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Bioarchaeology of Neolithic Çatalhöyük: Lives and Lifestyles of an Early Farming Society in Transition

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Abstract The bioarchaeological record of human remains viewed in the context of ecology, subsistence, and living circumstances provides a fundamental source for documenting and interpreting the impact of plant and animal domestication in the late Pleistocene and early to middle Holocene. For Western Asia, Çatalhöyük (7100–5950 cal BC) in central Anatolia, presents a comprehensive and contextualized setting for interpreting living circumstances in this highly dynamic period of human history. This article

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provides an overview of the bioarchaeology of Çatalhöyük in order to characterize patterns of life conditions at the community level, addressing the question, *What were the implications of domestication and agricultural intensification, increasing sedentism, and population growth for health and lifestyle in this early farming community?* This study employs demography, biogeochemistry, biodistance analysis, biomechanics, growth and development, and paleopathology in order to identify and interpret spatial and temporal patterns of health and lifestyle under circumstances of rapid population growth and aggregation and changing patterns of acquiring food and other resources. The record suggests that the rapid growth in population size was fueled by increased fertility and birthrate. Although the household was likely the focus of economic activity, our analysis suggests that individuals interred in houses were not necessarily biologically related. Predictably, the community employed resource extraction practices involving increased mobility. Although oral and skeletal indicators suggest some evidence of compromised health (e.g. elevated subadult infection, dental caries), growth and development of juveniles and adult body size and stature indicate adjustments to local circumstances.

Keywords Domestication · Paleodemography · Paleopathology · Stable isotopes · Biomechanics · Biodistance · Growth

Introduction

During the last few millennia of the Pleistocene, small groups of mobile hunter-gatherers in southwestern Asia began a process of transitioning from a lifeway based exclusively on hunting, gathering, and collecting non-domesticated plants and animals to one relying at least in part on the management and production of domesticated plants and animals. In this region, as elsewhere around the globe, the causes of this fundamental alteration in the manner of food acquisition, processing, and consumption involved various climatic, demographic, social, behavioral, and evolutionary factors arising during the terminal Pleistocene and into the Holocene (Düring 2013; Flannery 1972; Fuller et al. 2010; Larson et al. 2014; Riehl et al. 2013; Smith 1995; Winterhalder and Kennett 2006). Once set into motion, the foraging-to-farming transition led to the development of a Neolithic package involving changes in population size, nutrition, workload, mobility, and lifestyle throughout Asia, Europe, Africa, and the Americas, setting the stage for alterations in health, wellbeing, and living circumstances in the millennia to follow.

The study of human remains from archaeological settings provides a powerful means to document and interpret the impact of domestication. Indeed, there is a large and growing record based on the study of skeletons from archaeological settings to show that both the foraging-to-farming transition and the early intensification of agricultural production occasioned a general increase in morbidity and compromised health, along with significant changes in activity, workload, and lifestyle (Cohen and Armelagos 1984; Cohen and Crane-Kramer 2007; Larsen 1995, 2006, 2015; Oxenham and Tayles 2006; Pechenkina and Oxenham 2013; Pinhasi and Stock 2011; Steckel and Rose 2002). Viewed within the framework of an emerging archaeological context, this human bioarchaeological record provides an essential dataset for addressing hypotheses and questions about the foraging-to-farming transition and economic intensification, specifically for those regions of the world having comprehensive skeletal series with long temporal duration and substantive

Fig. 1 Map showing location of Çatalhöyük. Copyright National Geographic, Esri, DeLorme, HERE, UNEP-WCMC, USGS, NASA, ESA, METI, NRCAN, GEBCO, NOAA, iPC

contextual records of settlement, diet, living circumstances, ecology, and environment. For Western Asia, Çatalhöyük in the Konya Basin in central Anatolia (see map, Fig. 1) is such a locality. Among the largest (13 ha) and best-known Neolithic sites, Çatalhöyük combines a comprehensive human skeletal record with detailed contextual documentation of ecology, resource extraction, dietary reconstruction, food-processing, settlement, habitation and housing, community and social structure, art, and mortuary practices (various in Hodder 2014a). This level of contextualization of human remains is unmatched by any other early farming setting, certainly with respect to the Old World.

The purpose of this article is to provide an overview of the bioarchaeology of Çatalhöyük, and specifically to characterize how human health and lifestyle at the community level were impacted by changing circumstances and how the community's inhabitants adapted to their altered natural and social environments. While largely focused on a single locality, findings based on the study of the human remains from this particular setting, illustrating how members of this particular community interacted with their environment and shaped their living conditions, serve to deepen our understanding of early farmers in the Near East and elsewhere. The bioarchaeological research program at Çatalhöyük presented in this article is motivated by the following question: *What were the implications of farming and agricultural intensification, both in consumption and labor investment, increasing sedentism, and population growth for health and lifestyle in this early farming community?*

Biocultural Context of an Early Farming Community in Transition

For most of the recent history of excavation at Çatalhöyük, the earliest excavated deposits were placed at c. 7400 BC and the latest at c. 6000 BC (Bayliss et al. 2015). However, new radiocarbon assays of the earliest occupation of the site based on a Bayesian statistical framework indicate that culturally-mitigated deposits began to accumulate c. 7100 cal BC (Bayliss et al. 2015) and the latest deposits c. 5950 cal BC (Marciniak et al. 2015), thus representing about 1150 years of the Neolithic. The site is wholly or partially contemporary with many Pre-Pottery and subsequent Pottery Neolithic sites in the Levant (Hodder 2010). Based on various lines of evidence involving the number and size of domestic structures occupied at any one point in time, the peak population size was estimated at 3500–8000 (Cessford 2005b). Other Neolithic localities in central and southeastern Anatolia and across the Levant, either pre-dating or contemporary with Çatalhöyük, show population settlement and aggregation along with farming (Baird 2005; Braidwood et al. 1981; Esin and Harmankaya 2007; Gérard and Thissen 2002; Özdoğan 1999; Özdoğan and Özdoğan 1998). However, none of these localities has the contextual depth or breadth, nor the long duration (cf. Çatalhöyük's c. 1150 years of continuous occupation), to permit interpretation of health and lifestyle in relation to early farming.

Çatalhöyük was first excavated by James Mellaart between 1961 and 1965 (Mellaart 1967). His excavations in the southern area of the site's East Mound revealed considerable evidence for houses, architecture, elaborate art and other symbolism, and a complex mortuary program involving interment of the deceased in pits located in the floors of houses. Mellaart identified a series of stratigraphic levels of occupation, beginning with his level 0 at the mound surface, followed by level I through levels XII. Ian Hodder subsequently began a 25-year research program in 1993, focusing on the northern area of the mound and an expansion of Mellaart's original excavation in the southern area of the mound (Hodder 1996, 2005a, b, c, 2006, 2007, 2010, 2013a, b) (Fig. 2). Hodder's excavation revealed a more complex sequence of levels than envisioned by Mellaart, one that required the development of a site-wide stratigraphic sequence referred to for the purposes of this article as the Early period (7030–6370 BC), Middle period (6610–6250 BC), and Late period (6410–6150 BC; Farid 2013; Table 1).

Each level contains numerous rectangular mud-brick houses densely packed together. These houses range in size from 15 m^2 to 25 m^2 and are clustered in neighborhoods (Cessford 2005a; Düring 2001, 2005). A typical house contains a main room, having an oven, hearth, and central living space, and one or more slightly elevated clay-covered platforms along the walls. In addition to living spaces, these platforms often served for burial, mainly of older juveniles and adults (Boz and Hager 2013). Neonates and infants were frequently interred in pits by the walls, in foundation deposits, or sometimes towards the center of a house. Houses show a continuum of complexity from simple to elaborate, with the 'history houses' containing relief sculptures and wall paintings depicting animals, humans hunting animals, and a variety of other complex symbolism, cattle skulls and horns—some covered with a veneer of white plaster—and many burials. They also display long-term continuity involving several rebuilding episodes in the same location, often in sequences spanning multiple levels and representing multiple generations of occupants (Düring 2005; Hodder 2006, 2010, 2013b; Pilloud and Larsen 2011). In addition, the practice of removing crania, skulls and other body parts from earlier burials is associated exclusively with these buildings (Hodder and Meskell 2010). The placement of later houses on the remains of earlier houses, as well as control of temporal context, generally makes it possible to address temporal questions about changing patterns of community health and lifestyle via study of skeletal remains.

Analysis of house numbers, neighborhoods, and community structure reveals that Çatalhöyük was initially small, perhaps representing a few families, and then dramatically increased in size and density, peaking in the Middle period. Late period levels contain considerably fewer houses and more open spaces than before (Hodder 2014b; Cessford

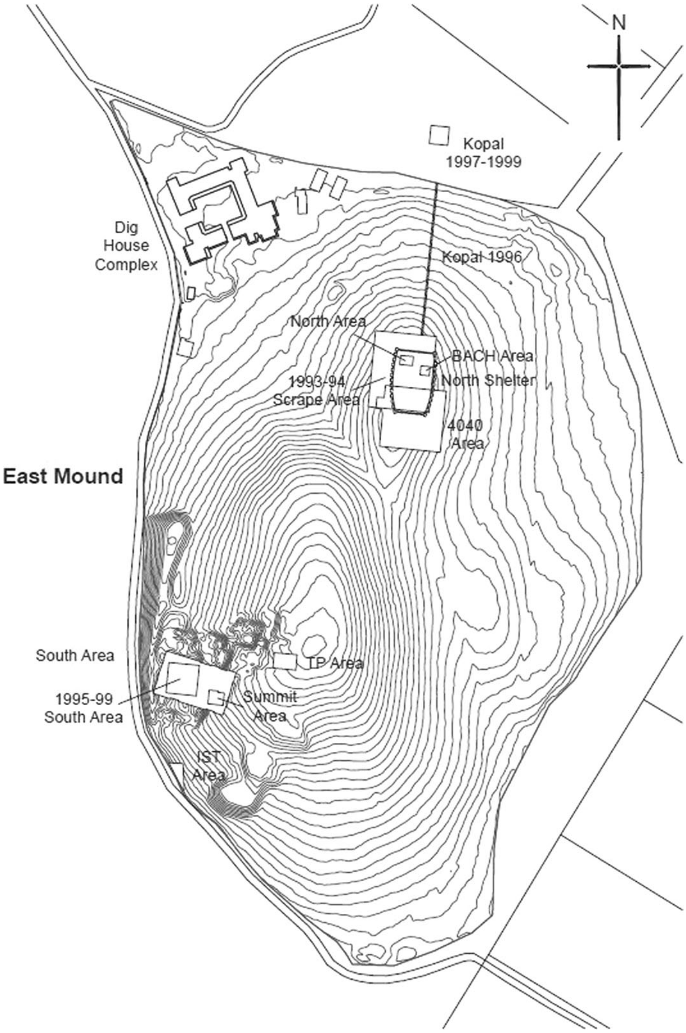

Fig. 2 Map of excavation areas on Çatalhöyük's Neolithic East Mound (adapted from Hodder 2014a, b)

Table 1 Definitions of the three time periods employed in the present analysis, with corresponding Hodder levels and estimated timespans in years BC

Time period	Corresponding levels	Estimated timespan[a]
Early ('pre-peak')	South H, J, K, and L	7030–6370 BC
Middle ('peak')	North G, BACH G, 4040 G, South M	6610–6250 BC
Late ('post-peak')	4040 H, South O, P, Q, R, S, and T	6410–6150 BC

[a] Based on Cessford's (2005b) absolute dating analysis (95% probability)

2005b). This record showing fewer and more widely-spaced houses indicates a substantial decline in population size and increased dispersal during the final occupation phase of the community. In summary, Çatalhöyük started small around 7100 BC, grew dramatically to its peak size in the Middle period, declined in the Late Period, and was ultimately abandoned by 6000 BC, although some form of continuity does likely exist between the latest levels of the site's East Mound and its Chalcolithic West Mound.

These changes in settlement and population during the later occupation occurred during a time of increased aridity in the Near East in general and central Anatolia in particular (Asouti 2005; Jenkins 2005). Human factors also contributed to altered living circumstances. Doherty (2013) concludes that the volume of digging in the clay colluvium in the area immediately surrounding the site was sufficient to produce a reduction in groundwater levels and loss of critical wetlands. The loss of economically important wetlands is confirmed in various other analyses, including of fish remains, mollusks, wood, and charcoal (Asouti 2013; Bar-Yosef Mayer 2013; Van Neer et al. 2013). Other disturbances to the wetlands surrounding the community are indicated by invasion of the reed *Phragmites* and likely reduction in plant and animal species diversity (Ryan 2013).

It is clear from the archaeological record that domesticated plants and animals were central elements of Çatalhöyük subsistence practices. Cereal crops (wheat, barley) and legumes (peas, lentils) are well in place in the earliest Aceramic Neolithic contexts, beginning with the founding of the settlement (Düring 2013). The record of cultigens is dominated by wheat, which represents more than 80% of domesticated plant remains (Bogaard et al. 2013). During the seventh millennium (Ceramic Neolithic), domestic sheep and goats are present, but domestic cattle do not appear in the record until c. 6500 BC (Bogaard et al. 2013; Fairbairn et al. 2005; Russell and Martin 2005; Russell et al. 2013). The great majority of animal remains consists of domesticated caprines, especially sheep (Russell 2005; Russell et al. 2013). In addition, various wild plants, deer, birds, and non-domesticated pigs and aurochs (cattle being domesticated later) were also consumed (Bogaard et al. 2013; Russell and Martin 2005; Russell et al. 2013). Fish from nearby streams and other bodies of water were eaten, albeit as a minor part of the diet (Van Neer et al. 2013).

The Çatalhöyük inhabitants' interest in animal species is famously represented by the many paintings on the interior of some house walls. These paintings depict wild animals—boars, bulls, leopards, and deer—sometimes being hunted by adult males partially clad in or carrying leopard skins (Mellaart 1967; Hodder 2006). The paintings and the presence of strategically-placed bucrania in living spaces in these houses demonstrate the strong symbolic presence of hunting and hunters, giving the impression that non-domesticated animal sources of food were important indicators of social status and diet. The minimal presence of wild cattle remains in the later occupation of the site, only a half-dozen skeletal elements of bear, and a single bone of a leopard indicate that while these animals were important in the community's symbolism and myth (Hodder 2006) they contributed little to diet.

Rosen and Roberts (2005) make the case that most of the farming was done on the higher, dryer, and better drained areas located 13 km to the south of the community (and see Roberts et al. 1996, 1999; Roberts and Rosen 2009; Rosen and Roberts 2005; Fairbairn et al. 2002, 2005). This scenario has important implications for the amount of labor and degree of mobility of the site's inhabitants who were involved in agricultural production and transport of foodstuffs (see below). Cultivation and transport of products would have involved considerable labor and mobility. For example, people would necessarily have been involved in tending distant crops, herding sheep and goats, and other economic activities in upland areas surrounding the community. Alternative hypotheses, however, suggest that cultivation and herding likely occurred close to the settlement (e.g. Bogaard et al. 2013, 2014; Doherty 2013), which would influence interpretations of mobility.

Various lines of evidence point to an increased mobility and coverage of the landscape in acquiring resources over the course of the site's occupation (Charles et al. 2014; Hodder 2014a, b). The reliance on herding and increased dependence on domestic sheep and cattle in the later occupation of Çatalhöyük has implications for the level of community mobility, especially among those responsible for herding. Analysis of sheep stable carbon and nitrogen isotope ratios reveals increased dietary diversity, indicating an extension of the landscape used for herding (Charles et al. 2014; Pearson et al. 2007; Hillson et al. 2013; but see Henton et al. 2010). Overall, the isotope record shows an escalation in the range of extractive activities, which would have necessarily involved increased mobility, as herders were required to travel greater distances over the course of the occupation of the site. It would seem likely that depletion of resources closer to the mound would have resulted in increased travel for and labor invested in the acquisition of food resources in farming and in herding (Pearson et al. 2007).

In addition to these aspects of resource acquisition, sources of raw materials for bead and pottery manufacture shifted from local to non-local (Doherty and Özbudak 2013; Hardy and van de Locht 2013; Nakamura and Meskell 2013). While raw material for production of querns and other ground stone tools come from sources at various localities, large blocks were carried from far distances to the site, where they were then manufactured into grinding stones (Wright 2013).

Hodder (2014a, b) suggests that this expansion of territory used for herding and the acquisition of food and other resources in the latest occupation of the site was related to a shift from dependence on cross-community social and ritual ties, where economic shortfalls were met between households, to a system where each household focused on its own production and acquisition of resources. That is, he argues that the more house-based economy required a greater range of resources and an expansion across the region for gathering, herding, hunting, and resource acquisition in general. It also seems likely that the heavy exploitation of the immediate region in combination with environmental deterioration may have depleted a once-rich landscape, especially near the community, obliging later Çatalhöyük inhabitants to travel farther in order to acquire these resources.

