COMING OF AGE IN THE ROMAN EMPIRE

COMING OF AGE IN THE ROMAN EMPIRE: EXPLORING THE SOCIAL AND PHYSICAL TRANSFORMATIONS OF *ADULESCENTIA* (ADOLESCENCE)

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LAY ABSTRACT

There are kids, and there are adults, but what about those in-between? When does one become the other? These are the questions driving this doctoral research, and in applying them to the Roman Empire, I examine patterns of puberty and changes in diet, to better understand when children started to look like and eat like adults in their communities. This research demonstrates that *adulescentia* (i.e., adolescence) was a period of extended biological development, with puberty occurring between 9 and 20 years of age. Changes in diet, however, occurred in different ways for males and females, and across space and time within the Roman Empire, suggesting that there was not a singular experience or definition of *adulescentia*, but that lived experiences were more variable and nuanced than ancient literary sources suggest.

ABSTRACT

In modern populations, adolescence is recognized as a pivotal part of the life course, but bioarchaeologists have not yet widely considered the experiences of adolescents in the past. This research investigates the biological and social changes during Roman *adulescentia* for individuals buried at *Isola Sacra* (1st-4th centuries CE; Italy) and Lisieux-Michelet (4-5th centuries CE; France).

To investigate biological changes, this thesis identifies osteological indicators of pubertal timing and peptide analysis to assess biological sex for pre-pubertal individuals (n=264). Results demonstrate that *adulescentia* experienced an extended period of puberty, from nine to 20 years of age; menarche occurred around 15 years of age. Comparisons between the two archaeological sites demonstrate similar patterns of pubertal timing, suggesting similar exposure to Early Life Stress.

To investigate the social changes, this research uses stable isotope analysis of incremental dentine sections in teeth, to investigate dietary change between childhood, adolescence, and adulthood. Incorporating literary sources, observed changes in diet are contextualized in relation to expected social age changes for middle-class individuals within the Roman Empire. At both sites, females exhibit a gradual dietary transition, reflecting a gradual social age change, or that diet is not an appropriate proxy for social age changes for women. For males, changing dietary patterns correspond with the beginning of *adulescentia*, when these young men took on new roles within their communities and underwent pubertal development.

This research demonstrates that *adulescentia* was an extended period of biological and social change for males and females, which took on different forms depending on one's sex/gender and social position. This research also demonstrates how investigations of adolescence can permit a more holistic interpretation of this transitional period of the life course and exposes the transitional experiences of these individuals as they come of age in the Roman Empire.

DEDICATION

In loving memory of Nika, aka "Stinkers"

In order to talk with the dead
you have to know how to wait:
they are fearful
like the first steps of a child.
But if we are patient
one day they will answer us

Excerpt from *In Order to Talk with the Dead* by Jorge Teillier (1935-1996)
(Translated by Carolyne Wright)

LAND ACKNOWLEDGEMENT

I take this space to recognize the peoples on whose land I live and conduct research.

I acknowledge that McMaster University is located on the traditional territories of the Haudenosaunee confederacy and Anishinabe nations, and within the lands protected by the "Dish with One Spoon" wampum agreement. This agreement, between the Iroquois Confederacy, the Ojibwe, and allied nations, set out for all peoples to peacefully share and care for the resources around the Great Lakes. In this agreement, the dish symbolises the territory and the spoon represents the people who are to share the resources and take only what they need.

Additionally, I live on the traditional territories of the Anishnawbe, Haudenosaunee and Neutral peoples in the land known as the Haldimand Tract. In 1784, the British gave this land to the Six Nations of the Grand River and Mississaugas of the Credit First Nation, in compensation for their role in the American Revolutionary War of Independence and for the loss of their traditional lands in update New York. This tract of land runs ten kilometers along each side of the Grand River, totalling 950,000 acres. Today, less than five percent of the original grant is under the protection of indigenous communities. The Haudenosaunee Confederacy Chiefs Council are actively working to reclaim the territory and prevent further erosion of this land. You can learn more about these on-going efforts and how you can support them by visiting www.protectthetract.com.

Lastly, I acknowledge that anthropology and archaeology is routed in colonial and racists ideologies, which has traditionally placed white researchers as gatekeepers of "knowledge" and has ignored or diminished the contributions of BIPOC community members. As a white settler in Canada, I acknowledge that I have benefitted from this history, and I endeavour to work towards a more equitable discipline that embraces and respects other ways of knowing and learning about people in the past.

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Thank you to my co-authors and collaborators, including Dr. Cecile Chapelain de Seréville-Niel and Julia Pacory from Centre de Recherches Archéologiques et Historiques Anciennes et Médiévale (Université de Caen Normandie, France), and Dr. Luca Bondioli and Dr. Alessandra Sperduti from Museo delle Civiltà di Roma (Rome, Italy), for providing access to the osteological collections and permissions to perform destructive analysis. Additional thanks Dr. Yu Lu and Dr. Sansi Xing of McMaster's RNA Proteomics Laboratory, for their technical expertise related to the peptide analysis of dental enamel.

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Thank you to my family, including my parents, brothers, in-laws and out-laws. I would have given up many times if not for your continued support, encouragement, and belief that I could accomplish anything. Thank you to my husband, D'Arcy, for vowing to keep me laughing every day (and accomplishing it). You've always seen the best in me, even when I could not, and your support has meant the world to me. Lastly, thank you to Nika. She passed shortly before this thesis was completed but was the best research companion. She could always get me away from the computer for a good walk and reminded me there was more to life than ancient Romans (like bananas and peanut butter).

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DECLARATION OF ACADEMIC ACHIEVEMENT

I declare that I am the main contributor to the three articles that make up this sandwich thesis. Chapter two, "Child and adolescent diet in Late Roman Gaul" is a co-authored paper in the *International Journal of Osteoarchaeology*. Chapter three (Puberty as a Measure of Developmental Stress) and chapter four (Eating Like Adults) are co-authored papers, prepared for submission to *American Journal of Biological Anthropology* and *Bioarchaeology International*, respectively. I am the first author for all three papers, collecting necessary data and conducting relevant lab work, and analyzing data, with input from my co-authors regarding methodology and appropriate sampling. I wrote the first draft, prepared the tables and figures, and collaborated with the co-authors on subsequent revisions.

CHAPTER 1: INTRODUCTION AND BACKGROUND

Adolescence is a key phase of the life course, marked by substantial biological and social changes. In modern populations, it is recognized as a pivotal period of life, capturing the outcomes of childhood experiences, and laying the foundation for adult physical and mental health and social well-being (Dorn *et al.*, 2019). Despite increased attention to adolescence in modern populations, the bioarchaeological study of adolescence is still lacking (Shapland & Lewis, 2014; Lewis *et al.*, 2016). Incorporating adolescence into the study of the past, however, holds the potential to understand these individuals more closely, and by extension, the communities and environments in which they lived and died.

Biologically, adolescence is the period in which individuals experience the pubertal growth spurt, gain half their adult weight, develop secondary sexual characteristics, and become capable of reproduction (Rogol *et al.*, 2002). Rather than an independent feature of somatic growth, however, clinical research has shown that the age at which individuals reach these milestones (i.e., pubertal timing), or the pace with which they progress through the stages of puberty (i.e., pubertal tempo), is influenced by childhood experiences including environmental, nutritional, and social conditions. Thus, some have proposed that pubertal timing and tempo may be used as a measure of early life stress (Joos *et al.*, 2018). For bioarchaeologists, this is an exciting area of research development, because it allows us to study early life experiences in the physical remains of individuals who survived the period of childhood. Clinical research has also linked pubertal timing with later health and disease outcomes, including adult bone density, mental health, risk of cancer, and cardiovascular disease (Sawyer & Patton, 2018; Viner *et al.*, 2015). Thus, the bioarchaeological analysis of adolescents may also provide insights into adult health and well-being within a population or highlight potential health consequences within a community.

Socially, adolescence is recognized as a transitional period between childhood and adulthood, and often includes a change in social position, as young people try on adult roles and take on new responsibilities within their families and communities (WHO, 2014). While the ways in which this achieved will vary between communities, as social age is culturally constructed, Sawyer & Patton (2018) suggest that the social and economic contexts in which young people experience these social transitions are profoundly influential on adolescent health and well-being. For bioarchaeologists, studying the social transitions during adolescence and the resulting changes on the human body can provide insights into the social environments, with high-quality, secure, and stable environments leading to lower rates of adolescent mortality, injury, and exposure to diseases.

By incorporating both the biological and social experiences of adolescence, bioarchaeologists can explore health impacts of childhood and the potential health outcomes in adulthood, as well as work to understand the social conditions in which young people were transitioning from child to adult roles within their community. This thesis is one of the first efforts

to explore this period of the life course and connect changes in adolescence to changes at other points in the life course, to better understand lived experiences of adolescents in the past.

