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Abstract

The aim of this paper is to present new information pertaining to the demographic profile of the juvenile burial assemblage (n=39) from a Late Holocene site located on the eastern shore of the San Francisco Bay. CA-ALA-329 is commonly referred to as Ryan Mound and now bears the Muwekma Ohlone name of *Mánni Muwékma Kúksú Hóowok Yatiš Túnnešte-tka*, which means Place Where the People of the *Kúksú* (Bighead) Pendants are Buried. This site has been extensively studied and has contributed significantly to our understanding of life on the Bay during the Middle and Late Periods. However, most of the previous studies have focused on adults. The goal of the present study is to identify patterns in the profiles of those who died prematurely, including their sex, their degree of stress experienced based on skeletal indicators of disease/malnutrition, and their social status based on associated grave goods. Results show high incidence of skeletal indicators consistent with nutritional deficiency, disease/infection, and/or metabolic disorder observed in the sample. This suggests that this population was experiencing stress. Individual circumstances, such as age and sex, may also have contributed to poor health because infants have the highest prevalence of cribra orbitalia and periostitis. The distribution of wealth as evidenced by burial goods associated with the sample shows some correlation with age-at-death and the types of artifacts. Distribution of wealth also differs temporally. Inequality seems to have been highest in the Middle Period, while inequality decreased, but overall wealth increased, into the Late Period.

Introduction

The goal of archaeology is to reconstruct the demographic profile, diet, lifestyle, and health of past human populations. As with most of archaeology, Bay Area archaeological investigations have focused mainly on adult skeletal remains to draw these conclusions. Children are seldom the topic of bioarchaeological studies because their remains are more rarely recovered, likely due to the fragility and porosity of bones, and because of limitations associated with analyzing developing skeletons (e.g. incomplete roots, smaller bones and teeth for sampling, inability to assess sex). The perspective of children is comparatively lacking in anthropological literature more generally, yet maturing members of a society clearly contribute to its sociocultural framework. The extended dependency period of human children requires adults to make decisions regarding energy expenditure and reproduction (Trivers, 1972; Cronk, 1991; Tracer, 2009; Whelan et al., 2013). Furthermore, studies of modern hunter gatherer populations show that children are active participants in subsistence activities to provide for the group, in accordance with their physical and cognitive development as they age (Hewlett and Cavalli-Sforza, 1986; Lancy, 1996; Bliege-Bird, 2000; Bird and Bliege-Bird, 2002; Hewlett et al. 2011; Lew-Levy et al., 2017). The perspective of children has been acknowledged as theoretically important (Crawford, 1991; Moore and Scott, 1997; Kamp, 2001; Lewis, 2007; Mays et al., 2017), but putting it into practice has been limited due to the aforementioned challenges.

The aim of this paper is to present new information pertaining to the demographic profile of a sample of the juvenile burial assemblage from a Late Holocene site located on the eastern shore of the San Francisco Bay. CA-ALA-329, sometimes referred to as Ryan Mound, now bears the Muwekma Ohlone name of *Mánni Muwékma Kúksú Hóowok Yatiš Túnnešte-tka*, which means Place Where the People of the *Kúksú* (Bighead) Pendants are Buried. The site will henceforth be referred to by its Muwekma Ohlone name.

Several aspects of the archaeological assemblage have been described for this site (Bennyhoff, 1993; Leventhal, 1993), but there is still much to learn, especially regarding the large juvenile assemblage. In the present study, we sought to identify the sex of 28 juveniles from *Mánni Muwékma Kúksú Hóowok Yatiš Túnnešte-tka* using sex-based differences in the amelogenin protein. The sex of all juveniles was noted as "unknown" in previous studies of the site (Jurmain, 1990; Bennyhoff, 1993; Leventhal, 1993) because macroscopic indicators used to estimate sex are not present on developing skeletons (Buikstra and Ubelaker, 1994). We explore patterns in the profiles of individuals who died prematurely, including their sex, the degree of stress based on skeletal indicators of disease/malnutrition, and their social status based on associated grave goods. We also assessed whether these patterns changed between temporal periods, using time-since-death estimations from radiocarbon dates and relative dates based on stratigraphic placement. We hope that our contribution and other recent research about childhood among Bay Area prehistoric populations (Greenwald et al., 2016) inspires additional consideration of children in the archaeological record.

Bay Area Ethnohistory

Hunter-gatherer-fishing peoples, referred to as the Ohlone, have occupied the San Francisco Bay Area for over 7,000 years. During the Early Period of occupation (5450–2500 calBP) (Groza et al., 2011), Bay Area Peoples subsisted mainly on resources from the Bay. Beginning in the Middle Period (2500–1000 calBP) and continuing into the Late Period (1000–180 calBP), exploitation of terrestrial resources increased (Kroeber, 1925; Basgall, 1987; Hylkema, 2002; Wohlgemuth, 2004; Bartelink, 2006; 2009; Broughton, 1999, 2002; Beasley et al., 2013; Eerkens et al., 2011, 2013, 2017). The Middle-Late Transition Period (abbreviated here as Transition Period) refers to the years 1000~650 calBP. In addition to subsistence changes, Middle and Late Period populations experienced important social changes, including increased village sedentism, intensified acorn (*Quercus* sp.) processing, and the establishment of a storage economy (Nelson, 1909; Leventhal, 1993; Hylkema, 2002; Lightfoot and Luby, 2002; Luby, 2004; Milliken et al., 2007; Arnold and Walsh, 2010). Major changes involving social inequality occurred during the Middle and Late Periods. Inequality appears to have increased during the Middle Period, as evidenced by relatively few burial assemblages displaying large quantities of grave goods and sociotechnic artifacts (e.g. *Olivella* beads, tubular stone tobacco pipes, *Haliotis* pendants, banjo pendants, mortars and pestles, whistles, charmstones, and bone awls) suggestive of high status and/or wealth (Binford, 1962; Milliken and Bennyhoff, 1993; Leventhal, 1993; Hylkema, 2002).