The Human Remains and Their Funerary Context

Mellaart's excavations in the southern area of Çatalhöyük produced more than three hundred skeletons. For the study of these remains, Mellaart recruited two biological anthropologists, J. Lawrence Angel and Denise Ferembach. Angel's and Ferembach's reports (Angel 1971; Ferembach 1972, 1982) provide preliminary descriptions of and speculations about demography, paleopathology, health, and skeletal morphology. Mellaart's assemblage had been kept in storage at Ankara University after Angel and Ferembach completed their analyses. Subsequent to their studies, dental remains were used in several published investigations (Boz 2005; Molleson et al. 2004; Pilloud and Larsen 2011; and see Hillson et al. 2013; Larsen et al. 2013), and ultimately, part of the collection was returned to the Human Remains Laboratory at Çatalhöyük. Study of the Mellaart cranial and postcranial remains by Haddow (see Hillson et al. 2013) indicates that the collection is considerably smaller now than when it was originally recovered. With the exception of dental remains included in research on biodistance and community structure (see Hillson et al. 2013) and the long bones (femora and humeri) included in research on mobility, lifestyle, and body size (see Larsen et al. 2013), these remains are not part of the present investigation, largely owing to their incompleteness and lack of provenience.

Peter Andrews and Theya Molleson directed the study of the human remains recovered in Hodder's excavations from 1995 until 2000 (Andrews et al. 2005; Molleson et al. 2004, 2005; Boz 2005). In 2003, Larsen and Hillson began directing the bioarchaeology research program discussed in this paper. The Hodder excavations produced the remains of more than 600 individuals. Many of these individuals are in disturbed contexts and minimally represented, disturbances resulting largely from later burials in the same or overlapping burial pits in house floors (and see Boz and Hager 2013). The bioarchaeological record discussed here focusses on the study of primary, secondary, and primary disturbed depositional contexts (Andrews et al. 2005; and see Boz and Hager 2013), from which the remains of 382 relatively complete individuals have been recovered (Hillson et al. 2013; Larsen et al. 2013). As discussed above, considerable numbers of remains disarticulated, scattered, or otherwise non-associated owing to disturbance by subsequent interments are not included in either this count or as part of this investigation.

Analysis of the mortuary program reveals a strong community preference for primary, single interment of the deceased (Andrews et al. 2005; Boz and Hager 2013), contrary to earlier suggestions that most burials at Çatalhöyük resulted from secondary inhumations (e.g. Mellaart 1967). Virtually all skeletal remains are from oval pits dug into house floors, including the aforementioned platforms (Fig. 3) (Boz and Hager 2013). Bodies were usually flexed and some wrapped in cloth or binding, at times accompanied by shells, beads, chipped stone and/or bone tools, textiles, wood, various personal ornaments, and animals, including a sheep with an older adult male (Nakamura and Meskell 2013; Pearson

Fig. 3 Intramural burials under the floors of Building 3 in the BACH area of Çatalhöyük's East Mound (Photo: Jason Quinlan, Çatalhöyük Research Project)

and Meskell 2014). Most interments lacked grave goods, and when these are present, they are often limited in number. There is some evidence for dismemberment of individuals, both during and after decomposition (Boz and Hager 2013), including at least four individuals lacking skulls and others missing a limb or limbs. One associated cranium and mandible has a plastered and painted face and was found in direct association with the skeleton of an adult female. The plaster face is similar to other plastered skulls in the Near East (Bonogofsky 2011).

Considerable effort has focused on understanding the circumstances that influenced health and lifestyle at Çatalhöyük (Andrews et al. 2005; Angel 1971; Boz 2005; Ferembach 1972, 1982; Molleson 2007; Molleson and Andrews 1996; Molleson et al. 1996, 2004, 2005). The results presented here build on the advances made by these earlier researchers, adding a substantial body of work deriving from the study of other populations undergoing sedentism, population crowding, and increasing social complexity in the context of early farming and agricultural intensification in the Near East (e.g. Angel 1984; Bar-Gal and Greenblatt 2007; Eshed et al. 2010; Horwitz and Smith 2000; Molleson 1994; Peterson 2002; Smith et al. 1984; Smith and Horwitz 2007; Thornton 1992) and elsewhere (e.g. various in Cohen and Armelagos 1984; Steckel and Rose 2002; Cohen and Crane-Kramer 2007; Pechenkina and Oxenham 2013; Pinhasi and Stock 2011). The present study extends this work by addressing the challenges, adjustments, and adaptations made by early farming communities and by discussing key themes that contribute to the development of our understanding of what life was like in such settings. These areas pertain to the rate of growth and organization of Çatalhöyük, how the community acquired and processed food and other resources, and the quality of nutrition and living conditions in this environment. These circumstances inform our understanding of demography and social organization and the implications of intensification of resource procurement, labor and activity, processing of food, and health impacts on the community. For the purposes of this article, we divide the Çatalhöyük skeletal series into three periods, including Early, Middle, and Late (see above; Table 1). Over the course of the occupation, there is considerable population growth, peaking in the Middle period, and declining and dispersing in the Late period. In the remainder of this article, we address five key questions relating to demography and population growth, dietary reconstruction and nutritional inference, social organization, labor and acquisition of food, and quality of the living environment.

How did Çatalhöyük Grow?

Archaeological site survey of the Konya Plain by Baird (2002, 2006) provides the record for documenting population growth at Çatalhöyük. This survey showed increasing population density and concentration of habitation culminating in the appearance of Çatalhöyük, basically a stand-alone community with little evidence of habitation beyond the boundary of the East Mound. The details of population trends based on the site structure suggest an increase in population for the first millennium peaking around 6250 BC, followed by decline, abandonment, and dispersal into multiple small communities during the Chalcolithic (and see Hodder 2014a). The first occupation of Çatalhöyük is pre-dated by at least several small communities in the Konya Plain. For example, Boncuklu Höyük, located 10 km from Çatalhöyük, contains several dispersed oval-shaped houses dating to 8500–7500 BC. Except for the shapes of the houses, they are similar to those at Çatalhöyük in having mud bricks, plastered walls, wall paintings, and burials in the floors (Baird 2007, 2010). One hypothesis is that Çatalhöyük was first formed when several of these small, relatively permanent villages amalgamated into a single community (Baird 2002, 2005).

Once the founding village of Çatalhöyük was in place, what were the mechanisms that drove the dramatic increase in population size that is implied by the large and growing number of houses at Çatalhöyük? It is likely that Çatalhöyük started as a small, dispersed population, perhaps like the much-smaller Boncuklu Höyük settlement. If that is the case, then how did Çatalhöyük transform itself from a tiny settlement having only a few dwellings to an enormous one with many dwellings and large population?

We test the hypothesis that the growth of the population was driven by demographic circumstances primarily involving increased fertility and birthrate. Sattenspiel and Harpending (1983) showed that mean age-at-death in archaeological skeletal series is inversely related to birthrate. That is, a low mean age-at-death for a skeletal series indicates a higher birthrate than a high mean age-at-death for some other series. In the Çatalhöyük series, half (about 50%) of the population are juveniles (0–3=34%; 3–19=23%) and the remainder are adults (Table 2). This is an extraordinarily large number of juveniles, especially in the youngest category, including many neonates (Hillson et al. 2013), resulting in a low mean age-at-death. Traditional approaches to interpreting this pattern of age composition in archaeological assemblages were that these high numbers of juveniles represent elevated infant and child mortality. However, population structure of archaeological death assemblages provides a record of fertility and growth rate rather than mortality and death rate (McCaa 2002; Milner et al. 1989; Sattenspiel and Harpending 1983; Wood et al. 1992). Buikstra et al. (1986) developed a simple juvenility index—a ratio of the number of deaths of individuals over age 30 to number of deaths over age 5, or D_{30+}/D_{5+}, to express fertility changes in the lower Illinois River valley of North America. Similarly, Bocquet-Appel and collaborators (Bocquet-Appel 2002, 2011; Bocquet-Appel and Naji 2006) indicate a juvenility index for Europe and North America, based on the ratio of juveniles relative to the overall sample (D_{5-19}/D_{5+}). These investigations show an elevated juvenility index in early farmers compared to foragers and in intensive farmers

Table 2 Composition of the skeletal sample in terms of age and sex for the three major time periods of Çatalhöyük's occupation

	Early	Middle	Late
Age			
Fetal	1	1	2
Neonate (birth–2 months)	7	10	52
Infant (2 months–3 years)	6	26	10
Child (3–11 years)	1	29	9
Adolescent (12–19 years)	1	8	6
Young adult (20–29 years)	2	6	10
Middle adult (30–49 years)	0	14	11
Older adult (50+ years)	3	10	4
Unknown adult (20+ years)	0	13	11
Sex			
Female/female?	3	20	13
Male/male?	3	13	17
Indeterminate	0	12	7

Table 3 Number of individuals in the D_{3-19} and D_{3+} age categories along with the juvenility index as a measure of fertility for the three major time periods of Çatalhöyük's occupation

	Early	Middle	Late
D_{3-19}	2	37	15
D_{3+}	7	80	51
D_{3-19}/D_{3+}	0.2857	0.4625	0.2941

compared to incipient farmers. For this study, we use the juvenility index D_{3-19}/D_{3+}, representing the number of individuals aged 3–19 years (children and adolescents) relative to the total number of individuals in the series above 3 years. The juvenility indexes for the respective Early, Middle, and Late periods show a dramatic increase in the Middle period followed by a dramatic decline in the Late period (Table 3). We interpret this pattern to represent an increase in fertility in the Middle period, followed by significant decline in the Late period. Importantly, the demographic profile change is consistent with the record of population size implied by the number of houses, making the case that it was increasing fertility that fueled the dramatic population growth, peaking in the Middle period.

Other factors may have also contributed to the rise in population over the course of the first millennium of the community's history. For example, there could have been an influx of immigrants to the community. This seems unlikely, however, because the settlement data presented by Baird (2002, 2005) shows the presence of very little population in the region outside of Çatalhöyük, even during the site's peak population in the Middle period. This suggests that there was not a significant potential migrant population pool that could have immigrated to Çatalhöyük. Moreover, the remarkable reduction in numbers of juveniles in the Late period Çatalhöyük skeletal series and lowered juvenility index is consistent with a model of population decline based on numbers of houses, increased dispersal of houses, and ultimately, abandonment of the community. Finally, biodistance analysis based on dental markers reveals no evidence of an influx of migrants (Pilloud 2009).

What did Çatalhöyük People Eat that Fueled the Remarkable Growth in Population?

The above discussion shows a population change involving increase consistent with other localities globally where farming is adopted. For this setting, then, what was the diet that helped to sustain the high level of growth in population size experienced at Çatalhöyük? Temporal analysis of plant and animal remains indicates an increasing dependence on cereal grains, especially wheat and barley, and domesticated caprines, especially sheep (Bogaard et al. 2013; Russell et al. 2013; Twiss et al. 2009). The record of preserved plant and animal remains documents *what* foods were consumed, but does not necessarily provide a diagnostic record of *proportions* that individuals or the population as a whole were consuming. Simply, the question of what is available does not tell us about importance in the diet. Stable carbon and nitrogen isotope ratios are more specific in this regard, especially because rather than providing a record of what types of foods were available, stable isotope analysis offers a record of relative importance of foods consumed.

Stable isotope analysis is employed here to provide a record of dominant foods eaten, as well as an understanding of variation in diet through the life cycle, including timing and duration of weaning and variation in adult diet. This investigation uses ratios of stable carbon isotopes (^{13}C, ^{12}C) and stable nitrogen isotopes (^{15}N, ^{14}N) determined from a large sample (n=874) of plants, animals, and humans in order to determine key elements of diet—especially the source of protein—in the population living at Çatalhöyük (and see Richards et al. 2003; Richards and Pearson 2005; Hillson et al. 2013; Pearson 2013). For this investigation, the stable isotope values are derived from bone collagen and analyzed following methods outlined by Pearson (2013).

The record of stable carbon and nitrogen isotope ratios ($\delta^{13}C$, $\delta^{15}N$) reveals that the mean values for women and men are statistically indistinguishable, thus indicating a strong similarity of diet between sexes (females: $\delta^{13}C=-18.8$ ‰, $\delta^{15}N=12.6$ ‰; males: $\delta^{13}C=-18.6$ ‰, $\delta^{15}N=12.7$ ‰). In both males and females, the nitrogen values are approximately 2 ‰ higher than for sheep and cattle (Pearson 2013; Pearson and Meskell 2014). These values meet expectations for a population eating sheep and cattle as the leading sources of animal protein. When viewed in diachronic context, stable isotope ratios are indistinguishable between men and women for all three periods (Fig. 4). There is an indication of increase in $\delta^{15}N$ values in the Late period (Fig. 4), although the increase is not statistically significant. It may be that the Çatalhöyük population began a practice of manuring—which would introduce additional nitrogen to plants, the animals that eat the plants, and the humans eating the spectrum of foods in this farming economy. Alternatively, however, the temporal increase in $\delta^{15}N$ values is consistent with the expectation for a population experiencing an increase in protein consumption derived from animal (sheep and cattle) sources, especially considering the earliest appearance of domesticated cattle during this period of the site's occupation (Russell et al. 2013). On the other hand, it is possible that increasing aridity in the region may have played a role in the changing $\delta^{15}N$ values. These values are sensitive to climate and are higher in arid settings (see Katzenberg 2008). However, the record of diet derived from study of animal remains from the site is consistent with wider availability of animal sources of protein.

Analysis of stable nitrogen isotope ratios in juvenile remains provides a record of age-related dietary changes, especially related to breastfeeding and weaning. Breast milk has

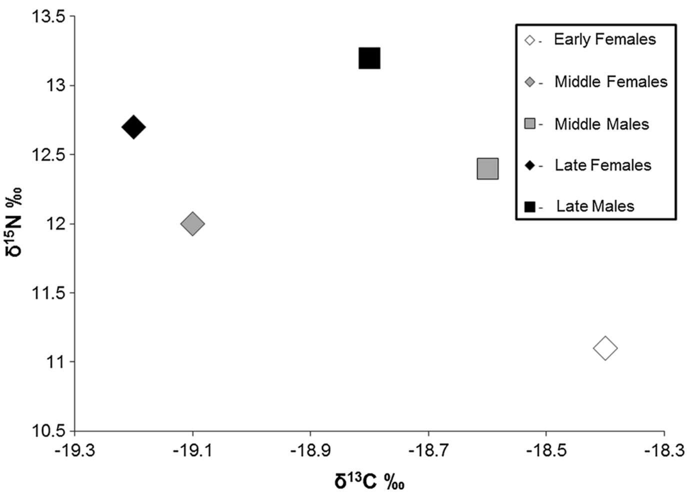

Fig. 4 Stable carbon and nitrogen isotope ratios for adult males and females by time period (Early Males not included due to small sample size)

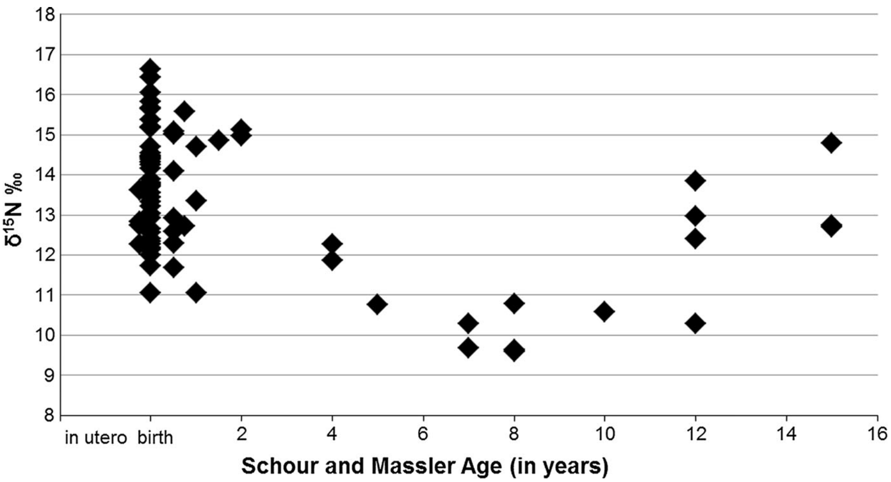

Fig. 5 Nitrogen isotope ratios for subadults aged in utero to 15 years (using Schour and Massler age methodology)

$\delta^{15}N$ values that are identical to the mother's other tissues (e.g. Miller et al. 2008). Similarly, the newborn has the same $\delta^{15}N$ values as the mother. Once breastfeeding begins, owing to the trophic effect, the $\delta^{15}N$ values of the consumer (the infant) become approximately 3–5‰ higher than the $\delta^{15}N$ values of the producer (the mother). Thus, it is possible to track the course of the infant's period of breastfeeding (relatively higher $\delta^{15}N$ values than baseline at birth), decline of breastfeeding (reducing $\delta^{15}N$ values), and final adoption of a fully mature diet ($\delta^{15}N$ ratios the same as the mother or the adult population generally: Fogel et al. 1989). Consistent with this model, the Çatalhöyük record of infant protein consumption through breastfeeding shows a rise in $\delta^{15}N$ values soon after birth, followed by a decline in values beginning at about 18 months, and a return to birth values at about 3 years (Fig. 5). The beginning of weaning—a process by which the mother introduces adults foods—at a year-and-a-half is typical of many traditional farming societies worldwide, as well as in the archaeological past (Larsen 2015). This timing of the weaning process indicates that young juveniles lose the full complement of immunity provided by mother's milk, at an age where the child's immune system is not fully developed. Thus, the individual may well have a compromised immune system and greater susceptibility to infectious pathogens generally.