In the Roman Empire (31 BCE – 476 CE), literary sources describe *adulescentia* as a period of learning and exploration (Harlow & Laurence, 2002). However, literary sources tend to focus on the experiences of wealthy individuals rather than middle or lower social status groups, and as a result, we are uncertain how *adulescentia* was experienced in these populations. The purpose of this thesis is to explore the period of *adulescentia* in two middle-class populations in the Roman Empire through the analysis of their physical remains. By considering both the social and biological changes associated with the period of *adulescentia* incorporating bioarchaeological, literary, and clinical evidence, this dissertation explores coming of age in the Roman Empire, and how these experiences may have varied for men and women at different places within the Empire. In doing so, I also seek to expand how bioarchaeologists might examine, explore, and understand the lives and lived experiences of adolescents and children in the past. To accomplish this, my doctoral research has two objectives:

1. To correlate historical evidence for social age changes between childhood, adolescence, and adulthood for middle-class individuals from Roman populations, with dietary evidence derived from stable isotopes of incremental tooth dentine sections.
2. To understand when the physical changes of puberty occurred for individuals from two middle-class Roman populations from France and Italy, as determined through observed changes in the human skeleton using criteria developed by Shapland and Lewis (2013, 2014).

To accomplish these objectives, my research uses a biocultural approach, which emphasizes how sociocultural and political-economic processes influence the biology of people, and how these altered biological states subsequently change social environments (Goodman & Leatherman 1998). In using the biocultural approach, anthropologists work to understand the basis for biological states, through an analysis and interpretation of the social conditions (Goodman & Leatherman, 1998). Within the context of the current research, this is accomplished by understanding the social conditions and lived experiences that contributed to stable carbon and nitrogen isotope ratios in teeth or contributed to the timing of pubertal changes in these Roman populations. In doing so, my research also demonstrates how bioarchaeologists can investigate adolescence in the past, offering a tangible way to consider their lived experiences, which up until now has largely been absent from discussions of past lifeways.

The objectives are investigated and addressed in the three articles included in this thesis, which have been submitted to relevant peer-reviewed journals. The first article (Chapter two), 'Child and adolescent diet in Late Roman Gaul' is published in the *International Journal of Osteoarchaeology*. In this study, dietary stable isotopes of incremental dentine sections from Lisieux-Michelet (France, 4-5th centuries CE) are examined to explore gendered dietary patterns in childhood and adolescence, and to understand these patterns in relation to expected social age changes in the Late Roman life course. 'Pubertal timing as a measure of early life stress in Roman Italy and Roman Gaul' (Chapter three) identifies when the physical changes associated with puberty occurred for individuals buried at *Isola Sacra* (Italy, 1st-4th centuries CE) and Lisieux-Michelet, based on pubertal timing methods proposed by Shapland and Lewis (2013, 2014). We contextualize these results in relation to ancient literary discussions of pubertal timing patterns for both men and women. To assess biological sex for pre- and peri-pubertal individuals, peptide

analysis is used, identifying amelogenin X and Y peptides in tooth enamel. Integrating models of allostatic load and early life stress (ELS), this article explores differences in pubertal timing and tempo between males and females, and between the two archaeological sites. In doing so, this research demonstrates how pubertal timing may be used by bioarchaeologists as a proxy for physiological stress during childhood. This manuscript is prepared for submission to the *American Journal of Biological Anthropology.* The last article, 'Eating like adults' (Chapter four) investigates dietary change at the Roman Imperial site of *Portus Romae* (1^{st}-4^{th} centuries CE), using stable isotope analysis of incremental dentine sections from the *Isola Sacra* necropolis where the people of *Portus Romae* were buried. This article investigates the transition from a child to adult diet, relating patterns of change to possible social age changes for men and women. This paper also investigates sex-specific patterns of dietary change, to consider how gender may have continued to influence dietary patterns during *adulescentia*. The manuscript has been submitted to *Bioarchaeology International*, and is in review for a special issue entitled, 'Emerging Adolescence'.

For the three papers included in this thesis, I analyzed the macroscopic skeletal remains, recording data for age and sex estimates, as well as osteological indicators of pubertal timing. In consultation with the respective collection holders, I collected dental samples for subsequent biochemical analyses including dietary stable isotopes and peptide analysis. Permission to access the skeletal collections and extract dental samples from Lisieux-Michelet and *Isola Sacra* were provided by Dr. Cecile Chapelain de Seréville-Niel and Dr. Luca Bondioli, respectively. For the stable isotope analysis, I prepared the dental samples and sent the powdered collagen to the Ján Veizer Lab in Ottawa, Canada, for mass spectrometry. To validate the peptide methodology, I obtained ethics approval, under Dr. Tracy Prowse's guidance, and collected modern dental samples. I then established a protocol for extracting peptides from enamel, based on publications by Stewart *et al.* (2017), and worked with Dr. Yu Lu and Dr. Sansi Xing (RNA Proteomics Lab, McMaster University) to refine this protocol using modern teeth from individuals of known sex. I performed all statistical analysis and wrote the first draft of each paper. All co-authors provided feedback on subsequent drafts.

In addition to these three articles, this thesis includes an introductory chapter, which provides essential background information on physical and social changes associated with the period of adolescence, and background on the two archaeological sites included in this research. The discussion and conclusion chapter (Chapter five) outlines how these three articles meet the objectives of this thesis, draws out the implications of this research, and provides recommendations for the continued study of adolescence from a bioarchaeological perspective.

SOCIAL CHANGES IN ADOLESCENCE

Throughout history, many societies have differentiated between children and adults based on biological and social developments, often with a transitional period between the two (Crockett, 1997). However, we cannot assume that these divisions of the life course occurred at the same time throughout history, nor can we assume that they encompassed similar experiences. Rather, we must consider social age changes within the context of the life course for each population or community (Revel, 2005). As a starting point for the Roman Imperial period (1^{st}-5^{th} centuries CE), life course models suggest that there was a distinct phase between childhood and adulthood entitled *adulescentia,* which ancient writers describe as a period of exploration and learning (Eyben, 1993).

For young men, literary sources suggest that this period began when they removed their *bulla* (protective amulet) and childhood toga and put on the adult toga for the first time. Following this change, young men would be allowed to start small businesses and were encouraged to drink heavily and visit brothels. However, these experiences were likely only available for wealthy young men (Eyben, 1993). For middle- or lower-class individuals, literary sources are largely silent; however, historians and archaeologists suggest that *adulescentia* for these men was likely focused on experiences in the military or in apprenticeships (Isayev, 2007; Dixon, 1992).

Relative to the men, very little is known about the women's life course in Roman society (Laurence, 2000). Literary sources are inconclusive, but historians believe a woman's *adulescentia* began at menarche (or possibly puberty more generally) and continued until marriage (Caldwell, 2015). According to Graeco-Roman medical writers such as Rufus of Ephesus (1st-2nd centuries CE) and Soranus (1st-2nd centuries CE), puberty in girls (as indicated by breast budding) began around 12 years of age, and menarche occurred around age 14, suggesting the beginning of *adulescentia* around this time (Eyben, 1972). While the legal minimum age of marriage was set at 12 years of age for girls, studies of Roman epitaphs demonstrate that middle-class women often married in the late-teens or early twenties (Caldwell, 2015; Lelis *et al.*, 2003; Saller, 1987; Shaw, 1987; Revel, 2005). Between pubertal onset and marriage, it is likely that these women would have learned domestic skills from female relatives (Laes & Strubbe, 2014; Bradley, 1991). However, these interpretations are still based, predominantly on literary sources, thus, it is unclear how applicable they are for non-wealthy individuals, or for those living further away from Rome.

To further consider social age changes, some researchers examine mortuary profiles (i.e., grave goods, grave constructions and grave locations), relating sex- and age-based patterns to changing social roles within a community (Gowland, 2016). Using this approach at Late Roman Winchester (4th century CE, Winchester, UK), Gowland (2001) noted that females aged 18-25 years were buried with a higher number of grave goods than other age categories, indicating that this was the period in which young women were marrying at the site. Assessing life course transitions at various sites in Roman Britain (1-5th centuries CE) Moore (2009: 177) found that females aged 11 to 39 had a higher number of grave goods than other age categories, suggesting "these years were pivotal within the female life course". For males, the highest number of grave goods occurred slightly later in the life course, between 20 and 39 years of age, suggesting that men experienced a later entry into adulthood than women (Moore, 2009). While these studies demonstrate that the analysis of mortuary profiles has the potential to expose social age transitions at a particular site or settlement, there are also limitations to this approach. For example, if burials have been heavily looted or disturbed by modern and historic constructions, the mortuary profiles will be incomplete and unreliable. Examining the burial remains of deceased children also brings up issues related to the Osteological Paradox, and if the burial inclusions were included because they were of a particular social age, or because they died too young (Wood *et al.*, 1992; Binford, 1971). Burial practices can also be complicated by other aspects of identity. For example, at Lankhills, the archaeological site analyzed by Gowland (2001) to investigate social age, researchers also examined mortuary profiles in relation to social status based on grave constructions (Avery *et al.*, 2019) and ethnic identity based on burial patterns and grave goods (Baldwin, 1985), demonstrating that the burial environment is not solely an indicator of social age. Lastly, as macroscopic methods to estimate sex in pre-pubertal skeletal remains are unreliable, we are largely prevented from analyzing sex-specific differences at the youngest ages (Lewis, 2019). As a result, we may be unable to assess sex-based or gendered patterns within the mortuary

environment, preventing a more nuanced understanding of social age changes for younger individuals.