In contrast, overall wealth inequality appears to have decreased because a high proportion of Late Period burials contain grave goods and high quantities of *Olivella* shell beads. This suggests that more people could attain a wealthy status. However, some individuals were buried in association with especially high quantities of *Olivella* shell beads and high-status objects (Milliken and Bennyhoff, 1993). Additionally, cremations, thought to represent elite burials because they require large amounts of firewood, occur for the first time during the Late Period (Harrington, 1942; Leventhal, 1993; Luby, 2004; Milliken et al., 2007; Arnold and Walsh, 2010). These findings support the idea that there did appear be an upper level of wealth that was reserved for some people, perhaps on the basis of lineage, craftsmanship skill, and/or political position. In particular, finding high-status objects in association with infant or child burials would suggest that status was ascribed in Bay Area populations, as has been previously suggested (Leventhal, 1993; Buonasera, 2013; Gardner, 2013). This is one of many reasons why the archaeology of children is essential to reconstructing a holistic view of the past, as only examining adult burials would make it difficult to ascertain whether mortuary artifacts are reflective of ascribed or acquired status.

Climate changes in the Bay Area associated with the Medieval Climatic Anomaly (MCA, 1221–821 calBP) consisted of prolonged periods of decreased precipitation, warmer terrestrial and sea-surface temperatures, and high incidence of fires (Jones et al., 1999; deMenocal, 2001; Meko et al., 2001; Benson et al., 2002; Jones and Ferneau, 2002; Mann et al., 2009; Coats et al., 2016; Abrams and Nowaki, 2019), all of which potentially diminished resource availability. The impact of the MCA on Bay Area peoples is debated. Some scholars consider the MCA a stressful time that prompted increased sedentism, food storage, and reliance on terrestrial resources (Jones et al., 1999; Jones and Ferneau, 2002; Schwitalla, 2013; Allen et al., 2016). Others cite the persistence of these adaptive cultural changes after climatic conditions improved in the Late Period as evidence that climate may not have been the primary driver (Bettinger, 2015: 101). Though it is debated whether the MCA itself caused stress, it is generally agreed that there is evidence of increased stress during and following the years associated with the MCA, such as a higher frequency of skeletal indicators of nutritional deficiency and/or infection and disease (Jones et al., 1999; Schwitalla, 2013) and a higher frequency of the types of fractures and trauma typically associated with interpersonal violence/warfare observed in adult skeletons (Jones et al., 1999; Milliken et al., 2007; Jurmain et al., 2009; Andrushko et al. 2010; Schwitalla, 2013; Allen et al., 2012, 2016).

Site Description

Mánni Muwékma Kúksú Hóowok Yatiš Túnnešte-tka is a large earthen mound site (~450x300 feet and 12–15 feet high) with shell mixed within its strata (Jurmain et al., 2009). It is one of four sites located in the Coyote Hills and is adjacent to wetlands along the southeastern side of the San Francisco Bay (Leventhal, 1993). Utilitarian, or technomic, artifacts from the site include groundstone (except charmstones and smoking pipes), flaked stone, battered/pecked stone, unmodified cobbles/manuports, and bone/antler tools (Binford, 1962; Leventhal, 1993). Religious/ceremonial, or ideotechnic, artifacts included flower-pot and large, formal bowl mortars, clay objects, shell beads and ornaments, quartz crystal, and red ochre (Binford, 1962; King, 1970; Leventhal, 1993; Buonasera, 2013). The primary use of this site is debated, with some scholars arguing that it served as both a habitation site and ceremonial/burial site (Arnold and Tissot, 1993; Milliken et al., 2007) and others emphasizing its ceremonial/burial use. Leventhal (1993) argues that the high quantity of burials and wealth objects is suggestive of a primarily ceremonial/burial site for what appears to be an elite population. Of the 283 burials recovered, 213 had associated grave goods (Leventhal, 1993). Subsistence consisted of marine, freshwater, and terrestrial resources, with an increased terrestrial contribution during the Middle and Late Periods (Basgall, 1987; Anderson, 1997; Hylkema, 2002; Hildebrandt and Jones, 1992; Broughton, 1999, 2002; Bartelink, 2006, 2009). *Mánni Muwékma Kúksú Hóowok Yatiš Túnnešte-tka* is an important site for exploring temporal changes in the Bay Area because it was continuously occupied throughout prehistory and into the historic period (Arnold and Tissot, 1993, Bettinger, 2015). Additionally, the site provides a large assemblage of juvenile skeletons to sample from, as 73 (~25%) were estimated to be 15 years old or younger (Jurmain, 1990; Leventhal, 1993; Jurmain et al., 2009).

{~?~IM: insert 329 map.tiff here.}

Figure 1. Map of CA-ALA-329. (Adapted from a map created by William Dimitio, Ph.DC)]

Proteomic Sex Estimation

A relatively new method for sex estimation of archaeological skeletons involves analyzing sex-specific peptides of the amelogenin protein present in tooth enamel (Stewart et al., 2017; Parker et al., 2019; Buonasera et al., 2020). The amelogenin proteins are coded for on the X- and Y-chromosomes and the genes produce different isoforms based on which chromosome they come from. Sex can be estimated based on the isoforms present (AMELX or AMELY). Because enamel preserves so well, this method is highly favorable for archaeological contexts (Demarchi et al., 2016; Buonasera et al., 2020).