How was the Çatalhöyük Community Socially Organized?

The shift from foraging to farming and early intensification of farming has considerable implications for how human societies were organized. At Çatalhöyük, it has long been assumed that those interred in the floors of houses were members of extended family groups, including immediate family members and relatives. In order to test the hypothesis that individuals interred within the same house represent a biologically-defined kin group, we undertook a biodistance analysis of individuals within houses, within clusters of houses (neighborhoods), and between the northern and southern areas of the mound. The latter may represent two separate communities or larger social groups marked by changes in terrain still visible at the site today. The use of biodistance analysis is based on the premise that the phenotype correlates with genetic variation (Ricaut et al. 2010; Shinoda et al. 1998). Moreover, individuals or groups of individuals that are more genetically similar are more closely related than individuals who are less genetically similar. Biodistance analysis has been successfully applied to a wide variety of archaeological settings, providing a means of reconstructing biological relationships (e.g. Corruccini and Shimada 2002; Howell and Kintigh 1996; Irish 2005; Hemphill et al. 1991; Stojanowski 2013; Stojanowski and Schillaci 2006; and many others). We use dental phenotypic traits provided by the Arizona State University Dental Anthropology System for recording dental traits (Turner et al. 1991) and tooth crown measurements (mesiodistal, buccolingual) specific to this type of analysis (Pilloud and Larsen 2011).

Especially important in this analysis is developing an understanding of the nature of relationships within households in this community. The archaeological record for Çatalhöyük suggests that the household is the central unit of social organization and the center of social and economic activity (Hodder 2006). Moreover, earlier studies emphasized the centrality of biological relatedness in early farmers (e.g. Bar-Yosef 2001; Flannery 1972, 2002). Dental biodistance analysis (univariate and multivariate) of the Çatalhöyük dentitions reveals remarkably minimal phenotypic patterning in dental size or morphology for deciduous or permanent teeth either at the household or neighborhood levels. There are some relatively rare traits in the Çatalhöyük series that are above the mean for individual houses (e.g. 50% frequency of peg-shaped upper third molars in one house). Similarly, neighborhood variation is not patterned in the same manner as found in other series (e.g. Corruccini and Shimada 2002; and see below). These findings suggest that biological affinity may have played only a limited role in who is and who is not associated with specific houses and neighborhoods. Thus, habitation at Çatalhöyük may have been constituted by 'practical kin' rather than 'official kin' (sensu Bourdieu 1977). That is, house affiliation may have been determined not on biological terms (official kin) but rather as groups of largely biologically unrelated individuals (practical kin) co-habiting for various social or cultural reasons. At this early farming community, this arrangement was likely originally motivated by the adoption of domesticated plants and animals. Individuals may have aligned themselves with practical kin for economic-related activities such as herding animals, planting and harvesting crops, and other functions that required groups of individuals. This interpretation of a very early farming society dependent on domesticated plants and animals is similar to an analysis of co-residence patterns for a large sample of present-day foraging societies (see Hill et al. 2011).

Most individuals in the sample of residential groups at Çatalhöyük show no clear evidence of biological relatedness. This finding is in sharp contrast to the long-held assumption that residence patterns are biological-kin based (e.g. Service 1962), and it underscores the importance of residence for cooperation and social learning, which are not functions that necessarily have to be constituted through biological relatedness. Thus, biological kinship was not the sole or even the most important defining principle of social organization at Çatalhöyük.

Our analysis of kin identity in Çatalhöyük households and neighborhoods does not mean that other phenotypic patterning was not present in this community. That is, there are two key patterns that emerge that suggest important indicators of social organization. First, statistical treatment of dental traits and tooth size revealed a distinction in dental variation in comparison of the north and south areas, suggesting the presence of two sub-communities (Fisher's Exact Test; $p<0.1$). Second, there is considerably less variation in adult males than adult females (t test; $p<0.001$) (Hillson et al. 2013; Pilloud and Larsen 2011).

The presence of greater variability in females suggests that the Çatalhöyük community practiced patrilocal residence, whereby women may have been moving into the community on a greater scale than men and perhaps over some distance.

These results disclose the complexity of the social system at Çatalhöyük, which was based only in part on biological relationships. That is, the Çatalhöyük population relied on the house as a focus of social interactions and especially for defining and maintaining social unions. This characterization of household social organization is a departure from what Bourdieu (1977) called ‘official kin’ or biological kin that likely describes the earlier, more dispersed foraging societies that were ancestral to this early, highly-amalgamated farming society. Rather, these data show that there was a focus on ‘practical kin’ as the basis for membership in households (Pilloud and Larsen 2011; Hillson et al. 2013). In this regard, practical kin are not motivated by biological relationships but are groups of mostly unrelated people coming together for a variety of cultural, social, and economic reasons. At Çatalhöyük, there were likely many circumstances for forming these kinds of relationships, such as planting crops, herding animals, harvesting, and a wide variety of other activities that would promote the success of the household.

How much Labor did it Take to Acquire Resources?

Broader considerations of the adaptations that were involved in the foraging-to-farming transition and agricultural intensification have been of interest to a wide range of social and behavioral scientists, especially in addressing concerns regarding workload and lifestyle. Ethnographic-based models and observations of foraging and farming societies worldwide present sometimes contradictory evidence and no clear patterns of variation. That is, workload and lifestyle are often very much influenced by highly localized circumstances involving various factors, such as the kinds of plants and animals produced, climate, ecology, and social organization (Kelly 1995). Here, we use biomechanical analysis of long bones and pathological markers on articular joints of the skeleton to document and identify patterns having behavioral significance. These data sources are highly informative about workload, mobility, and lifestyle, primarily because they reflect the person’s cumulative record of behavior and activity during life. Thus, archaeological skeletons contain an archive of behavior from which to interpret general patterns of activity and workload when the person—and the population collectively—was living.

This activity-based focus is built on the notion that in life bone is a living tissue that is highly responsive to physical stresses and loading patterns (Larsen 2015; Ruff 2008). Long bones—such as the femur—are subjected to loading forces, especially bending and twisting, during walking, running, and overall physical activity. In order to resist deformation and breakage, bone adapts through the years of growth and development to these forces through remodeling that enhances strength. The measurement of strength is accomplished by collection and analysis of cross-sectional geometric properties (Ruff 2008). Used by civil and mechanical engineers to measure strength or resistance of building materials to mechanical loading, these properties measure strength characteristics of long bone diaphyseal cross-sections and how the bone is distributed in order to reconstruct behavioral patterns at both individual and population levels.

For the Çatalhöyük series, we used biplanar radiographs in combination with molding external surfaces of femora taken at the midshaft diaphysis (50% section) in order to have the full image of the cross-sections required for geometric analysis, and subsequently applied custom-written software that automatically calculates cross-sectional geometric properties called section moduli (Z_x, Z_y: O'Neill and Ruff 2004; Ruff 2008; Sylvester et al. 2010). In addition to an adult sample of 30 males and 31 females, we also present analysis of juvenile femora in order to document the ontogeny of bone changes during the years of growth and development leading to the fully mature patterns. Some of the data collected for the juveniles employed computed tomography, required for analysis of the very small amount of bone in young juveniles (Larsen et al. 2013). Forty-five adults could be assigned to specific levels, including three individuals from the Early period, 35 individuals from the Middle period, and seven individuals from the Late period. All mechanical properties are standardized for body size using methods developed by Ruff and coworkers (2006a). Specifically, we use femoral midshaft polar section moduli, including Z_x, the measure of antero-posterior (A-P) bending strength, and Z_y, the measure of medio-lateral (M-L) bending strength. In order to address the sample population mobility as identified above, we use the ratio Z_x/Z_y that provides an index of the level of mobility in an individual—the higher the ratio value, the greater the level of mobility. This is because highly mobile individuals—persons who engage in considerable walking and running—place relatively high A-P bending loads on the femur as their limbs move front-to-back (Larsen 2015; Ruff 1987; Ruff et al. 2006b). In order to situate these findings within a larger temporal and geographic context, we present these data in comparison with Late Pleistocene and Early Holocene European populations, including the Early and Late Upper Paleolithic, Neolithic, and Bronze Age (Fig. 6) (Holt 2003; Ruff et al. 2006a, b; Sládek et al. 2006). Looking at just the Çatalhöyük series, there are temporal changes in the Z_x/Z_y mobility index through time (Fig. 7). This finding is consistent with a relative increase in mobility in the Middle period, a pattern that continues for females but not males in the Late period.

In addition to the manner in which bone is distributed in cross-section, levels of mobility are also strongly inferred from the external shape of the femoral diaphysis (Larsen 2015). Therefore, in order to provide additional insight into mobility, we measured the external A-P and M-L dimensions for all available adult and adolescent femoral diaphyses

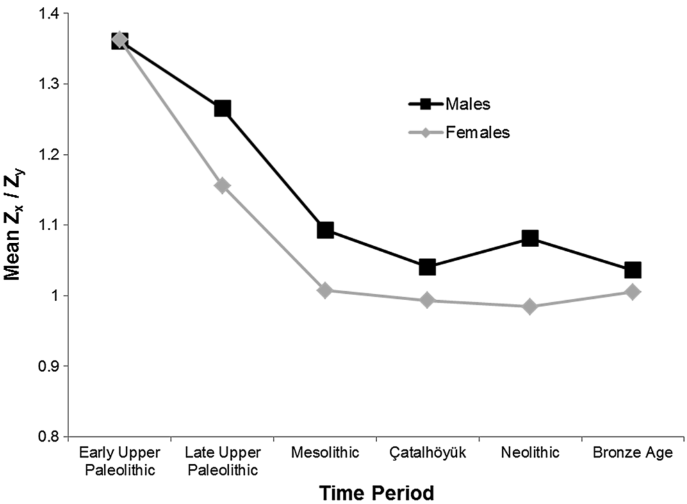

Fig. 6 Femoral midshaft A-P/M-L bending strength (mean Z_x/Z_y) in males and females at Çatalhöyük and comparative Pleistocene and Holocene European samples

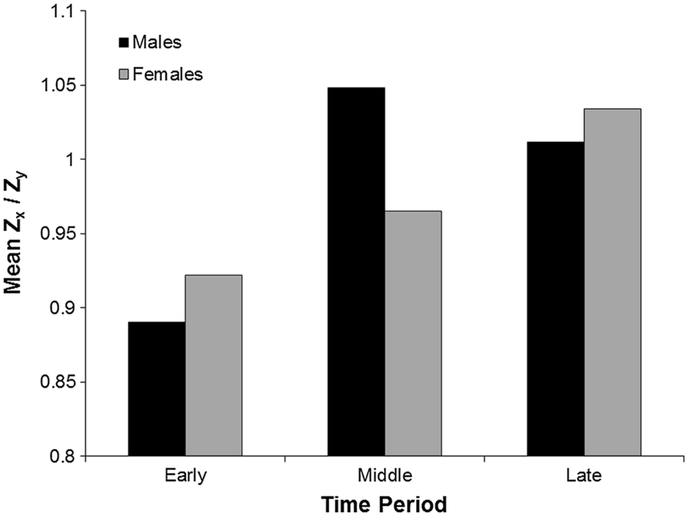

Fig. 7 Femoral midshaft A-P/M-L bending strength (mean Z_x/Z_y) in males and females across the three temporal periods of Çatalhöyük's occupation

(n=41) and calculated the shape index formula: $(T_{ml} \times 100)/T_{ap}$, where T_{ml} is the total diameter in the medio-lateral plane and T_{ap} is the total diameter in the antero-posterior plane. Lower shape values reflect higher mobility, and conversely, higher values reflect lower mobility. In comparison of houses containing multiple burials and those containing fewer burials, the index was significantly greater in the former than the latter (0.85 vs. 0.95; Monte Carlo; $p<0.05$). This suggests that adults, especially males, from multiple-burial houses—a type of 'history' house (see Hodder and Pels 2010)—have greater mobility than adults from other houses, suggesting that males living (or ultimately interred) in these houses may have had a different pattern of work and behavior than males from other houses. As expected, females have somewhat lower mobility (0.97) than males (0.93), but the difference is not statistically significant (Monte Carlo; $p>0.05$). Lastly, there is a clear trend in mobility in comparing the three temporal groups for both males and females. From the Early to Late periods, values for males decreased from 1.00 to 0.90 to 0.87, a pattern of change approaching statistical significance (Kruskal–Wallis; $p=0.06$), and values for females decreased over the sequence from 1.00 to 0.99 to 0.90, a pattern of change that is suggestive of an increase in mobility but is not statistically significant (Kruskal–Wallis; $p=0.36$). Combined with the record of cross-sectional geometry, there is a strong suggestion of increasing mobility over the course of the occupation of Çatalhöyük.

Reconstructing Activity and Lifestyle: Osteoarthritis

Osteoarthritis, sometimes referred to as degenerative joint disease, is a multifactorial disorder that is exhibited as bony changes arising from wear-and-tear on the articular joints, especially for surfaces of joints that typically have limited movement and are highly stabilized (amphiarthrodial joints), such as vertebral bodies, and joints that routinely involve movement (diarthrodial joints), such as those of the limbs (e.g. hand, elbow, knee). Osteoarthritis is manifested by lipping (osteophytes) of joint margins, porosity on the joint surfaces, and in the extreme, polishing (eburnation) of articular surfaces due to disintegration of the cartilage and resulting bone-on-bone contact (Figs. 8, 9, 10). There are a considerable number of factors that influence the condition, including systemic factors (e.g. age, sex, genetics, nutrition, and hormonal influences) and localized conditions (especially mechanical stress and/or trauma; Felson 2000, 2003; Jurmain 1977; Larsen 2015). Clinical, experimental, and bioarchaeological studies are largely in agreement with the 'stress hypothesis', namely that localized repetitive mechanical loading will determine and direct the rise and progression of degenerative changes in the joints (Felson 1990, 2003; Hemphill 1999; Radin 1976; Radin et al. 1991). Overall, then, while it is not usually possible to identify specific activities from degeneration, we can draw general conclusions about level of activity based on presence and severity of the condition.

For this investigation, we documented presence and severity of changes associated with osteoarthritis for older juveniles (i.e. adolescents) and adults (n=142), focusing on six appendicular joints and three vertebral regions—shoulder, elbow, wrist/hand, hip, knee, ankle/foot, cervical vertebrae, thoracic vertebrae, lumbar vertebrae—using the coding scheme of the Global History of Health Project (Steckel et al. 2011). A score of 'moderate' indicates presence of slight lipping and articular surface porosity, and a score of 'severe' indicates severe lipping/porosity, eburnation, and/or joint surface destruction for one or more joints.

The Çatalhöyük series shows an age-related increase in frequency and severity of osteoarthritis (Fig. 11). Per expectation for individuals affected, there is a statistically significant difference between the three age classes—young adults (20–29 years), middle adults (30–49 years), and older adults (50+ years)—in both prevalence and severity (Chi square; $p<0.05$). For example, 27.3% of young adults have osteoarthritis, in contrast to 82.8% of older adults. Similarly, 9.1% of young adults express severe osteoarthritis in contrast to 48.3% of older adults. No statistically-significant differences are present between males and females within each of the age groups for either individuals affected or for each of the articular joints studied (Fisher's Exact Test; $p>0.05$). This pattern of no differences between males and females is also present in comparison of northern and southern areas (Fisher's Exact Test; $p>0.05$).