Another potential avenue to explore social age changes is to investigate dietary changes through the study of serial dentine sections, which develop during childhood and adolescence. By extracting these dental samples from adult skeletal remains, we are able to conduct more reliable sex estimations, and mitigate many of the previously identified issues. By contextualizing these changes in diet to expected social age changes, we may be able to identify when social age changes occurred for individuals in the past. One of the first applications of this approach was completed on teeth from Wharram Percy (10-16th centuries CE; Yorkshire, UK), where Fuller and colleagues (2003) examined stable isotopes of carbon and nitrogen in seriated dentine sections across different tooth types. When discussing the longitudinal profiles, Fuller *et al.* (2003) noted that, for one female individual, the stable isotopes indicated increased marine resource consumption during later childhood and/or early adolescence; for a male individual, however, a similar dietary change was noted in the "late teenage years" (Fuller *et al.*, 2003: 1679). Although this approach was only applied to a few samples and, thus, cannot represent sample-wide patterns, the study completed by Fuller and colleagues (2003) demonstrates the possibility of using stable isotope analysis of incremental dentine to investigate dietary change around the period of adolescence. Through greater contextualization of the results, we may also be able to link changes in diet to possible changing social roles. Applications of seriated dentine sections in stable isotope analyses have largely focused on patterns of weaning, by examining the first molar. Yet, by applying this approach to second and third molars, we may be able to explore these embodied experiences during later childhood and adolescence, investigating how diets changed as individuals aged. By using a biocultural approach and contextualizing the stable isotope results, we may, therefore, be able to investigate social age changes for those not documented in literary depictions of *adulescentia*.

PHYSICAL CHANGES IN ADOLESCENCE

Puberty is a period of rapid physical changes characterized by the development of secondary sexual characteristics and the pubertal growth spurt (Nadler, 1998; Dimeglio, 2006). Hormonally, puberty consists of two separate physical processes: adrenarche and gonadarche, which are controlled through the hypothalamic-pituitary-adrenal (HPA) and hypothalamic-pituitary-gonadal (HPG) axes, respectively (Lam *et al.*, 2015; van den Berg *et al.*, 2006; Ebling, 2005). When discussing puberty, researchers often sub-divide this period of development into five stages: pre-puberty, acceleration, peak height velocity (PHV), deceleration, and post-puberty. The first outwardly physical signs of puberty occur during the acceleration stage, including breast budding in girls, and the growth of the testes and scrotum in boys (Tanner, 1986). At this point, the rate of vertical growth also begins to increase, corresponding to the pubertal growth spurt. At mid-puberty, PHV is reached, with an average height increase of 8.3 cm/year for girls and 9.5 cm/year for boys (Carswell & Stafford, 2016). Approximately one year after PHV, during the deceleration phase, menarche in girls and voice masculinization in boys are achieved (Hagg & Taranger, 1982; Demirjian *et al.*, 1985). Puberty ends after the completion of the pubertal growth spurt, when breast and genital development are complete and reproductive capacity is achieved (Cameron, 2003).

The physical developments associated with puberty are often described in relation to the Tanner stages or Sexual Maturity Ratings (SMR), which categorize the changes associated with

the breasts, genitalia, and pubic hair, from pre- to post-puberty (Marshall & Tanner, 1969; 1970). Although these soft-tissue changes are not typically accessible to bioarchaeologists, clinicians have also identified several osteological changes that coincide with pubertal development. These methods have been summarized and adapted for use on dry bone by Shapland and Lewis (2013, 2014). By evaluating features of the hand and wrist, cervical vertebrae, mandibular canine, and iliac crest, osteologists can determine the pubertal stage-at-death for an individual and begin to build a pattern of pubertal timing for a sample based on the presence and development of these features. To date, the pubertal timing methods have been applied to a wide range of contexts, including Bronze Age Spain (Doe *et al.,* 2019), Roman Britain (Arthur *et al.,* 2016), medieval England (Lewis *et al.*, 2016; DeWitte & Lewis, 2021), post-medieval Netherlands (Blom *et al.*, 2020) and early modern Portugal (Henderson & Padez, 2017). These studies have worked to validate and expand the applicability of pubertal timing methods and have demonstrated that pubertal timing has varied across human history.

Variation in pubertal timing can be attributed to a number of factors, including nutritional and metabolic conditions (Soliman *et al.,* 2014), exposure to pollution and endocrine disrupting chemicals (EDCs) (Walvoord, 2010), experiences of illnesses and medical treatments (Rosen & Foster, 2001; Pozo & Argente, 2002), as well as social conditions including low socioeconomic status, migration status, father absence, and urban environments (Walvoord, 2010; Sun *et al.*, 2017), in addition to genetic influences (Francis, 2014; Wohlfahrt-Veje *et al.,* 2016). As pubertal timing and tempo are influenced by so many factors, some researchers (e.g., Joos *et al.,* 2018) suggest that these measures may provide insights into early life stress (ELS) and childhood adversity (explored in Chapter three). Thus, by understanding when puberty occurred in an archaeological sample, and contextualizing the results with other lines of evidence, we may be able to gain a more thorough understanding of childhood experiences for those who survived the immediate period of childhood, as well as life more broadly, in past populations.

ARCHAEOLOGICAL SITES

To facilitate comparisons between geographical and temporal locations within the Roman Empire, two sites were selected for analysis in this research.

ISOLA SACRA

Located approximately 23km southwest of Rome, the necropolis of *Isola Sacra* is located on the artificially created island of *Isola Sacra* and is associated with the Roman Imperial town of *Portus Romae* (Keay & Millett, 2005). Constructed between 42 and 64 CE, *Portus* became one of the most important trading centres in the Mediterranean, directly supporting the approximately one million inhabitants of Rome with shipments of food, goods, and people (Hoover *et al.*, 2005). Relying on the port for much of its commercial activities, the community of *Portus* included merchants, traders, shopkeepers, carpenters, craftsmen, and artisans (Cho & Stout, 2003; Sperduti *et al.*, 2012). Little evidence remains of an elite class living within the community; rather, it seems that rich landowners and aristocrats lived in their estates closer to *Ostia Antica* (Crowe *et al.*, 2010; Keay & Millett, 2005). By the end of the 4th century CE, commercial activity at *Portus* began to decline, but the port remained operational, and harboured the Roman fleet during invasions of the

5th and 6th centuries CE (Prowse *et al.*, 2008). The port and surrounding settlement were eventually abandoned in the 9th century CE (Baldassarre, 1978).

The necropolis of *Isola Sacra* was established between *Portus* and *Ostia* and served as the main necropolis between the 1st-4th centuries CE (Calza & Becatti, 2008). It was re-discovered as early as 1699 CE and excavated by various individuals and institutions since the 19th century (Germoni *et al.,* 2011). More than 200 funerary buildings and 2000 individuals from over 600 single and collective inhumations have been excavated (Baldassare, 1990; Sperduti *et al.*, 2012). Calza and Becatti (2008) suspect that only a small portion of the necropolis has been identified and excavated, and that the remainder of the tombs and burials are under surrounding cultivated fields. The human remains are currently housed at the Museo delle Civiltà in Rome, Italy.

Previous bioarchaeological research based on samples from *Isola Sacra* has focused on enamel hypoplasia and Wilson bands in teeth (FitzGerald *et al.*, 2006; Hoover *et al.*, 2005; Nava *et al.*, 2019), external auricular exostoses (Crowe *et al.*, 2010; Manzi *et al.*, 1991; Sperduti *et al.*, 2012), vitamin D deficiencies (Brickley *et al.*, 2018; Mays *et al.*, 2018; Lockau *et al.*, 2019), mobility using stable isotope analysis (Prowse *et al.*, 2007; Stark, 2016), age-related bone loss (Cho & Stout, 2003), and ancient DNA investigations of thalassemia (Yang, 1997) and malaria (Marciniak *et al.*, 2018). Perhaps most relevant to the current thesis are the previous studies focused on dietary stable isotopes. These analyses demonstrated that the individuals from *Portus* ate a mixed diet of marine and terrestrial foodstuffs, although sex-based and age-based differences were present (Prowse *et al.*, 2004, 2005, 2008).