Materials and Methods

A single tooth and bone fragment were sampled from 39 juvenile individuals from *Mánni Muwékma Kúksú Hóowok Yatiš Túnnešte-tka* ranging in age from 0–15 years. Per the request of the Muwekma Ohlone Tribal Council and the San Jose State University Anthropology faculty, loose teeth and rib fragments were preferentially sampled. All samples were photographed, weighed, and measured prior to being analyzed for different aspects of this multi-phase project. The isotopic analysis phase utilizing the dentin and bone tissue is discussed in a recent article (Fournier et al., 2022) and the ancient DNA analysis phase utilizing a portion of each tooth will be described in an upcoming article. A subsample of approximately 2.0g of bone from 14 individuals was sent to DirectAMS and Lawrence Livermore National Laboratory for radiocarbon dating. Relative ages of the remaining samples were estimated based on their stratigraphic position within the site (Leventhal 1993). Based on these dates, the temporal period of each individual was identified for use in all phases of this study.

For the present study, tooth enamel was collected in a labeled glass 1 dram vial using a dental drill with diamond drill bits and submitted for proteomic sex estimation at UC Davis. Samples with at least 3 mg of powdered enamel (n=28) were processed at UC Davis between January 2020 and August 2020. The bit and drill were thoroughly sterilized with ethanol and gloves were changed between each sample to prevent cross-contamination. The surfaces where the sampling took place were also cleaned with ethanol between samples.

Proteomic methods followed those described in Parker et al. (2019) with the following changes. Mass spectrometry datasets (.RAW format) were processed with PEAKS™ (10.0) peptide matching software (Bioinformatics Solutions Inc., Waterloo, ON). Error tolerance for matching peptide spectral assignment was set to 10 ppm for precursor mass and 0.04Da for fragment ions. AMELX_HUMAN signals (CI/mg) were log transformed and then solved for Pr(F) using the equation $\Pr(F) = 1.0 + (0.059–1.0)/(1+(x/7.54)^{13.99}$ where “x” is the logarithm (base 10) of the AMELX_HUMAN (Parker et al. 2019). Samples with a $\Pr(F) \leq 0.5$ were considered indeterminate for proteomic sex estimation. To prevent and detect cross-contamination of amelogenin protein, all surfaces and tools were thoroughly cleaned between samples and sample blanks were prepared with each batch. Washing runs with saw-tooth gradients on liquid chromatography were employed between each sample and periodic blank runs were used to monitor sample carryover. The mass spectrometry proteomic data have been deposited into the proteomeXchange Consortium via the PRIDE partner repository with the accession number PXD035274 (https ://www.proteomexchange.org).

To more easily identify age-related patterns in the data, the sample was divided into five age cohorts that reflect developmental stages. Each individual in the sample was assigned to an age cohort based on the median of their estimated age range. Age cohorts 1 and 2 include individuals aged 0–3 years (0–2 years and 2.25–3 years, respectively). Because isotopic evidence from other Middle and Late Period Bay Area sites indicates that weaning began on average between 7–9 months and ended between 31–53 months (Greenwald, 2017; Gardner et al., 2018), age cohorts 1 and 2 are thought to represent infants whose diets consisted at least in part of breastmilk. Age cohort 3 consists of individuals in the lower range of Early Childhood (aged 3.25–5 years). The upper range of Early Childhood and start of Late Childhood is represented by age cohort 4, which includes individuals with an estimated age-at-death between 5.25–8 years. Finally, age cohort 5 consists of individuals in Late Childhood and Adolescence (aged 8.25–15 years). Data analysis was based on raw data and chi-square tests, whenever sample size permitted.

Results

The description of the sample (Table 1) includes the median age of the estimated age-at-death range for each individual and the corresponding age cohort that they were assigned to for the present study. The dental element sampled for proteomic sex identification is also included. Finally, grave goods associated with each burial and skeletal pathologies observed on the remains are listed (Table 1).

[Table 1. Description of the Sample]

Sample Composition: Age-at-Death and Temporal Period

Of the 39 individuals in the entire sample, 61.5% (n=24) were three years old or younger at the time of their death (e.g. age cohorts 1 and 2, Table 2). This is expected in societies lacking modern medicine, where mortality rates for infants and young children are high (Howell, 1979; Goodman and Armelagos, 1989; Hewlett, 1991; Boucquet-Appel, 2002; Kelly, 2013). The next highest proportion of individuals represents 5.25–8-year-olds, or age cohort 4 (n=7, 18%). Young children, or age cohort 3 (n=2, 6.25%), and adolescents, or age cohort 5, (n=6, 15.4%) are the least represented in the sample (Table 2). The same pattern holds across temporal periods, but a 2 x 3 chi-square test comparing age cohorts 1–2 vs. age cohorts 3–5 shows no difference in age distributions by temporal period (χ^2=0.5177; d.f.=2 p=0.77; V=0.08).

[Table 2. Temporal Period Description by Cohort]

Sample Composition: Biological Sex Estimated by Proteomic Analysis of Enamel

Enamel sample sizes and results of proteomic analysis are provided in Appendix 1. The low overall amounts of amelogenin in these samples are unusual and likely reflect analytical difficulties experienced due to an abrupt university-wide closure at the beginning of the Covid-19 pandemic, rather than poor archaeological preservation. Facility closures resulted in purified protein extracts being stored for an extended amount of time prior to analysis. Perhaps more importantly, instrumentation was no longer in optimal condition upon campus reopening. Unfortunately, for this study, additional enamel was not available for retesting from these teeth. In the end, reliable sex estimates were possible for 19 of the 28 samples submitted for analysis. Nine samples were indeterminate because levels of amelogenin were too low for reliable estimation. Importantly, for reasons described below, it is possible that a female bias exists among the indeterminate samples.

Male estimates rely on unambiguous detection of AMELY peptides at any level of signal, whereas female estimates need to have a summed intensity above the threshold of AMELX peptides giving a Pr(F) value > 0.5. In sample populations with low amelogenin signal and consequently high levels of indeterminate sex estimation, biases may be introduced due to different criteria being used to estimate male or female sex.

