, Xunzi, related learning to be a cultured gentleman to the processes acting on individuals during key periods of life through a simple analogy: "Through steaming and bending, you can make wood as straight as an ink-line into a wheel. And after its curve conforms to the compass, even when parched under the sun it will not become straight again, because the steaming and bending have made it a certain way" (Xunzi, transcribed by Hutton 2014:1). Gendered ways of being are historically contingent and learned (*habitus*) through observation, mimesis, modification, and reiteration over generations (*hexis*), with individuals and social groups constantly making and remaking the boundaries and, in a sense, rules of how differently gendered groups should behave and exist in the world (Bourdieu 1977; Butler 1999). Some of these social processes are created through dialogue and may even be embedded within linguistic structures (such as gendered language), others are materially communicated (such as clothing) or enacted (such as the activities/labor/products one can produce), and others, such as food, can operate along multiple dimensions, including uniquely being a material that becomes a part of the person's body itself (Dietler 2007). Dietary practices and the specific foods a person eats can be a part of gender identity and the gendering process. Childhood is a critical period of dynamic biological changes and complex social learning, and gender identities are one of many human experiences that may be catalyzed beginning in early life. The fact that children lack the ability to feed themselves for the first years of life makes studying early childhood foodways an exceptionally revealing space for illuminating social processes and the cultural values of specific foods, particularly as it speaks to the transgenerational aspects of social reproduction.

Through high-resolution dietary reconstructions of early life using an incremental dentin sampling approach, we have seen how for Eastern Zhou peoples living on the Central Plains of China, one food type in particular, meat, reveals social values and gender inequalities, while also becoming part of the gendering process and gender embodiment itself. Caretakers, primarily mothers, were responsible for feeding their children, and therefore in studying early life diets, we are observing intergenerational interactions materialized through food choice. Maleness becomes embodied through enacting particular characteristics that make up the category itself, and here we see mothers and other caretakers marking the maleness of specific children through the consumption of meat, and potentially millet to a minor extent, which in turn also marks female children in contrast to this (i.e., less meat consumption, less millet consumption). These gendered roles are relational and, in some ways, oppositional to one another, fitting within the dyadic frameworks of ancient Chinese philosophies, thought to create balance and harmony through their coexistence (Louie 2002). These dietary practices worked to create gendered bodies that were sensible in accordance with cultural norms and values, which followed particular ways of being in the world, including intersections with other aspects of identity, and reinforced gendered notions through their existence and repetition across generations.

Ethics Statement

Bioarchaeological analyses, including the chemical studies of the human remains described here, were undertaken with permission of the Henan Provincial Institute of Cultural Relics and Archaeology.

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