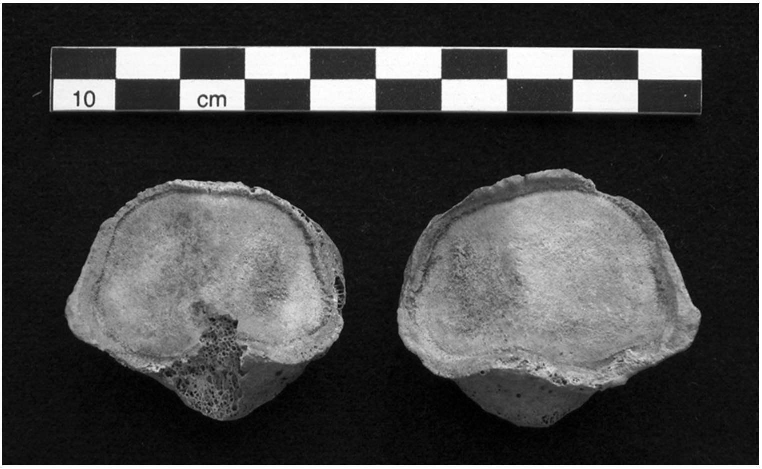

Fig. 8 Evidence of osteoarthritis at Çatalhöyük: marginal osteophyte growth on left and right patellae of an adult of indeterminate sex, Sk.8821 (Photo: Joshua Sadvari)

Fig. 9 Evidence of osteoarthritis at Çatalhöyük: marginal osteophyte growth on lumbar vertebra of an adult female, Sk.13609 (superior view) (Photo: Joshua Sadvari)

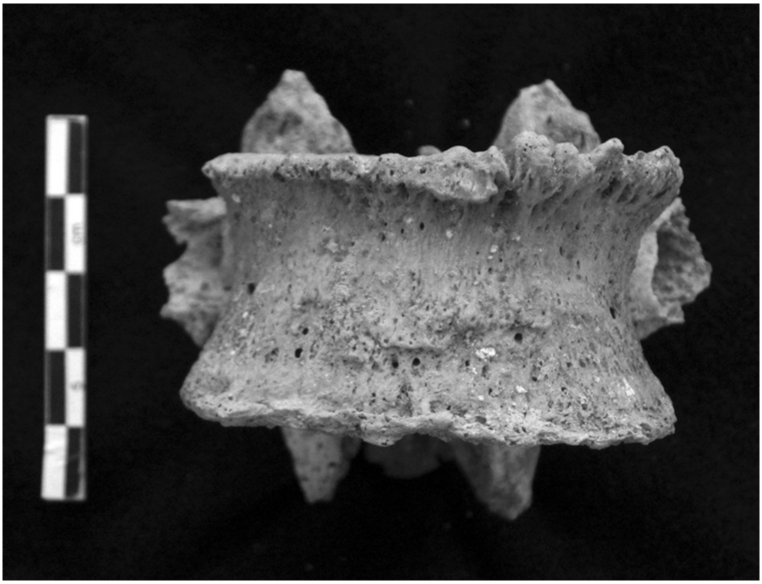

Fig. 10 Evidence of osteoarthritis at Çatalhöyük: marginal osteophyte growth on lumbar vertebra of an adult female, Sk.13609 (anterior view) (Photo: Joshua Sadvari)

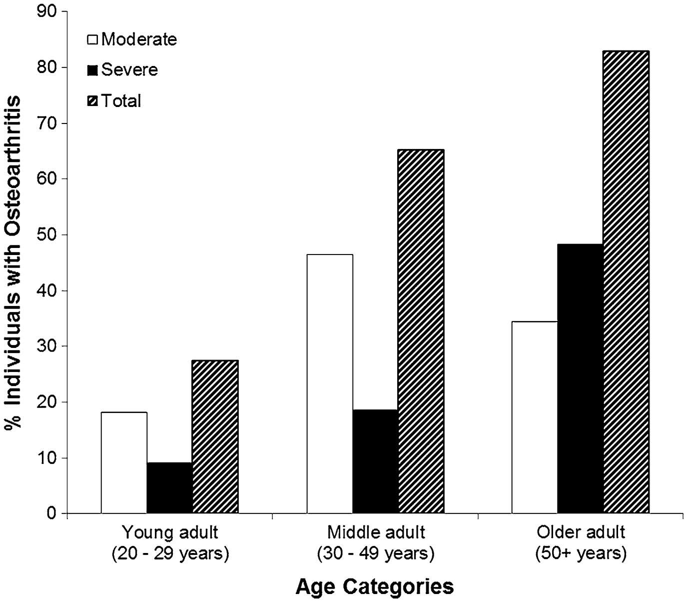

Fig. 11 Osteoarthritis prevalence by age among adults at Çatalhöyük

A broad pattern of temporal change in osteoarthritis is present in the series in comparison of the Middle and Late period samples (the Early period sample is too small to include in the comparative analysis). That is, across all three age classes, there is a reduction in the prevalence and severity of osteoarthritis in the Late period compared to the Middle period, though this reduction reaches statistical significance only among older adults (Fisher's Exact Test; $p<0.05$). Comparison by joint shows a reduction in osteoarthritis, with the change reaching or nearly reaching statistical significance for the cervical vertebrae (Fig. 12; Fisher's Exact Test; $p=0.05$) and thoracic vertebrae (Fisher's Exact Test; $p=0.07$). We conclude that workload as it impacts articular joints declined in an appreciable way, which likely reflects a reduction in behaviors that involved loading of these articular joints, especially in the neck and upper back. These trends of reduced loading in the Late period are coupled with increased mobility for females (based on section moduli) and suggested for males (based on external shape measurements). Thus, while the activity appears to be lighter in demand as it pertains to mechanical loading, it is accompanied by greater mobility. These findings are consistent with other data sources regarding acquisition of resources (e.g. food, fuel, building materials, and clay) farther and farther from the site over the course of its occupation (see above).

Comparisons of households show no significant differences between individuals interred in houses containing multiple burials and those without, or history houses versus non-history houses (Fisher's Exact Test; $p>0.05$). On the other hand, osteoarthritis is more severe in individuals interred in non-history houses than history houses overall, and for the cervical vertebrae in particular (Fisher's Exact Test; $p<0.05$). While not conclusive, this pattern suggests a higher level or intensity of workload among individuals interred in non-history houses compared to those associated with history houses. We speculate that this may represent a divergence from the egalitarian model of social behavior in this setting when it comes to some aspects of workload and procurement and provisioning of

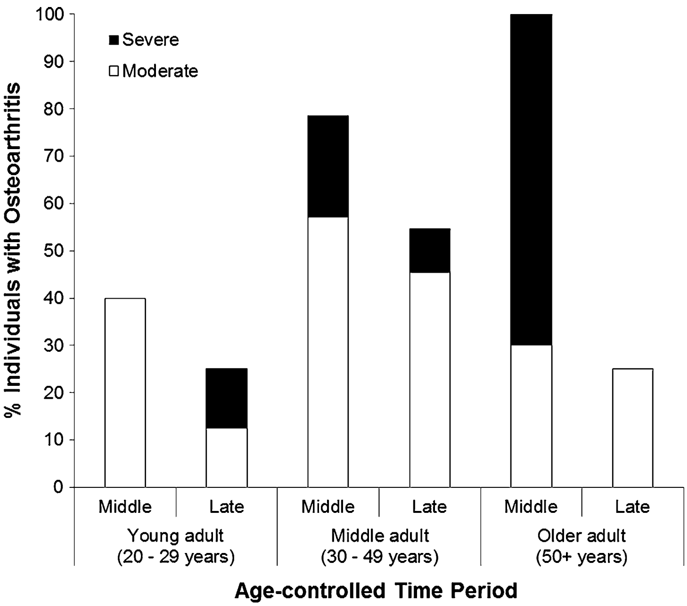

Fig. 12 Age-controlled osteoarthritis prevalence by time period among adults at Çatalhöyük (the Early period is not included due to small sample size)

resources, with certain segments of the community potentially bearing a greater burden with regard to these activities. That is, the evidence suggests different households may have had different roles in the community, at least with respect to the amount or type of labor.

How Healthy was the Nutritional and Living Environment?

Adequacy of Resources: Nutritional Stress and Quality of Living Circumstances

Much of the bioarchaeological record of the foraging-to-farming transition and/or farming intensification in past populations reveals a pattern of increasing morbidity, including more growth arrest and reduction in body size, increase in oral and skeletal infection and infectious disease, and other indicators of systemic stress and compromised health. At the community level, the Çatalhöyük setting provides the opportunity to test the hypothesis that health was adversely affected by a focus on the consumption of starches (especially derived from wheat) and by living in a large, densely occupied community. The expectation for the former is reduced growth and development owing to dietary focus on a food that is deficient in vitamins and essential amino acids and that contains phytate. Vitamins and all essential amino acids are required for adequate growth and development, and phytate is an inhibitor of iron availability. Unless a complete nutritional complement is available—adequate vitamins, minimal phytate, and sufficient energy (calories)—growth will likely be impeded. Moreover, the expectation would be that there is an elevated prevalence of dental caries in comparison with populations not relying as heavily on cereal grains. Living in close, crowded living conditions provides opportunities for spread of infectious disease. In order to further test the hypothesis that the population had a poor diet and that the living circumstances in general promoted the spread and maintenance of infectious disease, we document in the following a suite of complementary data on growth and development, evidence of poor oral health, and infection.

Growth and Development in Juveniles: Body Mass and Stature

Human growth is highly sensitive to environmental conditions, including those conditions created in one's living environment such as nutritional quality. Health in general and diet in particular play a highly significant role in influencing the trajectory and attainment of terminal height and body mass (Bogin 1999). Conditions involving poor nutrition and poor health will slow or attenuate the growth of the body, especially during periods that are particularly sensitive to environmental insult, such as infancy and early childhood (Bogin 1999; Frisancho et al. 1980; Habicht et al. 1974; various in Stinson et al. 2012).

In order to test the hypothesis that growth velocity was reduced owing to the compromised living conditions, we estimated heights and body masses for juveniles. Statures were calculated for individuals $\geq$0.5 years (n=30) and body masses for individuals $\geq$1.0 years (n=26) and growth curves produced. In addition, we use a sample of young adults (n=21), including both males and females, to serve as an endpoint in the constructed growth curves. For purposes of comparison, we contrast the Çatalhöyük growth curves with an archaeological Arikara series and with a longitudinally-documented middle-class twentieth-century population from Denver, Colorado, a group having adequate nutrition and positive living circumstances (Jantz and Owsley 1984; McCammon 1970; Ruff et al. 2013). For this series, dental ages were determined from tooth-length regression equations and dental development (Liversidge 1994, 2008; Liversidge and Molleson 2004; Smith 1991). Stature was estimated for the Çatalhöyük and Arikara juveniles via femoral length and body mass from distal femoral metaphyseal breadth or femoral head breadth using age-specific equations derived from the Denver series (Ruff 2007). Çatalhöyük adult statures were estimated from femoral lengths using a regression equation from Dynastic Egyptians (Raxter et al. 2008), and body mass estimates were estimated from the average of equations using femoral head breadth (Auerbach and Ruff 2004). Overall, these comparisons in growth and development reveal that early growth trajectories for all three series are similar in both stature and body mass, with Çatalhöyük located intermediate between the Arikara and Denver populations (Figs. 13, 14). Until reaching adolescence, the Çatalhöyük, Arikara, and Denver populations show a similar growth velocity. Beginning with adolescence, the Denver growth velocity accelerates, perhaps reflecting greater genetic growth in European and European-descent populations than other populations (Bogin 1999). This record suggests that the growth in early childhood—a period more subject to environmental insult than adolescence—at Çatalhöyük was normal, leading to the conclusion that children were born into a relatively healthy environment, certainly one that provided adequate resources and especially access to quality nutrition. Furthermore, the pattern of percent cortical area (%CA) observed in juveniles also supports the notion that food resources acquired through farming, herding, hunting, and gathering at Çatalhöyük provided adequate nutrition, at least as it is represented in normal growth of infants and young children.

Adult stature and body mass, heights and weights, respectively, were estimated from a substantial series of well-preserved remains. Statures were estimated from primarily femoral and tibial lengths using equations derived from Dynastic Egyptians (Raxter et al.

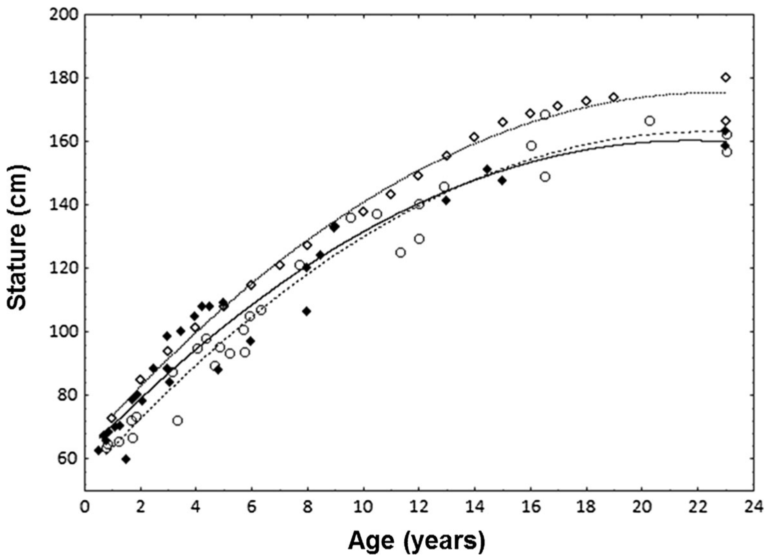

Fig. 13 Growth in stature for Denver (*open diamond*, *dotted line*), Arikara (*open circle*, *dashed line*), and Çatalhöyük (*closed diamond*, *solid line*) subadults. Adult data points represent male and female sample means

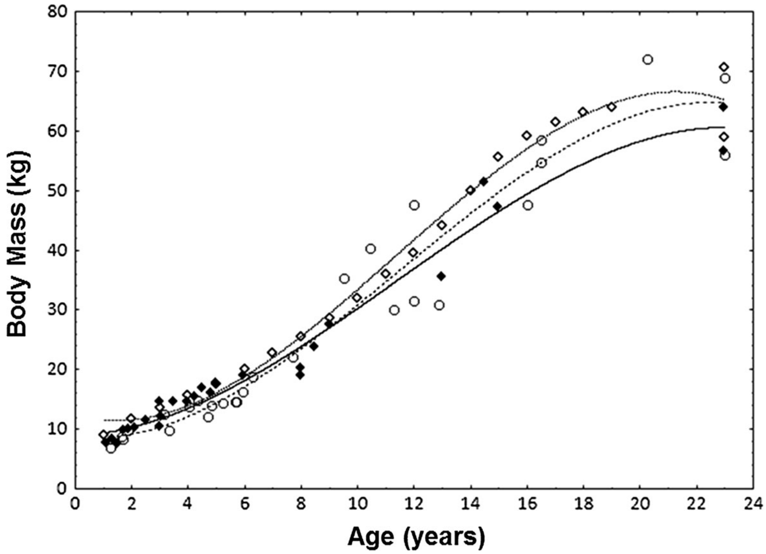

Fig. 14 Growth in body mass for Denver (*open diamond*, *dotted line*), Arikara (*open circle*, *dashed line*), and Çatalhöyük (*closed diamond*, *solid line*) subadults. Adult data points represent male and female sample means

2008) and US whites (Trotter and Gleser 1952). Body mass was estimated from femoral head breadths using the average of three equations developed from various other archaeological series (Auerbach and Ruff 2004; Ruff 2007). For Çatalhöyük, direct measurements from long bones derived from both the Mellaart and the Hodder excavations were used. In addition, long bone measurements from data collected by J. Lawrence Angel on Mellaart skeletons increased the sample available for analysis (Angel, n.d.; National Anthropological Archives, Smithsonian Institution). These combined datasets provided a sample of 113 adults for stature estimates and 115 adults for body mass estimates. Compared to other Neolithic samples, Çatalhöyük adults are relatively short, but not especially so (Fig. 15). Within the community, temporal comparisons reveal no change in stature in males, but a trend of decreasing stature is observed for females between the Early and Middle periods, although not significantly so (Kruskal–Wallis; p=0.12). Body mass estimates are in the middle of the Neolithic samples (Fig. 16). Thus, in terms of these two measures of body size, the record reveals a relatively normal population, suggesting that the Çatalhöyük inhabitants were living in a setting that had adequate nutrition and positive circumstances necessary for normal growth and development. Moreover, the living conditions suggested by the archaeological record—living in close crowded conditions and a focus on plant carbohydrates in diet—were successfully mitigated. This record of growth and development is notably different from the record of body size reduction in either mass or height documented in other areas of the world that underwent the foraging-to-farming or farming intensification transitions (see various in Cohen and Armelagos 1984; Cohen and Crane-Kramer 2007; Steckel and Rose 2002; Larsen 1995, 2006, 2015). As such, it represents a striking exception to the general pattern observed worldwide regarding growth and development and inferences drawn from skeletal remains about the living environment.

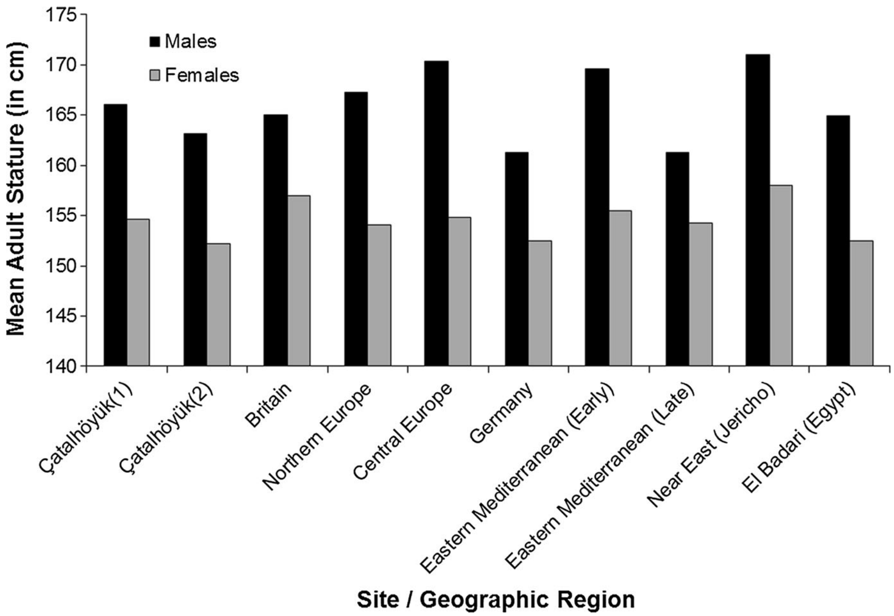

Fig. 15 Estimated adult stature in cm at Çatalhöyük and other Neolithic sites (1. Calculated using US white reference sample, 2. Calculated using Egyptian reference sample)

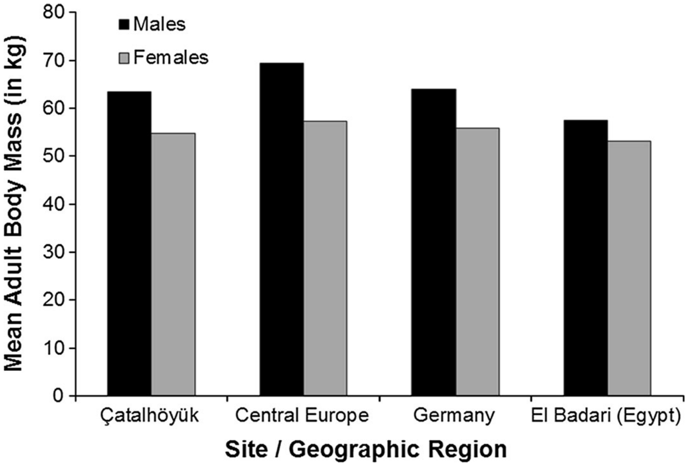

Fig. 16 Estimated adult body mass in kg at Çatalhöyük and other Neolithic sites (1. Calculated using U.S. white reference sample, 2. Calculated using Egyptian reference sample)

Health and Morbidity: Oral and Skeletal Patterns

Dental caries, a disease process characterized by focal demineralization of dental hard tissues (enamel, dentine, and roots) by acids produced by bacterial fermentation of dietary carbohydrates, provides an enormously important record of oral health (Fig. 17). The most important factor in producing carious lesions is the presence of fermentable dietary carbohydrates—sugars and starches (Hillson 2008; Larsen 2015). The demineralization process is progressive, leading to small opacities that eventually develop into clearly discernible cavities and eventually destruction of the tooth crown and root.