In the present case, potential biases are hard to quantify and may be influenced by proteome complexity, sample processing, degradation, dentin contamination, and mass spectrometry instrumentation. In this sample, two male estimates had low AMELX signals that would result in Pr(F) ≤ 0.5 if no AMELY had been detected (Appendix 1, Burials 95 and 255). One of these had only one AMELY peptide (burial 255). It should be noted that this situation has not occurred in previous or subsequent studies using the Parker et al. (2019) method of sex-estimation; amelogenin peptides are typically detected in high enough amounts such that all, or nearly all, samples produce highly reliable sex estimates.

Based on the 28 analyzed samples, there are 10 males, 9 females, and 9 individuals of unknown sex (Table 3). Interestingly, five of the 10 age cohort 1 individuals (50%) are male, while only one is female (10%). In contrast, all age cohort 2 individuals of known sex are female. Both of the age cohort 3 individuals are male (Table 3). Based on these results and assuming they are not biased by the issues described above, it appears as though male infants and young children had a slightly higher mortality rate. This result is consistent with human biological research showing that male infants are slightly more susceptible to mortality than females, especially while *in utero* (Boco, 2014; Bruckner et al., 2015; Zarulli et al., 2018). The result is also consistent with younger ancestral Ohlone boys engaging in more risk-taking behaviors leading to premature death (Harrington, 1942). By contrast, the sex-ratio is about equal for individuals who died in age cohorts 4 and 5 (Table 3). Future goals include trying to identify the sex of those who could not be identified through the proteomics method of amelogenin typing, which will hopefully provide further insight into the sex of those who died in each age cohort and temporal period.

[Table 3. Biological Sex Description by Cohort]

Sample Composition: Paleopathology

A skeletal pathology was observed in 23 of 39 individuals, or 60% of the sample. The most prevalent pathology is cribra orbitalia (CO), with 41% (n=16) of the sample presenting with at least unilateral CO and 30.8% (n=12) presenting with bilateral CO. Most of these individuals fall into age cohorts 1 and 2 (Table 4). There is no apparent relationship between sex and CO (Table 4). There is a higher prevalence of CO during the Late Period, but this is likely an artifact of sample size being much larger for the Late Period (n=11 for Middle Period, n=7 for Transition Period, n=21 for the Late Period, Table 2). The next most common pathology is periostitis (P) (n=11, 28.2%) on either the flat bones of the skull or the long bones. Again, age cohort 1 and 2 individuals have the highest prevalence (Table 4). Two of those individuals are male and the rest represent individuals of unknown sex (Table 4). Again, Late Period individuals have the highest prevalence (Table 4). A chi-square test comparing age cohorts 1–2 vs. age cohorts 3–5 shows no difference in the distribution of the most common pathologies, CO and P (χ^2=0.01473; d.f.=1 p=0.7011; Φ=0.0615). Comparisons between sexes and temporal periods were not performed due to sample size. A comparison of the distribution of CO and P between sexes will hopefully be possible after genetic sex identifications are complete.

Dental abscesses (DA), porotic hyperostosis (PH), and spina bifida (SB) were less common. DA were observed in four individuals (10.3%) (Table 4). One was a Late Period male from age cohort 4. Of the other three individuals, all of whom belonged to age cohort 5, one was a Late Period male, one was a Transition Period female, and the other is not among the sample analyzed for proteomics but dates to the Late Period. These results indicate that older children of both sexes were consuming carbohydrate-rich diets, which likely caused advanced dental caries that eventually developed into abscesses. PH was observed in only one individual, who is an age cohort 4 female from the Late Period (Table 4). Lastly, one Middle Period female from age cohort 4 (Table 4) had skeletal indicators consistent with SB, including an unfused neural arch of the 9th thoracic vertebra and congenital delayed maturation of the vertebral column.

Overall, results show that males and females had approximately equal prevalence of pathological lesions of the skeleton consistent with poor nutrition and/or health (Table 4), meaning they were exposed to similar degrees of stress. We will continue to evaluate this question as additional sex identifications become available. The most stress appears to have been experienced by the Late Period individuals, especially the infants, though we interpret this finding with caution given the larger sample size for the Late Period.

[Table 4. Skeletal Pathology Description by Age Cohort, Sex, and Temporal Period]

Sample Composition: Grave Goods

Most individuals (n=28, 71.8%) were buried in association with grave goods. This finding is consistent with *Mánni Muwékma Kúksú Hóowok Yatiš Túnnešte-tka* overall because 213/283 burials have associated grave goods (Leventhal, 1993). In the present study, 93% of age cohort 1 individuals, 50% of age cohort 2 individuals, 0% of age cohort 3 individuals, 86% of age cohort 4 individuals, and 67% of age cohort 5 individuals were buried in association with grave goods (Table 5). There is no apparent relationship between the presence of grave goods and age cohort that would suggest differential burial practices based on age-at-death. A chi-square test of age cohorts 1–2 vs. age cohorts 3–5 shows no significant relationship between age and the presence/absence of grave goods (χ^2=0.3166; d.f.=1; p=0.5737; Φ=0.09). There appears to be a slight relationship between the presence of grave goods and temporal period, with 81% of Late Period burials associated with grave goods compared with 63.6% of Middle and 57% of Transition Period burials. However, a chi-square test did not detect a significant difference between time periods and the presence/absence of grave goods (p-value=0.38; d.f.=2; $\chi^2$1.9734; V=0.16). According to present data, there does not appear to be a sex-related pattern in burial goods (Table 5). New analysis and chi-square tests comparing presence/absence of grave goods between males and females will be performed after additional sex identifications are completed.