LISIEUX-MICHELET

The ancient Roman city of *Noviomagus Lexoviorum*, in modern-day Lisieux, Normandy, France, was an urban center focused on trade and artisanal production, in Roman Gaul. Located 30km south-east off the north coast of France, the area consisted largely of grasslands and orchards, with sandy embankments around the Roman settlement (Paillard *et al.*, forthcoming). The Roman town was established in the 1st century CE and, due to its geographical position along major trade routes and proximity to the sea, expanded to a major urban and commercial centre in the 2nd century CE (Paillard *et al.*, 2006). At this time, craft production developed as a major industry in the community, with evidence of a large metallurgy workshop, ceramic production, and working of fine materials (Paillard, 1994). In the 3rd century, following a series of raids on *Noviomagus Lexoviorum*, the previously open-urban settlement became a smaller fortified village (Paillard *et al.*, 2006). In the 4th and 5th centuries, archaeological and literary evidence suggests the presence of a garrison in the city, specifically a fixed or mobile military contingent related to the *Litus Saxonicum* (Paillard *et al.*, forthcoming; Blondiaux *et al.*, 2012). After the fall of the Roman Empire, *Noviomagus Lexoviorum* was inhabited by the Merovingians from the 6th-9th centuries CE.

The Lisieux-Michelet archaeological site encompasses the main necropolis for *Noviomagus Lexoviorum*, used in the Late Roman and Merovingian periods (4th-9th centuries CE) (Blondiaux *et al.*, 2002). The site was discovered in the late 19th century, but not excavated until the 1990s in response to road construction in the area (Paillard *et al.*, 2006). Over four years, a total of 8400m^2 were excavated, uncovering 1156 skeletons from 970 graves (Paillard *et al.*, 2009). The osteological remains of the Michelet Necropolis are currently housed at the Centre Michel de

Boüard – CRAHAM[1] laboratories at the Université de Caen, in Normandy, France. To date, research on the osteological remains has focused on paleodemography (Paillard *et al.*, 2006), maternal death and obstetrics (Alduc Le Baogusee & Blondiaux, 2002), evidence of interpersonal trauma in adults and children (Blondiaux *et al.*, 2012; Blondiaux *et al.*, 2002; Timmins *et al.*, 2017), vitamin D deficiencies (Brickley *et al.*, 2018; Mays *et al.*, 2018), Paget's disease (Roches *et al.*, 2002) and infantile cortical hyperostosis (Alduc Le Baogusee & Blondiaux, 2001). In the current research, only skeletal remains dating to the Late Roman period (4-5th centuries CE) are included.

[1] Centre de Recherches Archéologiques et Historiques Anciennes et Médiévales.

CHAPTER 2: CHILD AND ADOLESCENT DIET IN LATE ROMAN GAUL

Title: Child and Adolescent Diet in Late Roman Gaul: An investigation of incremental dietary stable isotopes in tooth dentine.

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ABSTRACT

Incremental analysis of stable carbon and nitrogen isotopes in tooth dentine is used to explore child and adolescent diet among individuals in the Late Roman Michelet Necropolis (Lisieux, France; 4-5th centuries CE). We analysed 292 incremental sections from 46 second and third molars to explore dietary patterns between the ages of 4.5 and 23.5 years. Results indicate that individuals consumed more, or higher trophic level, terrestrial-based animal proteins as they aged. Sex-based comparisons also suggest that males and females consumed isotopically similar diets for most of their childhood; however, around age 16.5, males exhibited significantly lower $\delta^{15}N$ values than females with a large effect size ($U=21.0$, $p=.012$, $g=1.3$). This difference in diet occurs during an important age-based social change in the Roman life course, as individuals transitioned from childhood (*pueritia*) to adolescence (*adulescentia*). When the isotopic data are combined with literary and archaeological evidence, it suggests that this was the point when men and women diverged in their life course trajectories. Young men were expected to begin apprenticeships or military duty away from home, while women were kept close to their family home at this age. The isotopic results suggest these gendered experiences may have influenced dietary choices or access to foods at Lisieux-Michelet. The results of this study demonstrate the utility of using permanent dentition in adult remains to explore childhood experiences and provide new insights into child and adolescent diet and gendered experiences in the context of the Late Roman Empire.

INTRODUCTION

Exploring social changes throughout childhood can provide unique insights into lived experiences. These include the beginning of gendered actions or behaviours and the impact of social age changes along the life course. Some researchers have explored these changing social roles using mortuary profiles, by identifying changes in patterns and distributions of grave goods by age-at-death and osteological sex-based groups within a cemetery sample (Gowland, 2001). However, this approach faces challenges, due to limitations of current macroscopic methods to estimate osteological sex in non-adults, and issues related to the osteological paradox (i.e., studying deceased children to learn about childhood) (Lewis, 2019; Wood *et al.*, 1992). By employing stable isotopes, we can mitigate these issues and examine biological indicators of childhood captured in adult skeletal remains, allowing us to conduct more reliable osteological sex estimations, and better understand the experiences of individuals who survived the period of childhood. Dietary stable isotope analysis is a method used to investigate broad patterns of dietary intake, typically using bone or tooth samples (Schwarcz & Schoeninger, 1991). Incremental analysis of tooth dentine, developed over the last 15-20 years, allows researchers to explore evidence for dietary *change* within an individual, as well as dietary intake, providing researchers with greater temporal resolution of samples, and more data per tooth (Fuller *et al.*, 2003; Eerkens *et al.*, 2011).

With this in mind, we use stable carbon and nitrogen isotope analysis of incremental dentine sections to investigate child and adolescent diet at the Late Roman site of Lisieux-Michelet (Lisieux, France; 4-5th centuries CE). In particular, we investigate gendered dietary differences across the period of childhood and adolescence and work to understand these dietary patterns in the context of expected social age changes in the Late Roman life course.

To help differentiate between various measures of age, we use the term "non-adult" when discussing biological age and "child" or "childhood" when discussing social age. Rather than using Western terms for periods within childhood (e.g., infant, teenager), we use culturally specific terms to better reflect the social constructionism of childhood in Late Roman Gaul (e.g., *infantia, adulescentia)*. Following Halcrow & Tayles (2008), no cut-off point between non-adult/adult or child/adult is identified, as the division depends on the social context. Additionally, sex (male, female) is used when discussing osteological sex estimations and sex-based results, while gender (man, woman) is used when discussing lived experiences and contextualized data.

BACKGROUND

Childhood Social Theory is a theoretical framework that views childhood as a socially and culturally constructed period of life and emphasizes that the sub-divisions within childhood are dependent on the community, as well as the gender, age, and status of the individual (Ariès, 1962; Halcrow & Tayles, 2008; Buchet & Séguy, 2008). To investigate social age in the Late Roman Empire, we may use descriptions of Roman life course models as a guide. However, we acknowledge that variations and discrepancies may exist between the literary sources and lived experiences, in part because one's position in the Roman life course was guided by chronological age, physical and mental capabilities, and other aspects of identity (e.g., social position). The Late Roman life course model described by Isidore of Seville (560-630 CE) contains six stages for men, and in each stage, he describes the physical and mental capabilities along with an approximate age

range (Table 2-1; Sharpe, 1964; Lett, 2019). A woman's position in the life course, however, was not so clearly divided. Isidore's life course model mentions stages of *virgos* (virginal but physically mature woman), and *puerpera* (pregnant women) but does not mention life course stages past this point (Sharpe, 1964). Other life course models include *uxores* (wives) and *matronae* (mothers) as distinct stages, but do not provide age ranges or other characteristics (Harlow & Laurence, 2002).

Table 2-1: The Roman Imperial life course for men, as presented by Isidore of Seville (560-630 CE).

Social Age Period	**Approximate Ages**	**Description**
Infantia (infancy)	0-7 years	Teeth are "not yet properly arranged", and cannot clearly speak
Pueritia (childhood)	7-14 years	Pure; unable to reproduce; unable to grow facial hair
Adulescentia (adolescence)	14-28 years	Able to reproduce, maturing and rapidly growing
Juventus (youth)	28-50 years	Increased energy, strongest of all ages, prepared to help
Gravitas (maturity)	50-70 years	Mature but not yet old, sound judgement
Senectus (old age)	70+	Wise but weakened

Social age periods represent the experiences of men. Female terminology exists but is less well defined by age ranges and capabilities. Adapted from Sharpe, 1964:49-51.

Beyond social ages, Greek and Roman authors also wrote about recommended diets, and how these differed depending on ones' age and gender, largely based on medical theories of the time (Badel, 2012). For example, medical writers, including Galen and Hippocrates, suggested that men were "hot and dry" and encouraged them to consume "wet and cold" marine resources to help maintain balance, and ultimately, maintain health (Garnsey, 1999). Women, in contrast, were considered inherently "wet and cold" and were advised to avoid marine resources, and consume diets focused on cereals and terrestrial proteins (Garnsey, 1999). However, these sources may represent an idealized version of the Roman diet rather than an accurate representation of what the general population consumed (Beerden, 2019). To address these biases, complementary lines of evidence are often used to investigate diet, including human dietary reconstructions. As one might expect, there is a great deal of variation. For example, some bioarchaeological studies of the Roman Empire have shown clear dietary differences between males and females (e.g., Prowse *et al.*, 2005), while others show no significant differences (e.g., Fernandez-Martinez *et al.*, 2020), and others suggest that gendered diets depended, in part, on social status (e.g., Avery *et al.*, 2019).