Analysis of dental caries prevalence for posterior permanent teeth—third and fourth premolars, and first, second, and third molars—was undertaken following the protocol

Fig. 17 Dental caries in a Çatalhöyük adult (Photo: Simon Hillson)

developed by Hillson (2001), whereby lesions are recorded by tooth surfaces (e.g. occlusal, buccal, labial, mesial, and distal surfaces for crown lesions). Lesions were recorded as to severity of progression, from early stages in the enamel to involvement of tooth roots: enamel lesions (enamel affected only), dentine lesions (lesion penetrating both enamel and dentine), root surface lesions (developing following exposure of the root due either to continuous eruption and/or periodontal disease), and gross lesions (massive lesions that prohibit documentation of origin). Analysis of the record reveals the age-cumulative progression of dental caries in adults, with younger adults having lower prevalence in general than older adults. This finding simply reflects the greater exposure time that older adults have in regard to cariogenic factors than younger adults.

There is a considerable body of literature showing significant differences in a range of social distinctions in archaeological contexts, especially involving greater prevalence of dental caries in females than males in farming populations globally (reviewed in Larsen 2015; Lukacs 2008). Interestingly, comparison of Çatalhöyük adult females and males reveals no significant differences between them for enamel (Fig. 18), root (Fig. 19), or gross lesions (Fig. 20), suggesting a consistency with the isotopic record indicating no significant difference in diet between adult men and women. Thus, while diet appears to be highly gendered in many settings globally, at least with respect to dental caries variation, Çatalhöyük is an exception. Moreover, comparisons of the three periods show no temporal changes over the course of the site occupation in caries prevalence.

A highly informative record of skeletal health is provided via documentation of osteoperiostitis, an inflammatory response of the bone surface to bacterial infection or trauma (Larsen 2015; Ortner 2003; Weston 2012) (Fig. 21). It is most often characterized by periosteal surface pitting, longitudinal striations, and the formation of porous, woven bone (Larsen 2015; Ortner 2003; Roberts and Manchester 2005). These lesions are a nonspecific stress indicator, owing to the fact that osteoperiostitis is characteristic of multiple disease processes affecting bone and/or inflammatory reactions to localized trauma and infections.

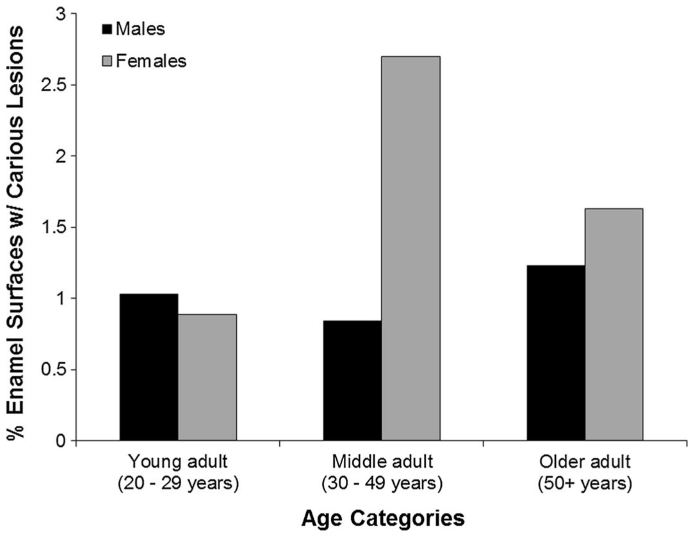

Fig. 18 Age-cumulative dental caries prevalence progression in comparison of younger, middle, and older adults at Çatalhöyük for lesions on enamel surfaces

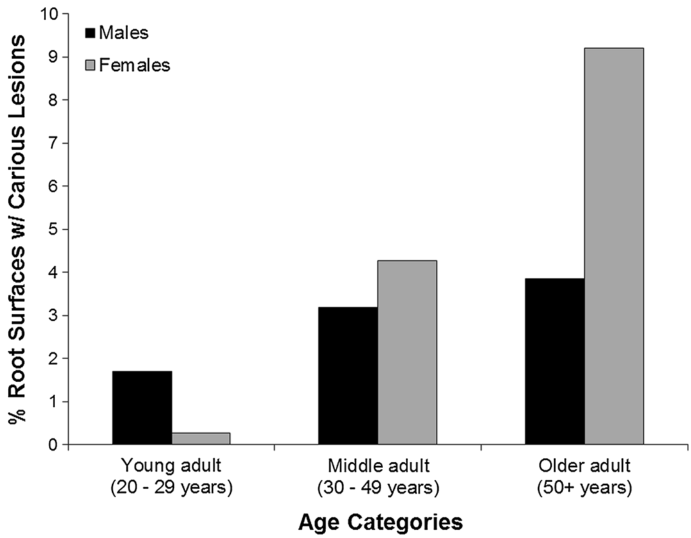

Fig. 19 Age-cumulative dental caries prevalence progression in comparison of younger, middle, and older adults at Çatalhöyük for lesions on root surfaces

Fig. 20 Age-cumulative dental caries prevalence progression in comparison of younger, middle, and older adults at Çatalhöyük for gross lesions

Moreover, comparisons of foragers and farmers show an increase in prevalence, reflecting heightened exposure to pathogens and related circumstances that promote infection and infectious disease (Larsen 2006). Here, we used the Global History of Health protocol for identifying and recording osteoperiostitis in the Çatalhöyük individuals (Steckel et al. 2011) for 166 adults and 213 juveniles.

The pattern of expression of osteoperiostitis in the Çatalhöyük series is most consistent with a general diagnosis of inflammatory response to localized infection. Moreover, most of the skeletal distribution was associated with the lower limb and especially the tibia for both adults and subadults (Fig. 22). Among subadults, neonates (19.8%) and infants (30.6%) have considerably higher prevalence than children or adolescents (Fig. 23). This high prevalence in the youngest age groups likely reflects their greater risk for infection in relation to an immature immune system compared to older juveniles and adults (Goodman and Armelagos 1989), and thus greater risk of death than more mature individuals. In adults, males have slightly more lesions than females (14.8% vs. 12.5%), but this difference is not statistically significant (Fisher's Exact Test; p=0.79).

There is considerable change in prevalence of osteoperiostitis over the course of the occupation of the site. In this regard, osteoperiostitis in adults peaks in the Middle period and declines dramatically in the Late period, a change that is statistically significant (Chi square; p=0.04; Fig. 24). For subadults, osteoperiostitis is highest in the Early period, declines slightly in the Middle period, and decreases yet further in the Late period (Fig. 24). This evidence shows that there is a pattern of increase in morbidity in the peak population size and density at Çatalhöyük. This finding is consistent with the notion of heightened risk of infection and infectious disease owing to increased population size and density. The lack of concomitant negative impacts on growth and development, as measured by stature and body mass (see above), suggests that adequate nutrition may have served as a buffer against the potential effects that disease stress imposed on Çatalhöyük's inhabitants.

In the Late period, changes in community structure, size, and distribution resulted in reduced risk of exposure to infection and infectious disease. These changes occurred simultaneously with increased mobility. That is, the isotopic and biomechanical records suggest that the population was likely smaller, more dispersed, and relatively more mobile in the Late period than in the Middle period. Perhaps this significant change is related to a combination of factors, including climate change, resource depletion, and social circumstances associated with changing living conditions on the Konya Plain in general, and the Çatalhöyük community in particular. The outcome for population reduction and dispersion

Fig. 21 Osteoperiostitis on a juvenile Çatalhöyük tibia (Photo: Scott Haddow)

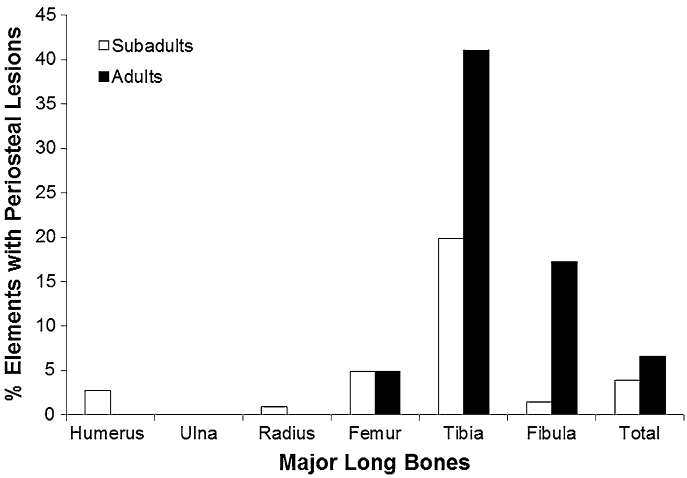

Fig. 22 Distribution of osteoperiostitis in subadults and adults based on the percentage of elements affected for major long bones

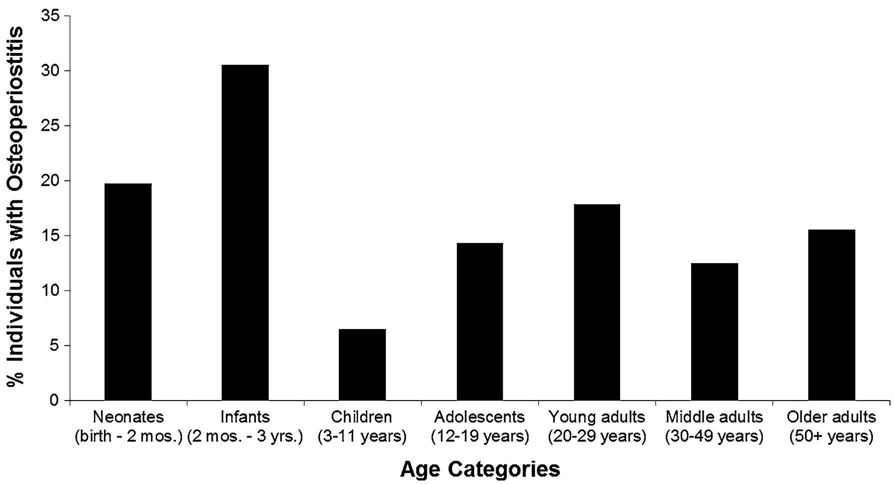

Fig. 23 Percentage of individuals with osteoperiostitis by age at Çatalhöyük

resulted in reduced risk of exposure to the mechanisms (e.g. pathogenic bacteria) that cause these skeletal lesions.

The social context for osteoperiostitis is more remarkable than other health indicators discussed in this paper. Adults from history houses have a slightly higher prevalence of osteoperiostitis than do those from other buildings (15.2% vs. 10.8%), but this result is not statistically significant (Fisher's Exact Test; p=0.43). However, subadults from history houses have considerably elevated prevalence compared to juveniles from non-history houses, a result which reaches statistical significance (26.2% vs. 14.2%; Fisher's Exact Test; p=0.05). Thus, if individuals associated with history houses had a special or elevated status in Çatalhöyük society, then those social factors did little to buffer them from stresses

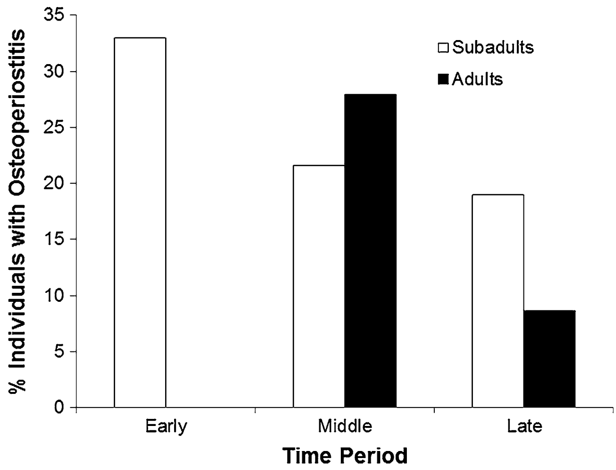

Fig. 24 Percentage of subadult and adult individuals with osteoperiostitis by time period at Çatalhöyük (the Early period is not included for adults due to small sample size)

associated with the various circumstances that promote infection and lead to its skeletal manifestations (osteoperiostitis).

In addition to, and working in conjunction with, crowding and population concentration, there were other circumstances that likely promoted infection. For example, presence of animal pens and trash deposits immediately adjacent to houses would have created poor sanitary conditions, increasing the likelihood of negative health outcomes (and see Molleson 2007). Similarly, while most house floors appear to have been relatively clean, at least one house shows coprolite residues suggesting its use as a latrine (Matthews 2005; Shillito et al. 2013). In all levels, human excrement (coprolites) has been recovered from within middens located outside of houses (Bull et al. 2005; Matthews, 2005).

Bone Health: Maintenance and Fragility in Adulthood

The above discussions about biomechanical adaptation and bone mass make clear that skeletal tissue is highly dynamic, representing a window into living circumstances, especially those relating to health and activity. Bone mass accumulates over the years of growth and development. Under circumstances involving poor nutrition and relatively low levels of loading, the accumulation of bone mass is slower than under circumstances involving adequate nutrition and relatively high loading levels. The factors influencing bone quantity and quality are mitigated by cultural and social circumstances that influence which members of a group receive adequate nutrition and access to other resources affecting quality of life. Universally, bone mass loss begins at about age 40, with losses accelerating in women relative to men (Garn 1970; Garn et al. 1992; Mays 2006; Riggs et al. 2008). Even after the end of the fourth decade of life, bone continues to perform as a dynamic tissue, with losses on the endosteal surface within bones, and simultaneous gain on the subperiosteal surface (i.e. the outer surfaces of bones). The continuous gain on the subperiosteal surface is likely a biomechanical adaptation to cortical bone loss. Simply, the strength of the cross-section is maintained via the increasing diameter of the bone (Garn 1972; Larsen 2015; Ruff 2008). Regardless, decreased bone mass renders the affected skeletal element prone to fracture in later decades of life. As with any other population, there is the expectation at Çatalhöyük that bone quality would be poorer in later adulthood, rendering the skeleton prone to increased fragility. In this setting, there is the expectation for relatively elevated levels of poor bone quality, especially in light of population crowding and a focus on plant carbohydrate consumption.

In order to test the hypothesis that bone quality was compromised in later life at Çatalhöyük, we document age- and sex-related patterns of bone loss in adult metacarpals, ribs, and vertebrae (see also Glencross and Agarwal 2011). Methods specific to documentation and interpretation of bone quality focus on radiographs of adult metacarpals, including 27 females and 22 males grouped into the three age cohorts described above: young adult, middle adult, and older adult. In order to assess bone mass and its loss, measurements of total bone width as a measure of gross size and medullary width reflecting bone loss on endosteal surfaces were collected following methods presented by Dequeker (1976), Mema and Mema (1987), and Mays (1996). These measurements were used to calculate cortical thickness, representing the overall amount of cortical bone carried by an individual, and the cortical index, a standard comparative index in the clinical and bioarchaeological literature for measuring bone loss (Dequeker 1976; Ives and Brickley 2004; Mays 1996, 2000, 2001).

This analysis reveals the expected and normal amount of decreasing cortical thickness and increasing medullary width in comparison of younger and older adults. Comparisons reveal no differences between the northern and southern areas of the East Mound for cortical width, cortical index, or medullary width. The expected patterns are also revealed through the analysis of rib cortical bone. This parameter is especially important because, compared to limb bones, ribs are relatively less mechanically loaded in life. Thus, unlike metacarpals, nutrition and other aspects of health rather than mechanical loading largely explain the cortical mass and morphology of ribs. For this setting, there were no discernible differences between age cohorts. However, following a universal pattern in humans, females at Çatalhöyük express earlier and greater bone loss than males, and these differences are especially pronounced in middle adulthood.