The specific artifacts found within each burial are more revealing of age-related mortuary behavior and temporal trends. Certain burials contain grave goods that are typically associated with wealth and status. For instance, several infant burials, including two Middle Period (B228 and B236), two Transition Period (B240 and B248), and two Late Period (B166, B247) burials, contain large quantities of shell beads. Pendants are the most commonly occurring artifact. They were found in association with B47, B107, B228, and B236 of the Middle Period, B240 of the Transition Period, and B43, B95, B170, B193, and B255 from the Late Period. B228 and B240 are noted as high-status infants. Quartz was found in association with B41 and B45, a Late Period older child and infant, respectively. B68 and B171, both Late Period infants, were the only burials found in association with charmstones. In California, charmstones are typically associated with ceremonial/religious activities, especially with shamans (Sharp, 2000; Gardner, 2013). Thus, these infants may have come from high-status lineages associated with shamanism. This also provides support for ascribed status in the Late Period (Leventhal, 1993; Buonasera, 2013; Gardner, 2013). Bone whistles were associated with B193, an older Late Period child, as well as B236 and B247, who are both Late Period infants. B247, an individual noted as a very high-status infant, was also found with a steatite pipe (Jurmain, 1990). One burial (B63) is associated with a large mortar. Finally, two Late Period burials with goods associated with wealth (B41 and B107) were noted as partially cremated, which supports that they were likely high-status and/or wealthy.

The relationship between wealth items and sex cannot be assessed given the data currently available for analysis. A near equal number of males (n=7) and females (n=8) were buried with grave goods and with goods specifically associated with wealth (n=4 for males and n=3 for females) (Table 5). Three males were buried without any goods, while there was only one female individual who was buried without goods, that we know of. This could very well change once we identify the sex of the unknown individuals. At that time, we will explore whether our data provide support for the argument that there was different gender-based and status-based mortuary practices in the Bay Area during the Middle and Late Periods (Buonasera, 2013).

In sum, there appears to be a relationship between wealth objects and infants. Although age cohort 1 infants account for just 36% of the individuals in this study, they represent half the cases of high-status grave lots (n=9). More Late Period burials (n=12) are associated with sociotechnic artifacts, suggesting high wealth/status (Binford, 1962), than Middle and Transition Period burials (n=4, n=2, respectively) (Table 5). These results support the findings of previous studies that emphasized higher social inequality in the Middle Period, followed by more evenly dispersed status/wealth among Late Period Bay Area peoples (Milliken and Bennyhoff, 1993; Hylkema, 2002). Transition Period burials in the present study are almost equal in the numbers of burials with (n=4) and without grave goods present (n=3) (Table 5). Given the smaller sample size of this group, it is difficult to interpret these findings at this time. With regard to interpreting status/wealth in the past, it is important to note that status can only be inferred archaeologically based on the artifacts available for analysis and perishable wealth items would not preserve.

[Table 5. Grave Goods Distribution by Age Cohort, Sex, and Temporal Period]

Discussion

Infants and children under the age of five years-old are known to have disproportionately lower resistance to infection and nutritional deficiency due to immature immune systems and high energetic cost of growth (Goodman et al., 1984a, 1984b; Goodman and Armelagos, 1989). This increases mortality rate among the very young, which is consistent with findings in the present study. Individuals from age cohorts 1 and 2 represent the largest proportion of the sample. Cause of death cannot be ascertained from the skeletal remains alone, but we can glean some insight into health from the presence or absence of skeletal pathologies.

Cribra orbitalia (CO) is the most prevalent (n=11) pathology observed in the sample, while porotic hyperostosis (PH) is one of the least prevalent (n=1). PH and CO are similar pathological conditions of the skeleton. Both are characterized by areas of pitting and porosity but on different skeletal elements. PH refers to pitting and porosity on the external surface of the occipital, parietal, and frontal bones of the skull (Angel, 1966a; Hill and Armelagos, 1990; Larsen, 1997; Walker et al., 2009; Schwitalla, 2013), while CO is only seen in the orbits.

CO and PH are among the most common pathologies observed in the archaeological record globally (El-Najjar et al., 1976; Ubelaker, 1984; Walker, 1985; Larsen, 1997, 2002). The etiology of these lesions is complex. They are produced by expansion of the diploe (spongy bone) in response to marrow hypertrophy (Stuart-Macadam, 1987; Larsen, 1997). Iron deficiency anemia was long thought to be the most likely reason for the marrow hypertrophy (Larsen, 1997; Walker et al., 2009; Schwitalla, 2013). More recently, it has been suggested that megaloblastic and hemolytic anemias are the more likely cause because these specific types of anemia lead to premature red blood cell death and increased erythropoiesis (red blood cell production) (Walker et al., 2009). The most common causes of megaloblastic anemia are chronic dietary deficiencies and/or malabsorption of vitamin B12 and/or folic acid. Because the diploe of the cranial bones are the primary red blood cell production centers during childhood and adolescence, active lesions are more commonly observed in these age groups, while healed lesions are seen in older adults (Walker et al., 2009).

This presence of CO in many of the infants in this sample has a few possible explanations. Infants are born with very low stores of vitamin B12, meaning they are susceptible to developing deficiency symptoms shortly after birth if they do not receive proper nutrition (Walker et al., 2009). This finding could also be reflective of maternal diets consisting of minimal animal protein during pregnancy and lactation. Malabsorption and/or chronic diarrhea is another possible explanation (Krugman and Dubowitz, 2003). Infants in the process of weaning are at high risk for diarrhea due to underdeveloped digestive systems (Kennedy, 2005). Based on the data available for analysis, it does not appear that males or females had a relatively higher risk for the nutritional deficiencies or metabolic conditions that are associated with CO and PH. The one individual with PH happens to be a female and the number of males and females presenting with CO is almost identical. We are hopeful that additional sex identifications will allow us to further explore whether there is a sex-based difference in risk of developing CO in this sample.

