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Dining together: Reconstruction of Neolithic food consumption based on the $\delta^{15}N$ values for individual amino acids at Tell el-Kerkh, northern Levant

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A B S T R A C T

We report here stable nitrogen isotope values of amino acids and stable carbon and nitrogen isotope values of collagen in human ($n = 18$) and faunal remains from Tell el-Kerkh, which was a large settlement in the northern Levant during the Neolithic period. A unique outdoor communal cemetery involving > 240 individual burials was found in the Pottery Neolithic levels at Tell el-Kerkh. To test the hypothesis that the burial locations of individuals within the cemetery were determined by household units sharing food resources, we separated individuals from one layer into seven groups within the cemetery, and compared the isotope values of collagen, glutamic acid, and phenylalanine. The results of analysis of individual skeletons in the cemetery suggest that the early farmers had different isotope values based on their burial locations, perhaps indicating distinct household burial spaces.

1. Introduction

Changes of culture, economy and community structure in prehistoric societies are thought to have often resulted from changes in food acquisition (Childe, 1942; Bellwood, 2004). For instance, in the Near East (including the Levant) the economic transition from hunter–gather communities to agricultural societies was a long process during the Pre-Pottery Neolithic (PPN) and Pottery Neolithic (PN) periods (Fuller et al., 2011; Tanno and Willcox, 2006a). This transition was accompanied by dynamic changes in settlement size and population. For example, the largest settlement sizes in the A period of the PPN (PPNA) were approximately 1 ha, whereas in the middle of the B period (PPNB) the largest settlements averaged > 10 ha (e.g. Kuijt, 2000; Bocquet-Appel and Bar-Yosef, 2008). The expansion in the Neolithic settlement size reflects an increase in population size, but also changes in social structure including household units, economic activity, and storage capacity (e.g. Bocquet-Appel and Bar-Yosef, 2008; Kuijt, 2008). For instance, during the PN nuclear families may have inhabited rectangular buildings, whereas circular buildings were probably used by extended families during the Natufian period and the PPNA (Flannery, 2002). Furthermore, food consumption must have changed along with the dynamic social transformations that occurred during the Natufian, PPN, and PN periods (Bar-Yosef, 2002). It is assumed that food procurement, including farming and herding, shifted from the community sharing among small groups during the early Neolithic period to the household sharing in large settlement societies (Düring and Marciniak, 2005; Marciniak, 2008). However, convincing evidence is not yet available to clarify the forms and customs of food consumption during these periods.

Burial practices are a primary source of information in the study of the social structure, and hierarchical and gender divisions in prehistoric subsistence communities (e.g. Binford, 1971; Kuijt and Goring-Morris, 2002; Hershkovitz and Gopher, 2008; Peterson, 2010; Pearson et al., 2013). Burial practices in the Neolithic Levant changed markedly between the PPN and PN periods. During the PPN period the deceased were commonly interred in the domestic environment, including below floors, near walls, or in courtyards. Evidence of secondary treatment of the deceased, including skull removal, has frequently been found in graveyards from the PPN period (e.g. Kenyon, 1956; Kuijt, 2008; Kanjou et al., 2013); the practice of skull removal has often been related to ancestor worship (Kenyon, 1956; Bienert, 1991). Special buildings for the deceased, termed *skull buildings*, *charnel houses*, and *house of*

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dead, have been excavated from several PPNB settlements, including those at Çayönü Tepesi, Dja'de el-Mughara and Tell Abu Hureyra (Bienert, 1991; Coqueugniot, 1999; Moore and Molleson, 2000). It has been argued that the shared ritual played a role in reconciling social inequalities in large settlements (Kuijt, 2000, 2008; Verhoeven, 2002). It was also notable that, based on dental phenotypes, the individuals buried together in each building at the Çatalhöyük PN site in central Turkey were not related (Pilloud and Larsen, 2011). Thus, it seems that relatives were not necessarily buried in the same house in the Neolithic Near East.

However, in the following PN period burial rituals in domestic spaces in the Levant were uncommon, except for those involving children (Kuijt and Goring-Morris, 2002). This change in custom seems to have been linked to the reduction in size and dispersal of settlements during this period (Bocquet-Appel and Bar-Yosef, 2008). However, a more direct reason for this change is likely to be related to development of communal cemeteries associated with settlements.

Until recently there was little evidence in the Near East for the origins of communal cemeteries during the Neolithic period. However, in the 2000s PN communal cemeteries were discovered at Tell el-Kerkh and Tell Sabi Abyad. At Tell el-Kerkh a PN cemetery that was used for several centuries in the late 7th millennium BC has been excavated in a settlement vacant lot (Tsuneki, 2011). The cemetery covers 200 m^2, and includes in excess of 240 skeletons of humans ranging from fetuses to older adults. The skeletons were commonly distributed in clusters within the cemetery, and these may indicate social groups, such as families, that were present in the community. Because the individuals within each cluster were buried intermittently and the clusters developed adjacent to each other over some hundreds of years, no temporal differentiation is evident. Articulated bones were found among secondary burial deposits, indicating that the graves were reopened and reused within short periods of time. This PN cemetery as a communal cemetery not associated with buildings at Tell el-Kerkh make it very different from the PPN graves found within houses, and may indicate a shift in the burial place from private houses to a public space. However, it is not clear whether the advent of the communal cemetery in this Neolithic society was an accommodation to enforce the unification of a large community, or the result of a growing divide within the community.