Analysis of trabecular bone—the porous spongy bone adjacent to cortical bone—reveals important patterning in microstructure and insight into skeletal and general health. For the purposes of this investigation, we document trabecular properties with high resolution micro-computed tomography applied to the bodies of adult fourth thoracic vertebrae. Specifically, the documentation of trabecular structure and density of the trabecular connections provide important insight into the quality of bone. This analysis revealed no sex differences. On the other hand, there is a clear record of loss of trabecular structure and connectivity with age, a pattern identical to what clinicians have routinely documented in modern populations.

Lastly, this study combines observations of bone loss as a central component to the suite of elements that puts the individual at risk for fragility fractures. In this study, there is little evidence for abnormal bone quality that would predispose individuals to increased fragility and risk of fracture. Only two individuals have low cortical bone mass for age, with one being a young adult male who also has multiple rib fractures showing various stages of healing. The remarkable degree of low bone mass in this individual likely resulted from a chronic systemic disorder affecting the skeleton generally but especially evident in the thoracic vertebrae. The other individual, an adolescent male, displays both low cortical bone mass (metacarpals) and long bone (fibula, tibia) fractures. The individual also has spondylolysis, a loading fracture involving the separation of the neural arch from the vertebral body. The fracture tends to be associated with older adults, and it is unusual for an individual this young to display this condition. The young age-association for the fracture is likely related to lowered bone mass in the skeleton generally, a condition predisposing the person to traumatic injury. The distinctive pattern of bone loss owing to endosteal resorption suggests the presence of a metabolic disorder, likely contributing not only to pathological fracturing but also to increased risk of early death.

In summary, the Çatalhöyük series represents a population showing normal age-related bone loss and trabecular connectivity, with losses affecting females more than males. These patterns match expectations for a normal population. Very few individuals have abnormally low bone mass, but those that we have documented display expected associated fracture incidence.

Summary and Conclusions

The bioarchaeological research on the human remains from Neolithic Çatalhöyük reveals the following key findings in relation to the implications that farming, sedentism, and population increase had for this community:

1. Population growth was rapid, peaking in the Middle period, and declining to the point of complete abandonment at c. 6000 BC;
2. The presence of an extraordinarily high number of neonates and young juveniles generally indicates that the population grew as a result of increased birth rates and not solely immigration;
3. Human carbon and nitrogen stable isotope analysis reveals the strong focus on cereal grains (especially wheat and barley) and reliance on and possibly increased consumption of animal sources of protein (especially sheep) with time;
4. Animal carbon and nitrogen stable isotope analysis reveals an increased diversity of diet in caprines, likely representing a geographic expansion of pastoral activities farther and farther from Çatalhöyük, possibly reflecting resource depletion;
5. Human carbon and nitrogen stable isotope ratios reveal a pattern of weaning that began in the second year of life and was completed by the end of the third year. If weaning was relatively early for an individual, their immune system may not have been fully developed, resulting in greater susceptibility to infection;
6. People interred within the same house have limited biological affinity, contradicting the expectation that those individuals were members of extended biological families;
7. Social structure was built around a patrilocal residence pattern whereby males tended to remain in their natal community and females traveled from other communities;
8. Individuals associated with the northern and southern areas of the site may have been from distinct social units;
9. There is a trend for change in workload and mobility over the course of the occupation of the site. Workload appears to peak in the Middle period, whereas mobility peaks in the Late period. These trends reflect alterations in lifestyle that correspond to changing resource availability;
10. Body size (stature and mass) and bone quality show a population having access to adequate nutrition and providing a picture of normal growth and development;
11. Dental caries is elevated, reflecting a carbohydrate-rich diet;

12. Infections and infectious disease were relatively elevated for young juveniles but not older juveniles or adults, likely reflecting the immature immune systems of the former but not the latter;
13. The reduction in population in the Late period and increased dispersion of population across the community resulted in reduction in prevalence of infection-related bone lesions;
14. Analysis of social context for diet and health revealed generally no association between residence location and outcome, excepting a distinctive pattern of a greater association of infection with history houses than with non-history houses;
15. The overall record does not suggest a pattern of gender or status variation in diet and health.

The results documented in this article build on earlier studies of the human remains assemblage at Çatalhöyük, both from the 1960s excavations and from earlier phases of the current project, and will also help to shape the bioarchaeological research program as excavation continues at this important site. A complex picture emerges from these studies, revealing a population not immune to the stresses commonly associated with the foraging-to-farming transition (e.g. population increase and aggregation, dental caries, infectious disease), but also one that successfully mitigated and adapted to such conditions, as shown in the record of relatively normal growth and development. As further bioarchaeological research is undertaken at Çatalhöyük and at other localities across Anatolia (e.g. Baird 2007; Duru and Özbaşaran 2005; Esin and Harmankaya 2007; Lösch et al. 2006; Özbek 1995, 1997, 1998, 2009; Pearson et al. 2013) and the broader Near East, our knowledge of the human experience during the Neolithic, and the ways in which environmental, economic, technological, and social changes have shaped the human condition during this pivotal period of the human past, will continue to expand, revealing the remarkable adjustments humans make to their ever-changing landscapes.

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References

Andrews, P., Molleson, T. I., & Boz, B. (2005). The human burials at Çatalhöyük. In I. Hodder (Ed.), *Inhabiting Çatalhöyük: Reports from the 1995–1999 seasons*. Çatalhöyük Research Project, Volume 4; British Institute for Archaeology at Ankara Monograph 38 (pp. 261–278). Cambridge: McDonald Institute for Archaeological Research.

Angel, J. L. (1971). Early Neolithic skeletons from Çatal Hüyük: Demography and pathology. *Anatolian Studies, 21*, 77–98.

Angel, J. L. (1984). Health as a crucial factor in the changes from hunting to developed farming in the Eastern Mediterranean. In M. N. Cohen & G. J. Armelagos (Eds.), *Paleopathology at the origins of agriculture* (pp. 51–73). Orlando: Academic Press.

Asouti, E. (2005). Woodland vegetation and the exploitation of fuel and timber at Neolithic Çatalhöyük: Report on the wood-charcoal macro-remains. In I. Hodder (Ed.), *Inhabiting Çatalhöyük: Reports from the 1995–1999 seasons*. Çatalhöyük Research Project Volume 4; British Institute for Archaeology at Ankara Monograph 38 (pp. 213–258). Cambridge: McDonald Institute for Archaeological Research.

Asouti, E. (2013). Woodland vegetation, firewood management and woodcrafts at Neolithic Çatalhöyük. In I. Hodder (Ed.), *Humans and landscapes of Çatalhöyük: Reports from the 2000–2008 seasons*. Çatalhöyük Research Project Volume 8; British Institute for Archaeology at Ankara Monograph 47; Monumenta Archaeologica, 30 (pp. 129–163). Los Angeles: Cotsen Institute of Archaeology Press.

Auerbach, B. M., & Ruff, C. B. (2004). Human body mass estimation: A comparison of 'morphometric' and 'mechanical' methods. *American Journal of Physical Anthropology, 125*, 331–342.

Baird, D. (2002). Early Holocene settlement in Central Anatolia: Problems and prospects as seen from the Konya Plain. In F. Gérard & L. Thissen (Eds.), *The Neolithic of Central Anatolia: Proceedings of the international CANeW round table, Istanbul*, 23–24 November 2001 (pp. 139–159). Istanbul: Ege Yayınları.

Baird, D. (2005). The history of settlement and social landscapes in the early Holocene in the Çatalhöyük area. In I. Hodder (Ed.), *Çatalhöyük perspectives: Reports from the 1995–1999 seasons*. Çatalhöyük Research Project Volume 6; British Institute for Archaeology at Ankara Monograph 40 (pp. 55–74). Cambridge: McDonald Institute for Archaeological Research.

Baird, D. (2007). The Boncuklu Project: The origins of sedentism, cultivation and herding in Central Anatolia. *Anatolian Archaeology, 13*, 14–18.

Baird, D. (2010). The Boncuklu Project: Investigating the beginnings of agriculture, sedentism and herding in central Anatolia. *Anatolian Archaeology, 16*, 9–11.

Bar-Gal, G. K., & Greenblatt, C. L. (2007). The emergence of zoonotic pathogens in the southern Levant. In M. Faerman, L. K. Horwitz, T. Kahana, & U. Zilberman (Eds.), *Faces from the past: Diachronic patterns of the biology of human populations from the Eastern Mediterranean* (pp. 228–232). Oxford: Archaeopress.

Bar-Yosef, O. (2001). From sedentary foragers to village hierarchies: The emergence of social institutions. *Proceedings of the British Academy, 110*, 1–38.

Bar-Yosef Mayer, D. E., Long, M. J., Aldridge, D. C., Arrowsmith, C., Gümüş, B. A., & Sloane, H. J. (2013). *Unio* shells from Çatalhöyük: Preliminary palaeoclimatic data from isotopic analysis. In I. Hodder (Ed.), *Humans and landscapes of Çatalhöyük: Reports from the 2000–2008 seasons*. Çatalhöyük Research Project Volume 8; British Institute for Archaeology at Ankara Monograph 47; Monumenta Archaeologica, 30 (pp. 87–92). Los Angeles: Cotsen Institute of Archaeology Press.

Bayliss, A., Brock, F., Farid, S., Hodder, I., Southon, J., & Taylor, R. E. (2015). Getting to the bottom of it all: A Baysesian approach to dating the start of Çatalhöyük. *Journal of World Prehistory*. doi:10.1007/s10963-015-9083-7.

Bocquet-Appel, J. P. (2002). The paleoanthropological traces of the Neolithic demographic transition. *Current Anthropology, 43*, 638–650.

Bocquet-Appel, J. P. (2011). When the world's population took off: The springboard of the Neolithic demographic transition. *Science, 333*, 560–561.

Bocquet-Appel, J. P., & Naji, S. (2006). Testing the hypothesis of a worldwide Neolithic demographic transition: Corroboration from American cemeteries. *Current Anthropology, 47*, 341–365.

Bogaard, A., Charles, M., Livarda, A., Ergun, M., Filipovic, D., & Jones, G. (2013). The archaeobotany of Mid-later occupation levels at Neolithic Çatalhöyük. In I. Hodder (Ed.), *Humans and landscapes of Çatalhöyük: Reports from the 2000–2008 seasons*. Çatalhöyük Research Project Volume 8; British Institute for Archaeology at Ankara Monograph 47; Monumenta Archaeologica, 30 (pp. 93–128). Los Angeles: Cotsen Institute of Archaeology Press.

Bogaard, A., Henton, E., Evans, J. A., Twiss, K. C., Charles, M. P., Vaiglova, P., & Russell, N. (2014). Locating land use at Neolithic Çatalhöyük, Turkey: The implications of ^{87}Sr/^{86}Sr signatures in plants and sheep tooth sequences. *Archaeometry, 56*, 860–877.

Bogin, B. (1999). *Patterns of human growth*. Cambridge: Cambridge University Press.

Bonogofsky, M. (2011). Contextualizing the human head: An introduction. In M. Bonogofsky (Ed.), *The bioarchaeology of the human head: Decapitation, decoration, and deformation* (pp. 1–50). Gainesville: University Press of Florida.

Bourdieu, P. (1977). *Outline of a theory of practice*. Cambridge: Cambridge University Press.

Boz, B. (2005). The oral health of Çatalhöyük Neolithic people. In I. Hodder (Ed.), *Inhabiting Çatalhöyük: Reports from the 1995–1999 seasons*. Çatalhöyük Research Project Volume 4; British Institute for Archaeology at Ankara Monograph 38 (pp. 587–591). Cambridge: McDonald Institute for Archaeological Research.

Boz, B., & Hager, L. (2013). Living above the dead: Intramural burial practices at Çatalhöyük. In I. Hodder (Ed.), *Humans and landscapes of Çatalhöyük: Reports from the 2000–2008 seasons*. Çatalhöyük Research Project Volume 8; British Institute for Archaeology at Ankara Monograph 47; Monumenta Archaeologica, 30 (pp. 413–440). Los Angeles: Cotsen Institute of Archaeology Press.

Braidwood, R. J., Cambel, H., & Schirmer, W. (1981). Beginnings of village-farming communities in southeastern Turkey: Çayönü Tepesi, 1978 and 1979. *Journal of Field Archaeology, 8*, 249–258.

Buikstra, J. E., Konigsberg, L. W., & Bullington, J. (1986). Fertility and the development of agriculture in the prehistoric Midwest. *American Antiquity, 51*, 528–546.

Bull, I. D., Elhmmali, M. M., Perret, V., Matthews, W., Roberts, D. J., & Evershed, R. P. (2005). Biomarker evidence of faecal deposition in archaeological sediments at Çatalhöyük. In I. Hodder (Ed.), *Inhabiting Çatalhöyük: Reports from the 1995–1999 seasons*. Çatalhöyük Research Project Volume 6; British Institute for Archaeology at Ankara Monograph 40 (pp. 415–420). Cambridge: McDonald Institute for Archaeological Research.

Cessford, C. (2005a). Absolute dating at Çatalhöyük. In I. Hodder (Ed.), *Changing materialities at Çatalhöyük: Reports from the 1995–1999 seasons*. Çatalhöyük Research Project Volume 5; British Institute for Archaeology at Ankara, Monograph 39 (pp. 65–99). Cambridge: McDonald Institute for Archaeological Research.

Cessford, C. (2005b). Estimating the Neolithic population of Çatalhöyük. In I. Hodder (Ed.), *Inhabiting Çatalhöyük: Reports from the 1995–1999 seasons*. Çatalhöyük Research Project Volume 4; British Institute for Archaeology at Ankara Monograph 38 (pp. 323–326). Cambridge: McDonald Institute for Archaeological Research.

Charles, M., Doherty, C., Asouti, E., Bogaard, A., Henton, E., Larsen, C. S., Ruff, C. B., et al. (2014). Landscape and taskscape at Çatalhöyük: An integrated perspective. In I. Hodder (Ed.), *Integrating Çatalhöyük: Themes from the 2000–2008 seasons*. Çatal Research Project Volume 10; British Institute at Ankara Monograph 49; Monumenta Archaeologica 32 (pp. 71–90). Los Angeles: Cotsen Institute of Archaeology.

Cohen, M. N., & Armelagos, G. J. (Eds.). (1984). *Paleopathology at the origins of agriculture*. Orlando: Academic Press. (Paperback edition, 2013).

Cohen, M. N., & Crane-Kramer, G. M. M. (Eds.). (2007). *Ancient health: Skeletal indicators of agricultural and economic intensification*. Gainesville: University Press of Florida.

Corruccini, R. S., & Shimada, I. (2002). Dental relatedness corresponding to mortuary patterning at Huaca Loro, Peru. *American Journal of Physical Anthropology, 117*, 118–121.

Dequeker, J. (1976). Quantitative radiology: Radiogrammetry of cortical bone. *British Journal of Radiology, 49*, 912–920.

Doherty, C. (2013). Sourcing Çatalhöyük's clays. In I. Hodder (Ed.), *Substantive technologies at Çatalhöyük: Reports from the 2000–2008 seasons.* Çatalhöyük Research Project Volume 9; British Institute for Archaeology at Ankara Monograph 48; Monumenta Archaeologica, 31 (pp. 51–66). Los Angeles: Cotsen Institute for Archaeology.

Doherty, C., & Tarkan, D. (2013). Pottery production at Çatalhöyük: A petrographic perspective. In I. Hodder (Ed.), *Substantive technologies at Çatalhöyük: Reports from the 2000–2008 seasons.* Çatalhöyük Research Project Volume 9; British Institute for Archaeology at Ankara Monograph 48; Monumenta Archaeologica, 31 (pp. 183–192). Los Angeles: Cotsen Institute for Archaeology.

Düring, B. S. (2001). Social dimensions in the architecture of Neolithic Çatalhöyük. *Anatolian Studies, 51*, 1–18.

Düring, B. S. (2005). Building continuity in the Central Anatolian Neolithic: Exploring the meaning of buildings at Aşıklı Höyük and Çatalhöyük. *Journal of Mediterranean Archaeology, 18*, 3–29.

Düring, B. S. (2013). Breaking the bond: Investigating the Neolithic expansion in Asia Minor in the seventh millennium BC. *Journal of World Prehistory, 26*, 75–100.

Duru, G., & Özbaşaran, M. (2005). A non–domestic site in Central Anatolia. *Anatolia Antiqua, 8*, 15–28.

Eshed, V., Gopher, A., Pinhasi, R., & Hershkovitz, I. (2010). Paleopathology and the origins of agriculture in the Levant. *American Journal of Physical Anthropology, 143*, 121–133.

Esin, U., & Harmankaya, S. (2007). Aşıklı Höyük. In M. Özdoğan & N. Başgelen (Eds.), *Neolithic in Turkey: The cradle of civilization, new discoveries* (pp. 255–272). Istanbul: Arkeoloji ve Sanat Yayınları.

Fairbairn, A. S., Asouti, E., Near, J., & Martinoli, D. (2002). Macro-botanical evidence for plant use at Neolithic Çatalhöyük, south-central Anatolia, Turkey. *Vegetation History and Archaeobotany, 11*, 41–54.