Periostitis (P) is the second most common pathology in the sample (n=10). It refers to destruction of the bone resulting from the inflammatory response to infection (Larsen, 1997; Waldron, 2009; Schwitalla, 2013). The inflammation is in the periosteum, the membrane on the outside of almost every bone in the body that plays a role in bone formation and remodeling (Bisseret et al., 2014). The periosteum can be triggered to start forming bone in response to a benign or malignant stimulus; this is referred to as a periosteal reaction (Greenfield et al., 1991). Stimuli include fractures, tumors, hemangiomas, and infection (Greenfield et al., 1991; Gladykowska-Rzeczycka, 1998; Rana et al., 2009; Bisseret et al., 2014). Infection like osteomyelitis typically causes a periosteal reaction in the long bones, though periostitis can occur in any infected bone (Rana et al., 2009). Infection can spread to the bones from blood (e.g. haematogenous spread), from an infected nearby organ, or from direct embedding of infectious agents due to injuries or animal bites. Of these three sources, haematogenous spread is the most common (Waldron, 2009). In most cases, a specific disease or pathogen causing these conditions cannot be identified, as the hyper-reaction of bones is common due to a variety of pathogens (Goodman and Armelagos, 1989).

The high prevalence of skeletal indicators of infection in this sample suggests that there was a lot of disease being transmitted in the community, which is common among densely populated sedentary groups such as Bay Area Middle Period peoples (Inhorn and Brown, 1990). Population density decreased in the Late Period when populations became more circumscribed, but sedentism was upheld (Luby, 2004; Milliken et al., 2007). Thus, high rates of infection are expected for this population beginning in the Middle Period based on disease theory. According to Bay Area bioarchaeological studies, infection is the only index of stress that is higher during the Late Period than the Middle Period (Schwitalla, 2013). This sample is skewed to the Late Period, which is likely inflating the apparent rate of disease, though we suspect that the prevalence of periostitis would still be higher in the Late Period based on earlier findings (Schwitalla, 2013).

Individual circumstances, such as age and sex, may also have contributed to risk of disease. For example, infants represent 7/10 individuals with periostitis, which is not surprising given that infants already have lower resistance to infection (Goodman et al., 1984a, 1984b; Goodman and Armelagos, 1989). Infants with a shorter duration of exclusive breastfeeding may have had a higher risk because they would not have received as much immune support provided by breastmilk to fight an infection before periostitis could develop (Gyorgy et al., 1954; Huffman and Lamphere, 1984; Shashikala and Prakash, 1984; Karav, 2019). Weaning patterns for this sample are presented in a recently published article (Fournier et al., 2022) and shed light on this issue. The relationship between sex and periostitis cannot be determined at this time because most individuals with periostitis are currently of unknown sex. Hopefully this can be explored once we are able to identify the sex of more individuals.

The three individuals with dental abscesses (DA) were at least 11 years-old when they died. This fits with the expectation that carious lesions would be more common for those with longer exposure to carbohydrates in their diets. Dental caries and tooth wear create opportunities for oral bacteria and toxic byproducts to access the periapical tissues and cause an abscess in the alveolar bone, which can lead to death (Dias and Tayles, 1997; Forshaw, 2014). Previous archaeological studies show a positive relationship between the amount of carbohydrates in the diet and dental caries (Turner, 1979; Costa, 1980; Larsen, 1984; Walker and Erlandson, 1986; Lukacs, 1992; Cucina and Tiesler, 2003; Alfonso-Durruty et al., 2014; Karsten et al., 2015). Bay Area populations consumed carbohydrates from several terrestrial plants, but acorns (*Quercus sp*.) were the largest source (Nelson, 1909; Anderson, 1997; Wohlgemuth, 2004, 2016). Acorn exploitation intensified in the Middle and Late Periods, so it was expected to find abscesses in older children because they all date to the Middle Period or later. All individuals with abscesses in the present study date to the Transition and Late Periods (Table 4). The sample size is too small to draw any conclusion regarding the relationship between sex and abscesses among juveniles.

It is interesting to find evidence consistent with spina bifida (SB) in one individual. This child very likely had the milder form of spina bifida occulta, given that she lived to a median age of 6.5 years (Groza et al. 2016). Spina bifida occulta is characterized by an incomplete fusion of the laminae of at least one vertebral arch with no herniation of the spinal cord or meninges (Hollinshead, 1964; Saluja, 1988). While spina bifida typically impacts the lumbar and/or sacral vertebrae (Hollinshead, 1964; Saluja, 1988; Groza et al., 2016), the congenital defects associated with spina bifida occulta can impact any portion of the spinal column. In this case, the 7th thoracic vertebra is congenitally open (Table 1).

The high incidence of skeletal indicators consistent with nutritional deficiency, disease/infection, and/or metabolic disorder observed in the sample suggests a population under stress. According to the paleoepidemiological stress model, environmental restrictions (e.g. climate change and resource availability), cultural practices, and host resistance (e.g. genetic, sex, physiological) are major factors causing stress (Goodman and Armelagos, 1989; Steckel et al., 2002; Schwitalla, 2013). As previously discussed, it is difficult to identify the causes of stress in the past. However, resource depression related to the environmental impact of the MCA and overharvesting, and/or increased sedentism coupled with increased population density, could have reasonably contributed.

The distribution of wealth as evidenced by burial goods associated with the sample shows some correlation with age-at-death and the types of artifacts. Infants represent half the cases of high-status grave lots (n=9) and the two individuals noted as very high-status based on the types of grave goods are all infants (Table 5). Additionally, both partial cremations are age cohort 4 individuals. Though the sample size is small, it is interesting that cremations were not observed in any other age group. Perhaps cremation was reserved for older individuals who had achieved a social role, such as an arranged marriage partner selected. It has been argued that there is a confounding relationship between age and social status because the number of social roles typically increases with age (Carr, 1995).

Distribution of wealth also differs temporally. Overall, relatively few Middle Period burials are associated with grave goods. The few that are have relatively small quantities of shell beads, and occasionally *Haliotis* pendants and tools made of bone and stone (Table 1). There is, however, one Middle Period infant (B228) and one Transition Period infant (240) who are noted as high-status infants because of an array of sociotechnic artifacts (Jurmain, 1990). In contrast, almost all Late Period burials had grave goods present (e.g. 17/21) (Table 1). Sociotechnic artifacts suggestive of high status were very common; 12 Late Period burials were found in association with at least one sociotechnic artifact (e.g. large quantities of *Olivella* shell beads, bone whistles, steatite pipes, pendants, charmstones, and quartz). The two partial cremations observed in the sample are from the Late Period (Table 1). Cremations are considered specialized treatment, and therefore indicative of high status, because they require large amounts of firewood, which would be difficult in the Coyote Hills because hardwood was not readily available (Leventhal, 1993). Pipes, bone whistles, effigy ornaments, charmstones, and flower-pot and finely crafted bowl mortars are considered indicative of especially high status/wealth (Bennyhoff, 1993; Leventhal, 1993; Buonasera, 2013).