To investigate changes in social structure during the Neolithic period, some archaeological studies, mainly in the southern Levant, have investigated links between household size and the activity and rituals of the community (Flannery, 1972; Kuijt, 2000; Kuijt and Goring-Morris, 2002; Kadowaki, 2012). In this context, the term household is defined as a unit of economic collaboration for subsistence ownership, rather than a unit based upon marriage and consanguinity (Kadowaki, 2012). The change in household size was interpreted from the size of the residence for accommodation and food storage (Kuijt, 2008). Some suggest that changes in the household structure during the late Neolithic period were a result of the initiation and development of food production (Byrd, 2002, 2005).

If the changes in social structure during the Neolithic period were associated with food production, social units may be distinguishable by differences in diet within the community. Furthermore, in addition to individual diets, evidence of food sharing within households suggests a social structure in early sedentary settlements. The assessment of individual diets and elucidation of the food sharing system, based on physical and chemical analyses, along with an investigation of burial practices, will provide much information about social structure in prehistoric communities (e.g. Schutkowski et al., 1999; Pearson et al., 2013: Itahashi et al., 2017).

Human paleodietary reconstructions, based on chemical analysis of stable isotopes in bone collagen, have been used in previous archaeological studies to provide direct information on past human activity (Vogel and Vandermerwe, 1977; Schoeninger and DeNiro, 1984; Szpak et al., 2017). Stable isotope values vary slightly among organisms according to the habitat in which they occur. Consequently, the carbon and nitrogen isotope ratios for each organism are specific, based on its ecology and position in the food chain (e.g. DeNiro and Epstein, 1978). Typically, the $\delta^{13}C$ value for an organism is primarily used as an indicator of habitat, environment, and ecosystem. It is known that the apparent tissue isotope ratio for diets based on plants using the C_3 photosynthetic pathway (−18‰) is larger than that based on plants using the C_4 photosynthetic pathway (−4‰) (O'Leary, 1981), as a result of differences in the efficiency of carbon fixation between C_3 and C_4 plants. In addition, because the $\delta^{15}N$ values for the muscle tissue and bone collagen of predators are 1.5–5‰ higher than that of the diet, within the same environment the $\delta^{15}N$ value for each organism will vary depending on its trophic position (Minagawa and Wada, 1984; Schoeninger and DeNiro, 1984; McCutchan et al., 2003). Therefore, tissue $\delta^{15}N$ values are useful indicators in understanding the prey–-predator relationships of animals and humans, and isotope analysis can be used to indicate the proportion of different food resources in human diets (Hedges and Reynard, 2007). On the other hand, the nitrogen isotope values of plants in an environment fluctuate under several influences, including the presence of animal feces and variations among soils (Szpak, 2014). Hence, people living in the same environment may have different nitrogen isotope values because of biases in consumption of food resources including plants and animals.

Several studies of isotope values of remains of Neolithic populations have been conducted in the Near East, including at Çatalhöyük (Richards et al., 2003a; Pearson et al., 2015), Nevalı Çori (Lösch et al., 2006), Aşıklı Höyük (Pearson et al., 2010), Çayönü Tepesi (Pearson et al., 2010, 2013), Aktopraklık (Budd et al., 2013) and Hasankeyf Höyük (Itahashi et al., 2017). Based on $\delta^{13}C_{col}$ values, the inhabitants of these Neolithic sites probably consumed mainly C_3 plants and terrestrial animals that had consumed C_3 plants (Lösch et al., 2006; Budd et al., 2013). Sheep and cattle at Çatalhöyük had higher $\delta^{13}C_{col}$ values (−16‰) than that typical of C_3 plant consumers, so it is possible that some livestock were fed C_4 plants (Richards et al., 2003a; Pearson et al., 2015).

The isotope ratios of collagen from humans buried in the same buildings in Neolithic Turkey have been analyzed and reported. For instance, because the $\delta^{13}C_{col}$ and $\delta^{15}N_{col}$ values of hunter–gatherers in the PPN period at Hasankeyf Höyük varied based on the building in which the individuals were buried, it was thought that the individuals buried in the same building consumed more similar diets within the community (Itahashi et al., 2017). In contrast, Pearson et al. (2015) made the interesting observation that individuals from the PN period at Çatalhöyük who were buried together in the same building did not have $\delta^{13}C_{col}$ and $\delta^{15}N_{col}$ values similar to others within the community. This interpretation was based on dental phenotype (Pilloud and Larsen, 2011), and does not suggest that each buried building was used by a particular household at Çatalhöyük. However, unlike Çatalhöyük, at Tell el-Kerkh in the PPN period the burial practices in open spaces were markedly different from those in buildings. Therefore, it may be possible to validate evidence of food sharing in the community of Tell el-Kerkh, based on isotope analyses of humans. However, reasons for the difference in isotope values for humans among burial groups cannot be determined based only on collagen isotope analysis. Hence, to evaluate dietary differences and similarities among individual remains from the cemetery at Tell el-Kerkh, it is important to distinguish between the quantity of dietary animal protein and differences in the main sources of that protein, including livestock.

To address this issue we determined the nitrogen isotope values of individual amino acids in collagen, in addition to determining the carbon and nitrogen isotope ratios of bulk collagen. The method has recently been applied in studies of ancient animal and human remains (e.g., Naito et al., 2010, 2013; Styring et al., 2010, 2015; Itahashi et al., 2014, 2017). Because this approach is based on a difference in the trophic isotope discrimination of two common amino acids (glutamic acid and phenylalanine), the trophic position (TP) of an organism can