Fairbairn, A. J., Near, J., & Martinoli, D. (2005). Macrobotanical investigation of the north, south and KOPAL area excavations at Çatalhöyük East. In I. Hodder (Ed.), *Inhabiting Çatalhöyük: Reports from the 1995–1999 seasons*. Çatalhöyük Research Project Volume 4; British Institute for Archaeology at Ankara Monograph 38 (pp. 137–202). Cambridge: McDonald Institute for Archaeological Research.

Farid, S. (2013). Timelines: phasing Neolithic Çatalhöyük. In I. Hodder (Ed.), *Çatalhöyük excavations: The 2000–2008 seasons.* Çatalhöyük Research Project Volume 7; British Institute for Archaeology at Ankara, Monograph 46; Monumenta Archaeologica, 29 (pp. 91–130). Los Angeles: Cotsen Institute for Archaeology Press.

Felson, D. T. (1990). The epidemiology of knee osteoarthritis: Results from the Framingham osteoarthritis study. *Seminars in Arthritis and Rheumatism, 20*(Suppl. 1), 42–50.

Felson, D. T. (2000). Osteoarthritis: New insights. *Annals of Internal Medicine, 133*, 635–646.

Felson, D. T. (2003). Epidemiology of osteoarthritis. In K. D. Brandt, M. Doherty, & L. S. Lohmander (Eds.), *Osteoarthritis* (pp. 9–16). New York: Oxford University Press.

Ferembach, D. (1972). Les hommes du gisement néolithique de Çatal Hüyük. In *Türk Tarih Kongresi*. Ankara VII, 1970 (pp. 15–21). Ankara: Türk Tarih Kurumu Basimevi.

Ferembach, D. (1982). *Mesures et indices des squelettes humains néolithiques de Çatal Hüyük (Turquie)*. Paris: CNRS.

Flannery, K. (1972). The cultural evolution of civilizations. *Annual Review of Ecology and Systematics, 3*, 399–426.

Flannery, K. (2002). The origins of the village revisited: From nuclear to extended households. *American Antiquity, 67*, 417–433.

Fogel, M. L., Tuross, N., & Owsley, D. W. (2002). Nitrogen isotope tracers of human lactation in modern and archaeological populations. Annual report of the Director, Geophysical Laboratory Vol. 89, (pp. 111–117). Washington, DC: Carnegie Institute of Washington.

Frisancho, A. R., Guire, K., Babler, W., Borken, G., & Way, A. (1980). Nutritional influence on childhood development and genetic control of adolescent growth of Quechuas and Mestizos from Peruvian lowlands. *American Journal of Physical Anthropology, 52*, 367–375.

Fuller, D. Q., Allaby, R. G., & Stevens, C. (2010). Domestication as innovation: The entanglement of techniques, technology and chance in the domestication of cereal crops. *World Archaeology, 42*, 13–28.

Garn, S. M. (1970). *The earlier gain and later loss of cortical bone in nutritional perspective*. Springfield: Charles C. Thomas.

Garn, S. M. (1972). The course of bone gain and phases of bone loss. *Orthopedic Clinics of North America, 3*, 503–519.

Garn, S. M., Sullivan, T. V., Decker, S. A., Larkin, F. A., & Hawthorne, V. M. (1992). Continuing bone expansion and increasing bone loss over a two-decade period in men and women from a total community sample. *American Journal of Human Biology, 4*, 57–67.

Gérard, F., & Thissen, L. (2002). *The Neolithic of Central Anatolia: Internal developments and external relations during the 9th–6th millennia cal BC*. İstanbul: Ege Yayınları.

Glencross, B., & Agarwal, S. C. (2011). An investigation of cortical bone loss and fracture patterns in the Neolithic community of Çatalhöyük, Turkey using metacarpal radiogrammetry. *Journal of Archaeological Science, 38*, 513–521.

Goodman, A. H., & Armelagos, G. J. (1989). Infant and childhood morbidity and mortality risks in archaeological populations. *World Archaeology, 21*, 225–243.

Habicht, J. P., Martorell, R., Yarbrough, C., Malina, R. M., & Klein, R. E. (1974). Height and weight standards for preschool children. How relevant are ethnic differences in growth potential*? Lancet, 1*, 611–614.

Hardy, K., & van de Locht, R. (2013). Starch granules and complex carbohydrates at Çatalhöyük. In I. Hodder (Ed.), *Humans and landscapes of Çatalhöyük: Reports from the 2000–2008 seasons*. Çatalhöyük Research Project Volume 8; British Institute for Archaeology at Ankara Monograph 47; Monumenta Archaeologica, 30 (pp. 191–212). Los Angeles: Cotsen Institute of Archaeology Press.

Hemphill, B. E. (1999). Wear and tear: Osteoarthritis as an indicator of mobility among Great Basin hunter-gatherers. In B. E. Hemphill & C. S. Larsen (Eds.), *Prehistoric lifeways in the Great Basin wetlands: Bioarchaeological reconstruction and interpretation* (pp. 241–289). Salt Lake City: University of Utah Press.

Hemphill, B. E., Lukacs, J. R., & Kennedy, K. A. R. (1991). Biological adaptations and affinities of Bronze Age Harappans. In R. Meadow (Ed.), *Harappa excavations 1986–1990: A multidisciplinary approach to third millennium urbanism* (pp. 137–182). Madison: Prehistory Press.

Henton, E., Meier-Augustine, W., & Kemp, H. F. (2010). The use of oxygen isotopes in sheep molars to investigate past herding practices at the Neolithic settlement of Çatalhöyük, central Anatolia. *Archaeometry, 52*, 429–449.

Hill, K. R., Walker, R. S., Božičevic, M., Eder, J., Headland, T., Hewlett, B., et al. (2011). Co-residence patterns in hunter-gatherer societies show unique human social structure. *Science, 331*, 1286–1289.

Hillson, S. W. (2001). Recording dental caries in archaeological human remains. *International Journal of Osteoarchaeology, 11*, 249–289.

Hillson, S. W. (2008). The current state of decay. In J. D. Irish & G. C. Nelson (Eds.), *Technique and application in dental anthropology* (pp. 113–135). Cambridge: Cambridge University Press.

Hillson, S. W., Larsen, C. S., Boz, B., Pilloud, M. A., Sadvari, J. W., Agarwal, S. C., et al. (2013). The human remains I: Interpreting community structure, health, and diet in Neolithic Çatalhöyük. In I. Hodder (Ed.), *Humans and landscapes of Çatalhöyük: Reports from the 2000–2008 seasons*. Çatalhöyük Research Project Volume 8; British Institute for Archaeology at Ankara Monograph 47; Monumenta Archaeologica, 30 (pp. 339–396). Los Angeles: Cotsen Institute of Archaeology Press.

Hodder, I. (1996). *On the surface: Çatalhöyük 1993–1995*. Çatalhöyük Research Project Volume 1; British Institute for Archaeology at Ankara Monograph 22. Cambridge: McDonald Institute for Archaeological Research.

Hodder, I. (2005a). Changing entanglements and temporalities. In I. Hodder (Ed.), *Changing materialities at Çatalhöyük: Reports from the 1995–1999 seasons*. Çatalhöyük Research Project Volume 5; British Institute for Archaeology at Ankara, Monograph 39 (pp. 1–22). Cambridge: McDonald Institute for Archaeological Research.

Hodder, I. (Ed.). (2005b). *Inhabiting Çatalhöyük: Reports from the 1995–1999 seasons*. Çatalhöyük Research Project Volume 4; British Institute for Archaeology at Ankara Monograph 38. Cambridge: McDonald Institute for Archaeological Research.

Hodder, I. (2005c). Memory. In I. Hodder (Ed.), *Çatalhöyük perspectives: Reports from the 1995–1999 seasons*. Çatalhöyük Research Project Volume 6; British Institute for Archaeology at Ankara Monograph 40 (pp. 183–196). Cambridge: McDonald Institute for Archaeological Research.

Hodder, I. (2006). *The leopard's tale: Revealing the mysteries of Çatalhöyük*. New York: Thames & Hudson.

Hodder, I. (Ed.). (2007). *Excavating Çatalhöyük: South, North, and KOPAL area reports from the 1995–1999 seasons*. Çatalhöyük Research Project Volume 3; British Institute for Archaeology at Ankara Monograph 37. Cambridge: McDonald Institute for Archaeological Research.

Hodder, I. (Ed.). (2010). *Religion in the emergence of civilization: Çatalhöyük as a case study*. Cambridge: Cambridge University Press.

Hodder, I. (Ed.). (2014a). *Integrating Çatalhöyük: Themes from the 2000–2008 seasons*. Çatalhöyük Research Project Volume 10; British Institute for Archaeology at Ankara Monograph 49; Monumenta Archaeologica 32. Los Angeles: Cotsen Institute of Archaeology Press.

Hodder, I. (2014b). Mosaics and networks: The social geography at Çatalhöyük. In I. Hodder (Ed.), *Integrating Çatalhöyük: Themes from the 2000–2008 seasons*. Çatalhöyük Research Project Volume 10; British Institute for Archaeology at Ankara Monograph 49; Monumenta Archaeologica 32 (pp. 149–167). Los Angeles: Cotsen Institute of Archaeology Press.

Hodder, I., & Meskell, L. (2010). The symbolism of Çatalhöyük in its regional context. In I. Hodder (Ed.), *Religion in the emergence of civilization: Çatalhöyük as a case study* (pp. 32–72). Cambridge: Cambridge University Press.

Hodder, I., & Pels, P. (2010). History houses: A new interpretation of architectural elaboration at Çatalhöyük. In I. Hodder (Ed.), *Religion in the emergence of civilization: Çatalhöyük as a case study* (pp. 163–186). Cambridge: Cambridge University Press.

Holt, B. M. (2003). Mobility in Upper Paleolithic and Mesolithic Europe: Evidence from the lower limb. *American Journal of Physical Anthropology, 122*, 200–215.

Horwitz, L. K., & Smith, P. (2000). The contribution of animal domestication to the spread of zoonoses: A case study from the southern Levant. *Ibex Journal of Mountain Ecology, 5*, 77–84.

Howell, T. L., & Kintigh, K. W. (1996). Archaeological identification of kin groups using mortuary and biological data: An example from the American Southwest. *American Antiquity, 61*, 537–554.

Irish, J. D. (2005). Population continuity vs. discontinuity revisited: Dental affinities among Late Paleolithic through Christian-era Nubians. *American Journal of Physical Anthropology, 128*, 520–535.

Ives, R., & Brickley, M. (2004). A procedural guide to metacarpal radiogrammetry in archaeology. *International Journal of Osteoarchaeology, 14*, 7–17.

Jantz, R. L., & Owsley, D. W. (1984). Long bone growth variation among Arikara skeletal populations. *American Journal of Physical Anthropology, 63*, 13–20.

Jenkins, E. (2005). The Çatalhöyük microfauna: Preliminary results and interpretations. In I. Hodder (Ed.), *Inhabiting Çatalhöyük: Reports from the 1995–1999 seasons*. Çatalhöyük Research Project Volume 4; British Institute for Archaeology at Ankara Monograph 38 (pp. 111–116). Cambridge: McDonald Institute for Archaeological Research.

Jurmain, R. D. (1977). Stress and the etiology of osteoarthritis. *American Journal of Physical Anthropology, 46*, 353–365.

Katzenberg, M. A. (2008). Stable isotope analysis: A tool for studying past diet, demography, and life history. In M. A. Katzenberg & S. R. Saunders (Eds.), *Biological anthropology of the human skeleton* (2nd ed., pp. 413–441). Hoboken: Wiley.

Kelly, R. L. (1995). *The foraging spectrum: Diversity in hunter-gatherer lifeways*. Washington, DC: Smithsonian Institution Press.

Larsen, C. S. (1995). Biological changes in human populations with agriculture. *Annual Review of Anthropology, 24*, 185–213.

Larsen, C. S. (2006). The agricultural revolution as environmental catastrophe: Implications for health and lifestyle in the Holocene. *Quaternary International, 150*, 12–20.

Larsen, C. S. (2015). *Bioarchaeology: Interpreting behavior from the human skeleton* (2nd ed.). Cambridge: Cambridge University Press.

Larsen, C. S., Hillson, S. W., Ruff, C. B., Sadvari, J. W. & Garofalo, E. M. (2013). The human remains II: Interpreting lifestyle and activity in Neolithic Çatalhöyük. In I. Hodder (Ed.), *Humans and landscapes of Çatalhöyük: Reports from the 2000–2008 seasons*. Çatalhöyük Research Project Volume 8; British Institute for Archaeology at Ankara Monograph 47; Monumenta Archaeologica 30 (pp. 397–412). Los Angeles: Cotsen Institute of Archaeology.

Larson, G., Piperno, D. R., Allaby, R. G., Purugganan, M. D., Andersson, L., Arroyo-Kalin, M., et al. (2014). Current perspectives and the future of domestication studies. *Proceedings of the National Academy of Sciences, 111*, 6139–6146.

Liversidge, H. M. (1994). Accuracy of age estimation from developing teeth of a population of known age (0–5.4 years). *International Journal of Osteoarchaeology, 4*, 37–45.

Liversidge, H. M. (2008). Timing of human mandibular third molar formation. *Annals of Human Biology, 35*, 294–321.

Liversidge, H. M., & Molleson, T. I. (2004). Variation in crown and root formation and eruption of human deciduous teeth. *American Journal of Physical Anthropology, 123*, 172–180.

Lösch, S., Grupe, G., & Peters, J. (2006). Stable isotopes and dietary adaptations in humans and animals at Pre-Pottery Neolithic Nevalı Çori, southeast Anatolia. *American Journal of Physical Anthropology, 11*, 181–193.

Lukacs, J. R. (2008). Fertility and agriculture accentuate sex differences in dental caries rates. *Current Anthropology, 49*, 901–914.

Marciniak, A., Barański, M. Z., Bayliss, A., Czerniak, L., Goslar, T., Southon, J. R., & Taylor, R. E. (2015). Fragmenting times: Interpreting a Bayesian chronology for the late Neolithic occupation of Çatalhöyük East, Turkey. *Antiquity, 89*, 154–176.

Matthews, W. (2005). Micromorphological and microstratigraphic traces of uses and concepts of space. In I. Hodder (Ed.), *Inhabiting Çatalhöyük: Reports from the 1995–1999 seasons*. Çatalhöyük Research

Project Volume 4; British Institute for Archaeology at Ankara Monograph 38 (pp. 355–398). Cambridge: McDonald Institute for Archaeological Research.

Mays, S. (1996). Age-dependent cortical bone loss in a Medieval population. *International Journal of Osteoarchaeology, 6*, 144–154.

Mays, S. (2000). Age-dependent cortical bone loss in women from 18th and early 19th century London. *American Journal of Physical Anthropology, 112*, 349–361.

Mays, S. (2001). Effects of age and occupation on cortical bone in a group of 18th–19th century British men. *American Journal of Physical Anthropology, 116*, 34–44.

Mays, S. (2006). Age-related cortical bone loss in women from a 3rd–4th century AD population from England. *American Journal of Physical Anthropology, 129*, 518–528.

McCaa, R. (2002). Paleodemography of the Americas: From ancient times to colonialism and beyond. In R. H. Steckel & J. C. Rose (Eds.), *The backbone of history Long-term trends in health and nutrition in the Americas* (pp. 94–124). New York: Cambridge University Press.

McCammon, R. W. (1970). *Human growth and development*. Springfield: Charles C. Thomas.

Mellaart, J. (1967). *Çatal Hüyük: A Neolithic town in Anatolia*. London: Thames & Hudson.

Mema, H. E., & Mema, S. (1987). Postmenopausal osteoporosis: Single screening method for diagnosis before structural failure. *Radiology, 164*, 405–410.

Miller, J. F., Millar, J. S., & Longstaffe, F. J. (2008). Carbon- and nitrogen-isotope-tissue-diet discrimination and turnover rates in deer mice, *Peromyscus maniculatus*. *Canadian Journal of Zoology, 86*, 685–691.

Milner, G. R., Humpf, D. A., & Harpending, H. C. (1989). Pattern matching of age at death distributions in paleodemographic analysis. *American Journal of Physical Anthropology, 80*, 49–58.

Molleson, T. I. (1994). The eloquent bones of Abu Hureyra. *Scientific American, 271*(2), 70–75.

Molleson, T. I. (2007). Times of stress at Çatalhöyük. In M. Faerman, L. K. Horwitz, T. Kahana, & U. Zilberman (Eds.), *Faces from the past: Diachronic patterns in the biology of human populations from the eastern Mediterranean* (pp. 140–150). Oxford: Archaeopress.

Molleson, T. I., & Andrews, P. (1996). Trace element analyses of bones and teeth from Çatalhöyük. In I. Hodder (Ed.), *On the Surface: Çatalhöyük 1993–1995*. Çatalhöyük Research Project Volume 1; British Institute for Archaeology at Ankara Monograph 22 (pp. 265–270). Cambridge: McDonald Institute for Archaeological Research.

Molleson, T. I., Andrews, P., & Boz, B. (2005). Reconstruction of the Neolithic people of Çatalhöyük. In I. Hodder (Ed.), *Inhabiting Çatalhöyük: Reports from the 1995–1999 seasons*. Çatalhöyük Research Project Volume 4; British Institute for Archaeology at Ankara Monograph 38 (pp. 279–300). Cambridge: McDonald Institute for Archaeological Research.