In sum, inequality seems to have been highest in the Middle Period, while inequality decreased, but overall wealth increased, into the Late Period. In addition, our findings provide further support for increased ascribed status and emphasis on wealth items during the Late

Period. These findings are consistent with a broader study in Central California focused on grave good distrubution in adult burials (Milliken and Bennyhoff, 1993; Buonasera, 2013). As previously mentioned, status can only be inferred from the grave goods that preserved. Objects such as feathers, cordage, and basketry were discussed in the ethnographic record as being prestigious items (Harrington, 1942; Hylkema, 2002), though none of these items typically survive in the archaeological record. Therefore, interpretations of wealth and status based upon shell, bone, and stone artifacts are likely incomplete (Hylkema, 2002).

Conclusion

This study provides a demographic profile of a sample (n=39) of the juvenile burial assemblage from *Mánni Muwékma Kúksú Hóowok Yatiš Túnnešte-tka*. This site has been extensively studied and has contributed greatly to our understanding of Late Holocene Bay Area peoples, but the present study adds sex identifications, paleopathology descriptions, and time-since-death estimates for children. It is known that understanding the lived experiences of children is integral to understanding society (Crawford, 1991; Moore and Scott, 1997; Kamp, 2001; Lewis, 2007; Mays et al., 2017). This study represents one phase of a research program exploring childhood in the Bay Area prior to European contact. In the future, we plan to use genetic sex typing methods to try to identify the sex of the unknown individuals in our sample. Several teeth were chipped post-mortem and therefore had a limited amount of enamel available to analyze. Genetic sex typing distinguishes between amplicons of the amelogenin gene produced by the X- and Y-chromosome and is not limited to enamel. Thus, we will hopefully be able to identify the sex of the nine individuals who did not have enough available enamel to identify sex using the amelogenin protein. This will provide additional insight into sex-based patterns relating to stress, social status, and age-at-death. We hope to encourage future archaeological investigations into the lifestyles of children.

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[Appendix 1. Results of proteomic analysis and sex estimation of amelogenin peptides in enamel samples following methods in Parker et al. 2019.]

Table 1. Description of the Sample

Burial	**Median Age (yrs) [Cohort]**	**Sex**	**Temporal Period calBP[ab]**	**Element**	**Grave Goods**	**Pathology**
B4	1.25 [1]	M	LP 543–507*	dM^1	No grave associations	Bilateral slight cribra orbitalia
B17	6 [4]	F	LP 522–340*	dM^1	Bone needle, unfinished obsidian biface, stingray barbs	Porotic hyperostosis (left parietal), bilateral cribra orbitalia
B35	2.5 [2]	F	MP 1363–1293*	dM_1	Bipointed bone object	No observed pathology
B41	6 [4]	M	LP 454–302*	dM_1	60 *Olivella* 1b beads and 100 *Olivella* 1a, quartz crystal. Possibly partial cremation	No observed pathology
B43	2 [1]	M	LP ~522–340	dM^1	*Haliotis* pendant	No observed pathology
B45	1.5 [1]	F	LP ~522–340	dM^1	Mortar near skull, quartz crystal, 161 *Olivella* beads	No observed pathology
B47	1.75 [1]	U	MP ~1820–1400	dM^1	25 *Olivella* beads, *Haliotis* rufescens complete shell (contained residue), *Haliotis* rufescens pendant	No observed pathology
B63	14 [5]	NA	LP ~536–480	NA	Large mortar, antler tine	Large abscess in 2nd premolar
B68	1.5 [1]	U	LP 646–526	dM_1	43 limpet shell beads and 1 or 2 *Olivella* beads, elk antler base, 2 large piled plummet charmstones, 53 *Olivella* beads	No observed pathology
B72	1.5 [1]	M	LP ~536–480	dM^1	86 *Olivella* beads	No observed pathology
B82	2.5 [2]	F	LP 647–537*	dM^1	24 *Olivella* beads (likely necklace)	Periostitis (R parietal), bilateral cribra orbitalia
B89	13.5 [5]	NA	MP 2307–2042*		Bear claw, worked stone	Bilateral cribra orbitalia
B95	2 [1]	M	LP <536–480	dM_1	Mortar, pestle, distal end of a split wide awl, Mytilus californicus pendant, distal end of awl	Periostitis (ulnae, R femur and fibula, tibiae), bilateral cribra orbitalia
B101	14 [5]	NA	LP 536–480*	NA	No grave associations	Periostitis (1st thoracic vertebra, humeri and glenoid fossae), remodeling of R humerus, cribra orbitalia (L frontal)
B107	6.5 [4]	F	MP 1929–1822*	dM^1	36 bird bone tubes, 3 *Haliotis* pendants, 2 drilled canine teeth (most likely coyote)	Unfused neural arch of 9th thoracic vertebra, congenital delayed