Dietary stable isotope investigations of non-adults in the Late Roman Empire typically focus on patterns of weaning, with few studies exploring childhood diet more broadly. In one such study, Mion and colleagues (2016) found that non-adults and adults at Amiens, France (3-5th centuries CE), consumed isotopically similar diets. In contrast, Redfern and colleagues (2018) found that non-adults in Roman London (1-5th centuries CE) consumed more freshwater resources than adults, and that adult diets were achieved by 17-19 years of age. In a study of Late Roman

Granada, Spain (4-7th centuries CE), Fernandez-Martinez *et al.* (2020) found that non-adults aged 0-3 years consumed diets that were significantly different from adults, possibly due to breastfeeding, while individuals aged 4-8 and 9-18 years were not significantly different from adults. However, these studies examined bone collagen which is problematic for two reasons. First, bone collagen turns over at a relatively slow rate, even among growing children, so the isotopic values from bone represent a long-term average (Waters-Rist & Katzenberg, 2010). Second, isotopic values from non-adult remains represent the "non-survivors" who did not make it through childhood, and who may have been eating a suboptimal or altered diet (Beaumont *et al.*, 2015). Therefore, by investigating stable isotope signals in permanent teeth of individuals who survived to adulthood, we do not have to contend with trying to infer living diet from non-survivors.

MATERIALS AND METHODS

NOVIOMAGUS LEXOVIORUM

The city of *Noviomagus Lexoviorum* was a *civitas* in Late Roman Gaul, located near present day Lisieux, France (Paillard *et al.*, 2009) (Fig. 2-1). The town was established in the 1st century CE and fortified with a *castrum* following a series of raids and conflicts at the end of the 3rd century (Paillard *et al.*, 2006). During the 4th century, *Noviomagus* had an estimated population of 400 permanent inhabitants living within the city walls (Paillard *et al.*, 2006). The chronology of the site was defined by the stratigraphic relationships and organization of the burials, dating of the funerary furniture and coins, and radiocarbon (^{14}C) dating (Paillard *et al.*, forthcoming).

Industry at *Noviomagus* was diverse, with evidence for trade, farming, and an artisanal district suggesting a predominantly middle-class population (Paillard *et al.*, 2009). Located along major roads, *Noviomagus* was an important commercial center for the area, facilitating trade from the coast into Roman Gaul and beyond (Munaro, 2012). Additionally, in the 4th and 5th centuries, a military garrison was likely present, probably as part of the *Litus Saxonicum* (Paillard *et al.*, 2006).

The Lisieux-Michelet Necropolis was discovered outside the city walls and used during the Late Roman (4-5th centuries CE) and Merovingian periods (6-9th centuries CE) (Paillard *et al.*, 2006). A total of 1156 skeletons were recovered from 970 graves (Paillard *et al.*, forthcoming). Only individuals associated with the Late Roman Period were included in the current study. This corresponds to a period of great socio-political transformation in the region, including the rise of Christianity, vast migrations, and changes in the seat of power (Halsall, 2012). We must be cognisant of these changes, as they may affect expected social age changes and gender roles (Alberici & Harlow, 2007).

AGE AND SEX ESTIMATION

To ensure that osteological sex estimations could be reliably completed, only those with an age-at-death above 15 years were sampled, based on dental development (Gustafson & Koch, 1974), epiphyseal fusion (Cardoso, 2008a; 2008b), and pubic symphysis morphology (Brooks & Suchey, 1990; Katz & Suchey, 1986). Sex was estimated using standard pelvic and cranial morphology (Acsádi & Nemeskéri, 1970; Phenice, 1969).

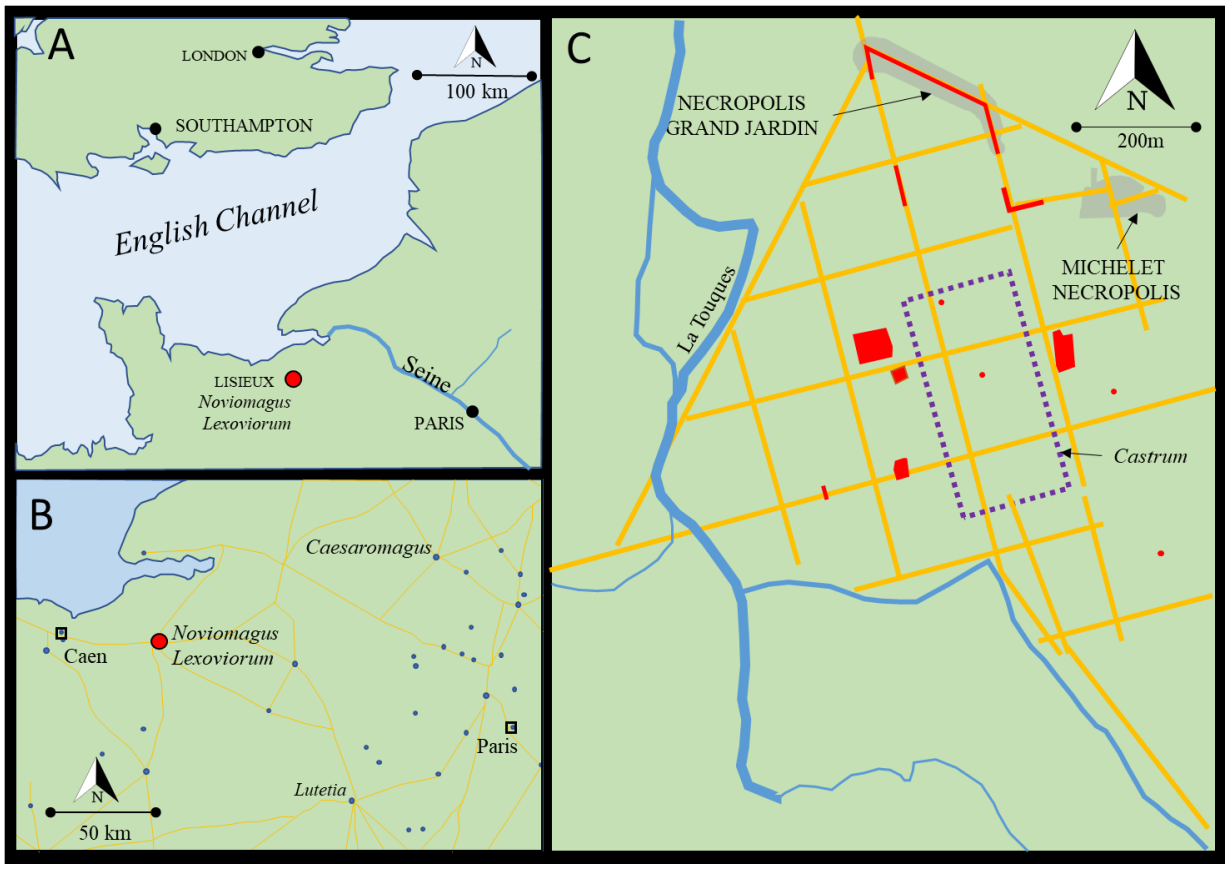

Figure 2-1: *Noviomagus Lexoviorum* (Lisieux, Normandy, France). A: *Noviomagus Lexoviorum* (in red) as positioned in relation to the English Channel. B: *Noviomagus* (in red) as positioned in Northern France, with major Roman roads indicated in yellow. C: The presumed town plan of *Noviomagus*. Red indicates excavated areas, grey indicates excavated cemeteries, including the Michelet Necropolis, and the purple dotted line indicates the fortified *castrum*, built in the 3rd century CE (adapted from Paillard *et al.*, 2006, Fig. 1 and 3).

STABLE ISOTOPE METHODOLOGY

Fully developed and well-preserved second and third molars were selected from 46 different individuals from Lisieux-Michelet to investigate dietary changes between 4.5 and 23.5 years of age. Teeth were cleaned, dried, and embedded in Buehler EpoThin epoxy, and sectioned along the mesio-distal plane using a Buehler IsoMet1000 slow-speed saw with diamond blade. Teeth were removed from the epoxy by soaking the embedded tooth in 100% acetone, which does not influence isotopic ratios (France *et al.*, 2011). One half of the tooth was used for isotope analysis and the other half was retained for future research.