Molleson, T. I., Boz, B., Nudd, K., & Alpagut, B. (1996). Dietary indications in the dentitions from Çatal Hüyük. *Arkeometri Sonuçları Toplantısı, 11*, 141–150.

Molleson, T. I., Ottevanger, J., & Compton, T. (2004). Variation in Neolithic teeth from Çatalhöyük (1961–1964). *Anatolian Studies, 54*, 1–26.

Nakamura, C., & Meskell, L. (2013). The Çatalhöyük burial assemblage. In I. Hodder (Ed.), *Humans and landscapes of Çatalhöyük: Reports from the 2000–2008 seasons*. Çatalhöyük Research Project Volume 8; British Institute for Archaeology at Ankara Monograph 47; Monumenta Archaeologica, 30 (pp. 441–466). Los Angeles: Cotsen Institute of Archaeology Press.

O'Neill, M. C., & Ruff, C. B. (2004). Estimating long bone cross-sectional geometric properties: A comparison of non-invasive methods. *Journal of Human Evolution, 47*, 221–235.

Ortner, D. J. (2003). *Identification of pathological conditions in human skeletal remains* (2nd ed.). New York: Academic Press.

Oxenham, M., & Tayles, N. (2006). *Bioarchaeology of Southeast Asia*. Cambridge: Cambridge University Press.

Özbek, M. (1995). Dental pathology of the Prepottery Neolithic residents of Çayönü, Turkey. *Rivista di Antropologia, 73*, 99–122.

Özbek, M. (1997). Musular Neolitik Insani. *Arkeometri Sonuçları Toplantısı, 13*, 161–173.

Özbek, M. (1998). Human skeletal remains from Aşıklı, a Neolithic village near Aksaray, Turkey. In G. Arsebük, M. J. Mellink, & W. Schirmer (Eds.), *Light on top of the black hill: Studies presented to Halet Cambel* (pp. 567–579). Istanbul: Ege Yayınları.

Özbek, M. (2009). Remodeled human skulls in Köşk Höyük (Neolithic age, Anatolia): A new appraisal in view of recent discoveries. *Journal of Archaeological Science, 36*, 379–386.

Özdoğan, A. (1999). Çayönü. In M. Özdogan & N. Basgelen (Eds.), *Neolithic in Turkey: The cradle of civilization, new discoveries* (pp. 57–97). Istanbul: Arkeoloji ve Sanat Yayınları.

Özdoğan, M., & Özdoğan, A. (1998). Buildings of cult and the cult of buildings. In G. Arsebük, M. Mellink, & W. Schirmer (Eds.), *Light on top of the black hill: Studies presented to Halet Cambel* (pp. 581–593). Istanbul: Ege Yayınları.

Pearson, J. A. (2013). Human and animal diets as evidenced by stable carbon and nitrogen isotope analysis. In I. Hodder (Ed.), *Humans and landscapes of Çatalhöyük: Reports from the 2000–2008 seasons.* Çatalhöyük Research Project Volume 8; British Institute for Archaeology at Ankara Monograph 47; Monumenta Archaeologica, 30 (pp. 271–298). Los Angeles: Cotsen Institute of Archaeology Press.

Pearson, J. A., Buitenhuis, H., Hedges, R. E. M., Martin, L., Russell, N., & Twiss, K. C. (2007). New light on early caprine herding strategies from isotope analysis: A case study from Neolithic Anatolia. *Journal of Archaeological Science, 34*, 2170–2179.

Pearson, J., Grove, M., Özbek, M., & Hongo, H. (2013). Food and social complexity at Çayönü Tepesi, southeastern Anatolia: Stable isotope evidence of differentiation in diet according to burial practice and sex in the early Neolithic. *Journal of Anthropological Archaeology, 32*, 180–189.

Pearson, J., & Meskell, L. (2014). Biographical bodies: Flesh and food at Çatalhöyük. In A. Whittle & P. Bickle (Eds.), *Early farmers: The view from archaeology and science Proceedings of the British Academy* Vol. 198, (pp. 215–232). Oxford: Oxford University Press.

Pechenkina, K., & Oxenham, M. (Eds.). (2013). *Bioarchaeological perspectives on migration and health in ancient East Asia*. Gainesville: University Press of Florida.

Peterson, J. (2002). *Sexual revolutions: Gender and labor at the dawn of agriculture*. Walnut Creek: Altamira Press.

Pilloud, M. A. (2009). *Community structure at Neolithic Çatalhöyük: Biological distance analysis of household, neighborhood, and settlement.* (Ph.D. dissertation). Columbus: Ohio State University.

Pilloud, M. A., & Larsen, C. S. (2011). 'Official' and 'practical' kin: Inferring social and community structure from dental phenotype at Neolithic Çatalhöyük, Turkey. *American Journal of Physical Anthropology, 145*, 519–530.

Pinhasi, R., & Stock, J. T. (Eds.). (2011). *Human bioarchaeology of the transition to agriculture*. Chichester: Wiley.

Radin, E. L. (1976). Mechanical aspects of osteoarthrosis. *Bulletin on the Rheumatic Diseases, 26*, 862–865.

Radin, E. L., Burr, D. B., Caterson, B., Fyhrie, D., Brown, T. D., & Boyd, R. D. (1991). Mechanical determinants of osteoarthrosis. *Seminars in Arthritis and Rheumatism, 21*(3 Suppl. 2), 12–21.

Raxter, M. H., Ruff, C. B., Azab, A., Erfan, M., Soliman, M., & El-Sawaf, A. (2008). Stature estimation in ancient Egyptians: A new technique based on anatomical reconstruction of stature. *American Journal of Physical Anthropology, 136*, 147–155.

Ricaut, F. X., Auriol, V., von Cramon-Taubadel, N., Sakai, T., Nakaya, H., Yano, W., & Kunimatsu, Y. (2010). Comparison between morphological and genetic data to estimate biological relationship: The case of the Egyin Gol necropolis (Mongolia). *American Journal of Physical Anthropology, 143*, 355–364.

Richards, M. P., & Pearson, J. A. (2005). Stable-isotope evidence of diet at Çatalhöyük. In I. Hodder (Ed.), *Inhabiting Çatalhöyük: Reports from the 1995–1999 seasons*. Çatalhöyük Research Project Volume 4; British Institute for Archaeology at Ankara Monograph 38 (pp. 313–322). Cambridge: McDonald Institute for Archaeological Research.

Richards, M. P., Pearson, J. A., Russell, N., Molleson, T. I., & Martin, L. (2003). Stable isotope evidence of diet at Neolithic Çatalhöyük, Turkey. *Journal of Archaeological Science, 30*, 67–76.

Riehl, S., Zeidi, M., & Conard, N. J. (2013). Emergence of agriculture in the foothills of the Zagros Mountains of Iran. *Science, 341*, 65–67.

Riggs, B. L., Melton, L. J., Robb, R. A., Camp, J. J., Atkinson, E. J., McDaniel, L., et al. (2008). A population-based assessment of rates of bone loss at multiple skeletal sites: Evidence for substantial trabecular bone loss in young adult women and men. *Journal of Bone and Mineral Research, 23*, 205–214.

Roberts, C., & Manchester, K. (2005). *The archaeology of disease* (3rd ed.). Ithaca: Cornell University Press.

Roberts, N., Black, S., Boyer, P., Eastwood, W. J., Griffiths, H., Leng, M., et al. (1999). Chronology and stratigraphy of late Quaternary sediments in the Konya Basin, Turkey: Results from the KOPAL project. *Quaternary Science Reviews, 18*, 611–630.

Roberts, N., Boyer, P., & Parish, R. (1996). Preliminary results of geoarcheological investigations at Çatalhöyük. In I. Hodder (Ed.), *On the surface: Çatalhöyük 1993–1995*. Çatalhöyük Research Project Volume 1; British Institute for Archaeology at Ankara Monograph 22 (pp. 19–40). Cambridge: McDonald Institute for Archaeological Research.

Roberts, N., & Rosen, A. (2009). Diversity and complexity in early farming communities of Southwest Asia: New insights into the economic and environmental basis of Neolithic Çatalhöyük. *Current Anthropology, 50*, 393–402.

Rosen, A., & Roberts, N. (2005). The nature of Çatalhöyük, people and their changing environments in the Konya Plain. In I. Hodder (Ed.), *Çatalhöyük perspectives: Reports from the 1995–1999 seasons*.

Çatalhöyük Research Project Volume 6; British Institute for Archaeology at Ankara Monograph 40 (pp. 39–53). Cambridge: McDonald Institute for Archaeological Research.
Ruff, C. B. (1987). Sexual dimorphism in human lower limb bone structure: Relationship to subsistence strategy and sexual division of labor. *Journal of Human Evolution, 16*, 391–416.
Ruff, C. B. (2007). Body size prediction from juvenile skeletal remains. *American Journal of Physical Anthropology, 133*, 698–716.
Ruff, C. B. (2008). Biomechanical analyses of archaeological human skeletons. In M. A. Katzenberg & S. R. Saunders (Eds.), *Biological anthropology of the human skeleton* (2nd ed., pp. 183–206). New York: Wiley-Liss.
Ruff, C. B., Garofalo, E., & Holmes, M. A. (2013). Interpreting skeletal growth in the past from a functional and physiological perspective. *American Journal of Physical Anthropology, 150*, 29–37.
Ruff, C. B., Holt, B. M., Sládek, V., Berner, M., Murphy, W. A., Nedden, D. Z., & Reicheis, W. (2006a). Body size, body shape, and long bone strength of the Tyrolean ice man. *Journal of Human Evolution, 51*, 91–101.
Ruff, C. B., Holt, B., & Trinkaus, E. (2006b). Who's afraid of the big bad Wolff?: 'Wolff's law' and bone functional adaptation. *American Journal of Physical Anthropology, 129*, 484–498.
Russell, N. (2005). Çatalhöyük worked bone. In I. Hodder (Ed.), *Changing materialities at Çatalhöyük: Reports from the 1995–1999 seasons*. Çatalhöyük Research Project Volume 5; British Institute for Archaeology at Ankara, Monograph 39 (pp. 339–368). Cambridge: McDonald Institute for Archaeological Research.
Russell, N., & Martin, L. (2005). The Çatalhöyük mammal remains. In I. Hodder (Ed.), *Inhabiting Çatalhöyük: Reports from the 1995–1999 seasons*. Çatalhöyük Research Project Volume 4; British Institute for Archaeology at Ankara Monograph 38 (pp. 33–98). Cambridge: McDonald Institute for Archaeological Research.
Russell, N., Twiss, K. C., Orton, D. C., & Arzu Demirergi, G. (2013). More on the Çatalhöyük mammal remains. In I. Hodder (Ed.), *Humans and landscapes of Çatalhöyük: Reports from the 2000–2008 seasons*. Çatalhöyük Research Project Volume 8; British Institute for Archaeology at Ankara Monograph 47; Monumenta Archaeologica, 30 (pp. 213–258). Los Angeles: Cotsen Institute of Archaeology Press.
Ryan, P. (2013). Plant exploitation from household and landscape perspectives: The phytolith evidence. In I. Hodder (Ed.), *Humans and landscapes of Çatalhöyük: Reports from the 2000–2008 seasons*. Çatalhöyük Research Project Volume 8; British Institute for Archaeology at Ankara Monograph 47; Monumenta Archaeologica, 30 (pp. 163–190). Los Angeles: Cotsen Institute of Archaeology Press.
Sattenspiel, L., & Harpending, H. C. (1983). Stable populations and skeletal age. *American Antiquity, 48*, 489–498.
Service, E. R. (1962). *Primitive social organization*. New York: Random House.
Shillito, L. M., Bull, I. D., Matthews, W., Almond, M. J., & Evershed, R. P. (2013). Integrated geochemical and microscopic analysis of human coprolites, animal dung, and organic remains in burials. In I. Hodder (Ed.), *Humans and landscapes of Çatalhöyük: Reports from the 2000–2008 seasons*. Çatalhöyük Research Project Volume 8; British Institute for Archaeology at Ankara Monograph 47; Monumenta Archaeologica, 30 (pp. 77–80). Los Angeles: Cotsen Institute of Archaeology Press.
Shinoda, K., Matzumura, H., & Nishimoto, T. (1998). Genetical and morphological analysis on kinship of the Nakazuma Jomon people using mitochondrial DNA and tooth crown measurements. *Zooarchaeology, 11*, 1–21.
Sládek, V., Berner, M., & Sailer, R. (2006). Mobility in Central European Late Eneolithic and Early Bronze Age: Femoral cross-sectional geometry. *American Journal of Physical Anthropology, 130*, 320–332.
Smith, B. D. (1995). *The emergence of agriculture*. New York: Scientific American Library.
Smith, B. H. (1991). Standards of human tooth formation and dental age assessment. In M. A. Kelley & C. S. Larsen (Eds.), *Advances in dental anthropology* (pp. 143–168). New York: Wiley-Liss.
Smith, P., Bar-Yosef, O., & Sillen, A. (1984). Archaeological and skeletal evidence for dietary change during the Late Pleistocene/Early Holocene in the Levant. In M. N. Cohen & G. J. Armelagos (Eds.), *Paleopathology at the origins of agriculture* (pp. 101–136). Orlando: Academic Press.
Smith, P., & Horwitz, L. K. (2007). Ancestors and inheritors: A bio-cultural perspective on the transition to agro-pastoralism in the southern Levant. In M. N. Cohen & G. M. M. Crane-Kramer (Eds.), *Ancient health: Skeletal indicators of agricultural and economic intensification* (pp. 207–222). Gainesville: University Press of Florida.
Steckel, R. H., Larsen, C. S, Sciulli, P. W., Walker, P. L. (2011). Global History of Health Project Data Collection Codebook. http://global.sbs.ohio-state.edu/new_docs/Codebook-01-24-11-em.pdf.
Steckel, R. H., & Rose, J. C. (Eds.). (2002). *The backbone of history: Health and nutrition in the western hemisphere*. Cambridge: Cambridge University Press.

Stinson, S., Bogin, B., & O'Rourke, D. (Eds.). (2012). *Human biology: An evolutionary and biocultural perspective*. Hoboken: Wiley.

Stojanowski, C. M. (2013). *Mission cemeteries, mission peoples: Historical and evolutionary dimensions of intracemetery bioarchaeology in Spanish Florida*. Gainesville: University Press of Florida.

Stojanowski, C. M., & Schillaci, M. A. (2006). Phenotypic approaches for understanding patterns of intracemetery biological variation. *Yearbook of Physical Anthropology, 49*, 49–88.

Sylvester, A. D., Garofalo, E. M., & Ruff, C. B. (2010). An R program for automating bone cross-section reconstruction. *American Journal of Physical Anthropology, 142*, 665–669.

Thornton, F. (1992). Change in oral pathology through time of Nile Valley populations Predynastic to Roman. In S. Campbell & A. Green (Eds.), *The archaeology of death in the ancient Near East* (pp. 41–44). Oxford: Oxbow Books.

Trotter, M., & Gleser, G. C. (1952). Estimation of stature from long bones of American Whites and Negroes. *American Journal of Physical Anthropology, 10*, 463–514.

Turner, C. G., Nichol, C. R., & Scott, G. R. (1991). Scoring procedures for key morphological traits of the permanent dentition: The Arizona State University Dental Anthropology System. In M. A. Kelley & C. S. Larsen (Eds.), *Advances in dental anthropology* (pp. 13–31). New York: Wiley-Liss.

Twiss, K. C., Bogaard, A., Charles, M., Henecke, J., Russell, N., Martin, L., & Jones, G. (2009). Plants and animals together: Interpreting organic remains from building 52 at Çatalhöyük. *Current Anthropology, 50*, 885–895.

Van Neer, W., Gravendeel, R., Wouters, W., & Russell, N. (2013). The exploitation of fish at Çatalhöyük. In I. Hodder (Ed.), *Humans and landscapes of Çatalhöyük: Reports from the 2000–2008 seasons*. Çatalhöyük Research Project Volume 8; British Institute for Archaeology at Ankara Monograph 47; Monumenta Archaeologica, 30 (pp. 317–327). Los Angeles: Cotsen Institute of Archaeology Press.

Weston, D. A. (2012). Nonspecific infection in paleopathology: Interpreting periosteal reactions. In A. Grauer (Ed.), *A companion to paleopathology* (pp. 492–512). Chichester: Wiley.

Winterhalder, B., & Kennett, D. J. (2006). Behavioral ecology and the transition from hunting and gathering to agriculture. In D. J. Kennett & B. Winterhalder (Eds.), *Behavioral ecology and the transition to agriculture* (pp. 1–21). Berkeley: University of California Press.

Wood, J. W., Milner, G. R., Harpending, H. C., & Weiss, K. M. (1992). The osteological paradox: Problems in inferring prehistoric health from skeletal samples. *Current Anthropology, 33*, 343–358.

Wright, K. (2013). The ground stone technologies of Çatalhöyük. In I. Hodder (Ed.), *Substantive technologies at Çatalhöyük: Reports from the 2000–2008 seasons*. Çatalhöyük Research Project Volume 9; British Institute for Archaeology at Ankara Monograph 48; Monumenta Archaeologica, 31 (pp. 365–416). Los Angeles: Cotsen Institute for Archaeology.