						maturation of vertebral column (spina bifida?)
B123	2.25 [2]	F	MLTP ~1264–965	dM$_2$	No grave associations	Periostitis (R humerus)
B148	13.5 [5]	U	MLTP 725–658 [b]*	PM^1	No grave associations	Periostitis (auditory meatus of L temporal), bilateral cribra orbitalia
B152	13 [5]	F	MLTP 733–661[b]*	PM^1	37 *Olivella* beads around cervical region (likely necklace) and sandstone pebble	Abscess (permanent mandibular canine)
B156	2.25 [2]	F	MLTP 954–797[b]*	dM$_1$	Antler	
B159	1.5 [1]	NA	LP ~536–480	NA	Pestle fragment	No observed pathology
B160	2 [2]	NA	MP 1616–1527*	NA	No grave associations	No observed pathology
B166	1.25 [1]	U	LP ~536–480	dM^1	3 sets of antlers and 518 *Olivella* beads	Periostitis (L humerus)
B170	7 [4]	F	LP 550–501*	PM$_1$	208 *Olivella* beads, 6 *Haliotis* rufescens (one with 3 beads glued to it). Beads found around neck region. Partial cremation	Bilateral cribra orbitalia
B171	1.25 [1]	U	LP 625–510*	dM^1	Bone needle, charmstone, obsidian point	Periostitis (R humerus), bilateral cribra orbitalia
B187	3.5 [3]	M	LP 664–552*	dM$_1$	No grave associations	
B193	7.5 [4]	M	LP 540–499*	dM$_1$	8 clam shells stacked above red ochre, 3 *Haliotis* pendants, 271 *Olivella* beads, bird bone whistle, Stockton serrated projectile point with residue (possible cause of death)	Abscess (permanent mandibular canine)
B228	1.5 [1]	M	MP ~1820–1400	dM^1	2 *Haliotis* bracelets around wrists, 2 square *Haliotis* buttons, 12 *Olivella* beads, worked stone. Noted as high status infant.	Cribra orbitalia (L frontal)
B233	3 [2]	U	MP 1257–1069*	dM$_1$	No grave associations	No observed pathology
B236	1.25 [1]	NA	MP ~1820–1400	NA	Bird bone whistles, bone awl, 245 *Olivella* beads, 2 *Haliotis* pendants	No observed pathology
B237	1.75 [1]	NA	LP ~626–326	NA	Obsidian projectile point with organic residue on it	Periostitis (R radius), bilateral cribra orbitalia
B240	2.5 [2]	NA	MLTP ~730–554	NA	1,557 *Olivella* beads, 5 *Haliotis* pendants, sting ray barb section. Noted as high status infant	Bilateral cribra orbitalia
B246	2.25 [2]	NA	MLTP ~1264–965[bc]	NA	No grave associations	No observed pathology
B247	2.25 [2]	U	LP 626–326	dM^1	Obsidian dart point, steatite pipe, awl tip of bird bone, long bird bone whistle, mammal bone whistle, bone necklace, 752 *Olivella* beads, bone pendant, 2 *Haliotis* buttons. Noted as probably very high-status infant	Bilateral cribra orbitalia
B248	1.5 [1]	U	MLTP <~1264–965[b]	dM^1	710 *Olivella* beads	Periostitis (parietals), cribra orbitalia (R frontal)

B255	11.5 [5]	M	LP > 626–326	dM^1	Reworked *Haliotis* pendant	Periostitis (R humerus), periodontal disease
B264	4 [3]	M	MP >1929–1822	PM$_1$	No grave associations	No observed pathology
B270	7.5 [4]	NA	MP < 2307–2042	NA	No grave associations	Cribra orbitalia (L)
B271	6.5 [4]	U	MP ~1820–1400	dM$_1$	Split bone awl	Periostitis (L fibula and humerus), bilateral cribra orbitalia
B272	2.5 [2]	NA	LP (<664–552)	NA	No grave associations	No observed pathology

[a]EP=Early Period, MP=Middle Period, LP=Late Period, MLTP=Middle/Late Transition Period. MLTP individuals were included with LP for analysis purposes. [b]corresponds with the MCA. *Radiocarbon dated sample. dM^1=deciduous maxillary first molar, dM$_1$=deciduous mandibular first molar, dM$_2$=deciduous mandibular second molar, PM^1=permanent maxillary first molar, PM$_1$=permanent mandibular first molar. M=male, F=female, U=unknown sex, NA=not analyzed.

Table 2. Temporal Period Description by Cohort

Age Cohort	N	Middle Period	Transition Period	Late Period
1	14	3	1	10
2	10	3	4	3
3	2	1	0	1
4	7	3	0	4
5	6	1	2	3
Total	39	11	7	21
Mean Age (yrs)		4.5	5.3	4.4

Table 3. Biological Sex Description by Cohort

Age Cohort	Males	Females	Unknown	NA
1	5	1	5	3
2	0	4	2	4
3	2	0	0	0
4	2	3	1	1
5	1	1	1	3
Total	10	9	9	11

Table 4. Skeletal Pathology Description by Age Cohort, Sex, and Temporal Period

	PH	CO	P	DA	SB
Age Cohort 1	0	6	5	0	0
Age Cohort 2	0	3	2	0	0
Age Cohort 3	0	0	0	0	0
Age Cohort 4	1	4	1	1	1
Age Cohort 5	0	3	3	3	0

Total	**1**	**16**	**11**	**4**	**1**
Male	0	3	2	2	0
Female	1	3	2	1	1
Unknown	0	5	5	0	0
NA	0	5	2	1	0
Total	**1**	**16**	**11**	**4**	**1**
Middle Period	0	4	1	0	1
Transition Period	0	3	3	1	0
Late Period	1	9	7	3	0
Total	**1**	**16**	**11**	**4**	**1**

Table 5. Grave Goods Distribution by Age Cohort, Sex, and Temporal Period

	Burials w/ Grave Goods	Burials w/out Grave Goods	High-Status Burials
Age Cohort 1	13	1	9
Age Cohort 2	5	5	2
Age Cohort 3	0	2	0
Age Cohort 4	6	1	4
Age Cohort 5	4	2	3
Total	**28**	**11**	**18**
Male	7	3	4
Female	8	1	3
Unknown	7	2	6
NA	6	5	5
Total	**28**	**11**	**18**
Middle Period	7	4	4
Transition Period	4	3	2
Late Period	17	4	12
Total	**28**	**11**	**18**