Enamel was removed with a Dremmel drill, and the remaining sample was rinsed, dried, and demineralized using 0.5M hydrochloric acid (HCl), changed daily until demineralization occurred (following Beaumont & Montgomery, 2016). Once demineralized, teeth were sectioned following dentine formation patterns, as illustrated by Brickley *et al.* (2019), using landmarks within each tooth (e.g., in relation to the pulp chamber or bifurcation of the roots). Compared to horizontal cuts (e.g., Beaumont & Montgomery, 2016), this approach takes the directionality and pace of incremental growth structures into account, by cutting at oblique angles and following patterns of tooth formation. In using this approach, we provide a more accurate representation of changes in diet over time. However, this approach is not perfect, as dentine develops in cone-like structures, and thus, even oblique cuts will result in some blending between age points (Eerkens *et al.*, 2011). Sectioning targeted 8 samples for M2s (mean: 7.4 sections), and 6 sections for M3s (mean: 5.6 sections), while maintaining the 2mg sample size necessary for mass spectrometry. The sectioned samples were heated in 0.001M HCl at 70º Celsius for up to 48 hours. The liquid collagen was then dried and weighed to determine the percent yield.

Prepared samples were sent to the Ján Veizer Stable Isotope Laboratory (University of Ottawa, Canada) for analysis on a Vario EL Cube Elemental Analyser connected to a Delta Advantage isotope ratio mass spectrometer, coupled with a Conflo IV interface. Stable carbon and nitrogen isotopic compositions were calibrated relative to the VPDB and AIR scales using USGS40 and USGS41. The precision of analysis for $\delta^{13}C$ and $\delta^{15}N$ is 0.2‰ or better. Sample integrity was assessed using C:N ratios (acceptable range: 2.9-3.6), collagen yields (>1.0‰ *coll*), and percent carbon and nitrogen by weight (>3%C, >1%N) (DeNiro, 1985; Schwarcz & Schoeninger, 1991; van Klinken, 1999; Ambrose, 1993). Samples that did not meet these limits were excluded from analysis.

Age estimation of dentine sections was completed by comparing the samples' anatomical location to the stage of dental development following The London Atlas, including mean ages and standard deviations (AlQahtani *et al.*, 2010; 2014; Liversidge *et al.*, 2020).

STATISTICAL ANALYSIS

Within bioarchaeology, the use of a significance test is very common, which can be drastically affected by sample sizes (Smith, 2017). Therefore, it is recommended that studies report both statistical significance (p value), which indicates *if* there is a significant difference, and substantive significance (effect size or confidence intervals), which indicates *how big* the difference might be (Sullivan & Feinn, 2012). If a result is not significant ($p>.05$) but has a large effect size ($g\geq0.8$), it suggests a difference may be present, but the sample size is too small to detect a significance. Alternatively, if a result is significant ($p\leq.05$) but has a small effect size

($g \leq 0.3$) it suggests that the differences are small and may not be meaningful (Fritz *et al.*, 2012). For this study, non-parametric tests were used to calculate significance (e.g., Mann-Whitney, Spearman's Correlation), with a threshold of 95% ($p \leq .05$). To calculate effect size, Hedge's G was selected as it is more conservative than Cohen's D and is more appropriate for small and unequal sample sizes (Fritz *et al.*, 2012).

RESULTS

Of the 309 dentine sections, 292 had acceptable sample integrity values and were subjected to statistical analysis (Table 2-2; Supplementary Table 2-6). Isotope values for $\delta^{13}C$ ranged between -20.8 and -18.9‰ (mean ± 1SD = -19.8 ± 0.4‰), exhibiting a weak positive correlation with age (r_s =.262, p<.000). For $\delta^{15}N$, values ranged between 6.7 and 11.7‰ (mean ± 1SD = 9.1 ± 0.9‰), with a weak positive correlation with age (r_s=.240, p<.000). The correlation between $\delta^{13}C$ and $\delta^{15}N$ values was not statistically significant (r_s=-.004, p=.947), suggesting diverse sources of consumed protein.

Table 2-2: Sample size by sex and tooth sampled, indicating number of teeth and number of incremental sections included in the statistical analyses.

Tooth	Sexes Combined	Male	Female
M2	30 teeth (207 sections)	13 teeth (90 sections)	17 teeth (117 sections)
M3	16 teeth (85 sections)	7 teeth (38 sections)	9 teeth (47 sections)
Total	46 teeth (292 sections)	20 teeth (128 sections)	26 teeth (164 sections)

M2 = second permanent molar. M3 = third permanent molar.

Sex-based analysis by age point reveals no significant difference between males and females between 4.5 and 15.5 years of age, nor at 23.5 years of age. Around 16.5 years, males had significantly lower $\delta^{15}N$ values than females, with a large effect size (U=21.0, p=.012, g=1.3; Table 2-3; Fig. 2-2); $\delta^{13}C$ values were not significantly different at this point (Table 2-4; Fig. 2-3).

To account for small sample sizes, we grouped data based on preliminary results and spatial patterning, creating three age-based groups: 4.5-12.5 years, 13.5-16.5 years, and 23.5 years. Mann-Whitney U tests for these age groups indicate that males had significantly lower $\delta^{15}N$ values than females in the 13.5-16.5-year-old group; differences for $\delta^{13}C$ were not significant (Table 2-5; Fig. 2-4). When testing between age groups, females show a positive correlation for both $\delta^{13}C$ (r_s=.194, p=.013) and $\delta^{15}N$ (r_s=.218, p=.005) values with age groups. However, for males, age groups are not correlated with $\delta^{13}C$ (r_s=.143, p=.108) or $\delta^{15}N$ (r_s=.099, p=.267) values.

Table 2-3: Mean ± 1SD $\delta^{15}N$ values for males and females by age point ± 1SD, along with sample sizes and statistical test results (Mann-Whitney U, p-value, and Hedge's g).

Age Point ± 1SD	Males		Females		Statistical Results		
	n=	$\delta^{15}N$	n=	$\delta^{15}N$	U=	p=	g=
4.5 ± 0.58	10	8.9 ± 0.8	15	9.0 ± 0.9	71.5	.846	0.2
5.5 ± 0.50	13	8.5 ± 0.9	14	8.8 ± 0.9	69.0	.286	0.3
7.5 ± 0.49	12	8.4 ± 1.0	16	8.9 ± 1.0	72.0	.265	0.5
8.5 ± 0.52	13	8.7 ± 1.0	17	8.9 ± 0.9	92.0	.439	0.3
9.5 ± 0.64	9	8.9 ± 1.0	7	8.8 ± 1.1	29.5	.832	0.1
10.5 ± 0.79	15	9.0 ± 0.8	22	9.2 ± 0.9	155.0	.757	0.2
11.5 ± 1.09	7	9.0 ± 0.9	9	9.6 ± 0.9	21.0	.266	0.7
12.5 ± 1.20	15	9.1 ± 0.9	20	9.3 ± 0.7	135.5	.629	0.3
13.5 ± 1.17	7	8.9 ± 0.4	8	9.6 ± 0.9	15.5	.148	1.0
15.5 ± 0.87	13	9.2 ± 0.9	15	9.3 ± 0.7	85.0	.565	0.1
16.5 ± 0.78	9	8.8 ± 0.5	13	9.6 ± 0.7	21.0	.012	1.3
23.5 ± 1.12	5	9.8 ± 0.7	8	9.8 ± 0.9	19.0	.884	0.1

SD = standard deviation. n = sample size. U= Mann Whitney U test results, p= significance test (p<.05, statistically significant differences bolded), g= Hedge's g for effect size (small effect size ≤ 0.2; 0.3 ≤ medium effect size ≤ 0.7; large effect size ≥ 0.8).

Figure 2-2: Boxplots representing $\delta^{15}N$ values for males and females at Lisieux-Michelet. Each boxplot indicates the minimum value, first quartile, median, third quartile and maximum value, with outliers labeled. Males: blue and left side of each pair. Females: green and right side of each pair. Red asterisk (*): statistically significant difference between males and females (p<.05).

Table 2-4: Mean ± 1SD $\delta^{13}C$ values for males and females by age point ± 1SD, along with sample sizes and statistical test results (Mann-Whitney U, p-value, and Hedge's g).

Age Point ± 1SD	Males		Females		Statistical Results		
	n=	$\delta^{13}C$	n=	$\delta^{13}C$	U=	p=	g=
4.5 ± 0.58	10	-20.1 ± 0.3	15	-20.0 ± 0.4	57.5	.322	0.3
5.5 ± 0.50	13	-19.9 ± 0.4	14	-19.9 ± 0.4	86.5	.827	0.0
7.5 ± 0.49	12	-19.8 ± 0.4	16	-19.8 ± 0.3	90.0	.781	0.0
8.5 ± 0.52	13	-19.7 ± 0.4	17	-19.7 ± 0.3	103.0	.754	0.0
9.5 ± 0.64	9	-19.7 ± 0.3	7	-19.8 ± 0.5	24.5	.458	0.3
10.5 ± 0.79	15	-19.6 ± 0.3	22	-19.8 ± 0.4	127.0	.240	0.6
11.5 ± 1.09	7	-19.8 ± 0.4	9	-19.7 ± 0.5	26.0	.560	0.2
12.5 ± 1.20	15	-19.8 ± 0.4	20	-19.7 ± 0.4	129.0	.484	0.3
13.5 ± 1.17	7	-19.6 ± 0.4	8	-19.7 ± 0.5	27.5	.954	0.2
15.5 ± 0.87	13	-19.7 ± 0.4	15	-19.7 ± 0.4	89.5	.712	0.0
16.5 ± 0.78	9	-19.8 ± 0.4	13	-19.6 ± 0.4	45.0	.367	0.5
23.5 ± 1.12	5	-19.6 ± 0.4	8	-19.4 ± 0.3	16.0	.557	0.6

SD = standard deviation. n = sample size. U= Mann Whitney U test results, p= significance test (p<.05, statistically significant differences bolded), g= Hedge's g for effect size (small effect size ≤ 0.2; 0.3 ≤ medium effect size ≤ 0.7; large effect size ≥ 0.8).

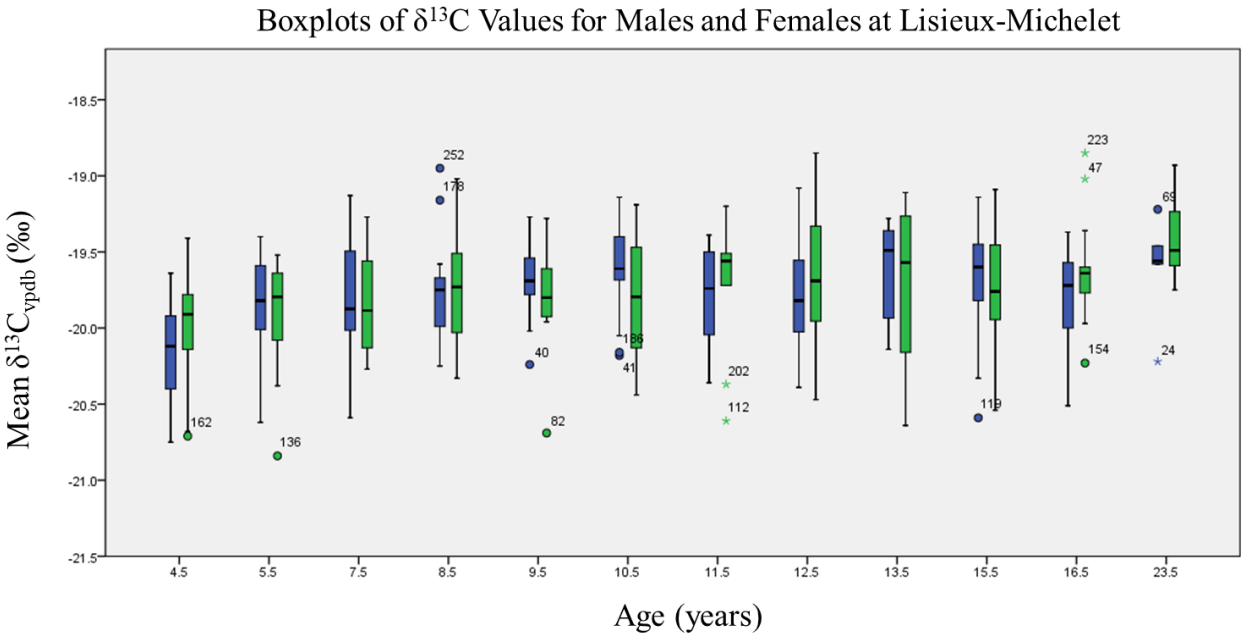

Figure 2-3: Boxplots representing $\delta^{13}C$ values for males and females at Lisieux-Michelet. Each boxplot indicates the minimum value, first quartile, median, third quartile and maximum value, with outliers labeled. Males: blue and left side of each pair. Females: green and right side of each pair.

Table 2-5: Mean ± 1SD $\delta^{13}C$ and $\delta^{15}N$ values for males and females by age group, along with sample sizes and statistical test results (Mann-Whitney U, p-value, and Hedge's g).

Age Range (yrs)	Males		Females		Statistical Results		
	n=	Mean $\delta^{13}C$ ± 1SD	n=	Mean $\delta^{13}C$ ± 1SD	U=	p=	g=
4.5-12.5	94	-19.8 ± 0.4	120	-19.8 ± 0.4	5630.5	.983	0.0
13.5-16.5	29	-19.7 ± 0.4	36	-19.7 ± 0.4	512.5	.900	0.0
23.5	5	-19.6 ± 0.4	8	-19.4 ± 0.3	16.0	.557	0.6
		Mean $\delta^{15}N$ ± 1SD		Mean $\delta^{15}N$ ± 1SD			
4.5-12.5	94	8.8 ± 0.9	120	9.1 ± 0.9	4925.0	.112	0.3
13.5-16.5	29	9.0 ± 0.7	36	9.4 ± 0.7	314.0	.006	0.6
23.5	5	9.8 ± 0.7	8	9.8 ± 0.9	19.0	.884	0.1

SD = standard deviation. n = sample size. U= Mann Whitney U test results, p= significance test (p<.05, statistically significant differences bolded), g= Hedge's g for effect size (small effect size ≤ 0.2; 0.3 ≤ medium effect size ≤ 0.7; large effect size ≥ 0.8).

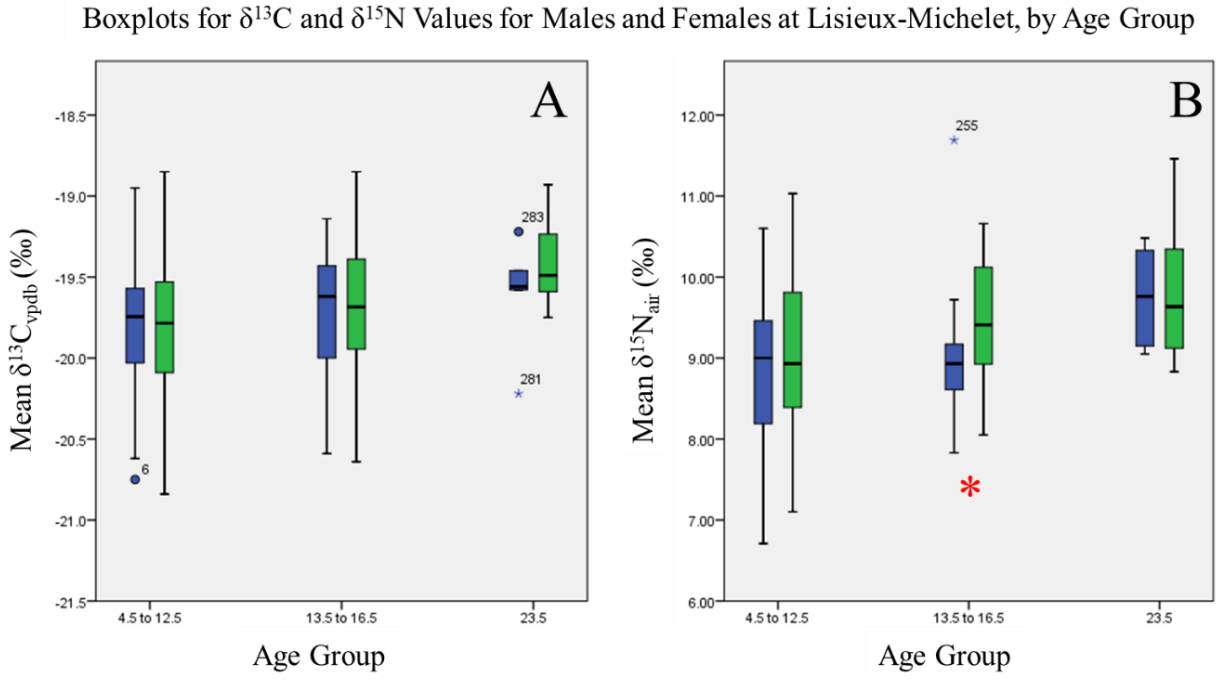

Figure 2-4: Boxplots representing (A) $\delta^{13}C$ and (B) $\delta^{15}N$ values for males and females, by age groups, at Lisieux-Michelet. Each boxplot indicates the minimum value, first quartile, median, third quartile and maximum value, with outliers labeled. Males: blue and left side of each pair. Females: green and right side of each pair. Red asterisk (*): statistically significant difference between males and females (p<.05).

DISCUSSION

Dietary isotope values for the Lisieux-Michelet sample indicate a diet based on C_3 plants with the inclusion of some terrestrial-based or freshwater proteins rather than marine-based resources. These values are largely consistent with Graeco-Roman literary descriptions of childhood diet, which recommended that children consume breads and other cereals, and avoid marine resources and fatty meats (Garnsey, 1999). Both males and females show weak positive correlations between age and $\delta^{13}C$ and $\delta^{15}N$ values, suggesting the gradual incorporation of more animal proteins or higher trophic level foods as individuals aged. However, the age specific analysis reveals more nuanced differences within the period of childhood.

INFANTIA (APPROXIMATELY 0-7 YEARS)

Medical treatises by Galen and Hippocrates recommended that cereals be introduced as complementary foods around six months of age and that children be fully weaned by 3 years of age (Laes, 2019). At Lisieux-Michelet, the consistent $\delta^{15}N$ values from 4.5 years and subsequent age points (e.g., 5.5 years, 7.5 years) suggests that, if individuals were breastfed, weaning was already accomplished by this age (Fig. 2-2).

PUERITIA (APPROXIMATELY 7-14 YEARS)

At Lisieux-Michelet, the isotope data demonstrate that between the ages of 4.5 and 15.5 years, or for the life course stages of *infantia* and *pueritia*, there were no statistically significant sex-based differences (with small to medium effect sizes), suggesting that males and females consumed isotopically similar foods. Studies of sex-based patterns in childhood are limited, in part due to unreliable non-adult sex estimation methods (Lewis, 2019). However, in a study of linear enamel hypoplasia at the Roman Imperial estate of Vagnari, Prowse *et al.* (2014) found that males and females had the same average number of hypoplastic defects per tooth, concluding that boys and girls experienced comparable levels of stress during infancy and childhood at this site. Other studies are needed to understand gendered experiences in childhood across the Roman Empire, but the data in the current study suggest that, at Lisieux-Michelet, diet during the periods of *infantia* and *pueritia* was not strongly influenced by gender.

ADULESCENTIA (APPROXIMATELY 14-28 YEARS)

Around 16.5 years, the isotopic data from Lisieux-Michelet suggest that men and women's diets started to differ, with males having significantly lower $\delta^{15}N$ values than females (Table 2-3). Although sample sizes are small, the effect size indicates these differences were very large. Differences in $\delta^{13}C$ values were not significant, whether comparing males and females by age point (Table 2-4) or age group (Table 2-5).

Changes in stable nitrogen isotopes without a change in stable carbon isotopes can be attributed to physiological stress (D'Ortenzio *et al.*, 2015); in which case, these differences could suggest that females experienced greater physiological stress than males, particularly around 16.5 years of age. This could be due to different energy requirements related to pubertal development, nutritional stress, or the effects of pregnancy (D'Ortenzio *et al.*, 2015). However, menarche likely

occurred around 14 years of age, and most middle-class women in the Late Roman period did not marry until their late teens or early twenties, suggesting that these explanations cannot account for the differences in $\delta^{15}N$ values between males and females (Alberici & Harlow, 2007). Examining linear correlations by age group demonstrate that females experienced a subtle increase in $\delta^{13}C$ and $\delta^{15}N$ values with increasing age, reflecting consistent and gradual incorporation of higher trophic level proteins across the three age groups. Meanwhile, males do not exhibit a linear correlation across age groups for $\delta^{13}C$ and $\delta^{15}N$, suggesting a different dietary pattern. Consequently, the differences in $\delta^{15}N$ values between males and females at 16.5 years may be attributed to dietary differences rather than physiological stress. Specifically, the isotopic evidence demonstrates that these young men were eating less protein, or lower trophic level protein, than young women of the same age.

The 13.5 to 16.5-age range closely corresponds to the beginning of *adulescentia*, a Roman life course stage roughly translating to "a period of youth" (Eyben, 1993). Roman writers describe this part of the life course as a period of exploration, learning, and debauchery, when young men were encouraged to drink heavily, visit brothels, and begin small business ventures (Eyben, 1993). However, these depictions may only be representative of higher-status families, who could afford such affluent lifestyles. For boys of the middle classes, like those at Lisieux-Michelet, *adulescentia* was more likely the period when they joined the military or began apprenticeships.

During the Roman Imperial period, there was no set age at which boys could enlist in the military, rather, they needed to have reached physical maturity and be at least 1.65m tall (Laes, 2011). Epitaphs show that boys frequently joined the military around 17, with some as young as 13 years old (Laes, 2011). At Lisieux-Michelet, ongoing research suggests that the vast majority of observed traumatic lesions affected males, predominantly in the lower limbs, suggesting sex-based differences in patterns of injury and risk (Paillard, 1994; Paillard *et al.*, forthcoming). In one case, the remains of a young male exhibit a 14cm long peri-mortem cut along the orbital, frontal and parietal bones, likely caused by a long sword (Paillard, 1994). These osteological results, along with evidence of a military garrison in the immediate area suggest that military involvement was a possibility for these young men (Paillard *et al.*, 2006; Munaro, 2012). In the military, daily dietary provisions included 880 grams of wheat, 620 grams of fruits, vegetables, and nuts, and 160 grams of meat, along with oil, vinegar, and salt (Kehne, 2007: 324-25; Badel, 2012: 142). However, it is unclear how applicable these provisions would be to the garrison near *Noviomagus*, or how this would have differed from their diet prior to military recruitment.

If they did not join the military during *adulescentia*, young men may have started formal apprenticeships. In the Roman Empire, apprenticeships typically lasted between six months and six years (Vuolanto, 2015). Only one surviving contract indicates the age of the apprentice (14 years-old), but Laes (2015) suggests that most began their apprenticeships in their mid-teens. The general working conditions of freeborn apprentices may not have been very different to the experiences of child slaves, with food and clothing typically provided by the apprentice's master (Vuolanto, 2015). Inhabitants at *Noviomagus* participated in a wide range of craft production, including metallurgy, bone work, and ceramics, suggesting that some young men would have participated in apprenticeships to learn an occupation or trade (Paillard, 1994: 37). Additionally, previous research at Lisieux-Michelet demonstrates that young adult males (aged 20-34) had greater cortical thickness and increased entheseal robusticity compared to middle and old adult males, suggesting they participated in manual labour, while older adults fulfilled a more supervisory role (Ingram, 2015).

Apprenticeships, however, were not for freeborn girls (Laes, 2015). In fact, for girls, *adulescentia* appears to have been a very different experience altogether. Researchers suggest that this period of the life course was either very short, occurring between menarche (i.e., 14 years, according to medical doctors and Roman jurists) and marriage, or non-existent, with young girls transitioning from childhood to adulthood on their wedding day (Alberici & Harlow, 2007; Caldwell, 2015). Those that do support a transitional phase of the woman's life course make clear that this period would have been focused on domestic training within their household and preparing them for marriage, not taking on new roles in their communities (Caldwell, 2015; Harlow & Laurence, 2002). Average age-at-marriage for middle class populations, like Lisieux-Michelet, has been extrapolated from epitaphs, by identifying the age at which commemoration of the deceased transitions from parents to spouses. These studies demonstrate that women, including those from Roman Gaul, tended to marry in their late teens (Scheidel, 2007; Shaw, 1987). However, epitaphs from Rome suggest that young women in Christian contexts married slightly later (Shaw, 1987). Thus, we may expect that women at Lisieux-Michelet entered their first marriage in their late-teens or early-twenties. This coincides with 4th century laws, which considered 18 to be the age at which a woman could conduct business and may have been viewed as an adult (Alberici & Harlow, 2007).

With the intention of curbing sexual appetites and to ensure their virginity until marriage, Rufus of Ephesus recommended that pubertal girls moderate their intake of food, avoiding wine, meat, and other nourishing foods (Laes, 2019: 184). While the isotopic evidence at Lisieux-Michelet does not suggest that meat was suddenly withheld from women at this age, it may be that the diets of women were more closely monitored (Alberici & Harlow, 2007). If these women were kept close to their natal home to learn domestic skills, or transferred to their new married lifestyle, they likely would continue to have access to similar diets, as women were responsible for preparing foods, and could continue to prepare foods that were familiar to them (Laes, 2019: 179).

Based on these historical accounts and archaeological evidence, it appears that men and women experienced very different periods of *adulescentia,* with men taking on new roles in their communities, while women retained similar roles in their natal or spousal household. The isotopic data suggest that these gendered experiences may have affected diets, with young men consuming less protein or lower trophic level protein than women at this time.

At the age of 23.5 years, males and females show no significant differences in $\delta^{13}C$ and $\delta^{15}N$ values (Tables 2-3, 2-4), suggesting that men and women had access to isotopically similar foods once again. However, the small sample sizes for this age point raises questions about the reliability of these statistical results. Future research at Lisieux-Michelet could expand in this area, by increasing sample sizes to increase statistical strength, and by focusing on sex-based diets during later periods of the life course. Examining dietary patterns and differences in adulthood, we may find that *adulescentia* was the starting point for gendered diets at Lisieux-Michelet, as literary sources told men and women to consume different foods (Garnsey, 1999). Alternatively, we may find that *adulescentia* was a unique period of gendered diets, before men and women returned to eating similar foodstuffs. The latter may be explained by young men transitioning to *juventus*, getting married in their late twenties, and consuming diets similar to their wives (Eyben, 1993; Shaw, 1987).

More broadly, future bioarchaeological studies may benefit from focusing on the experiences of adolescents to learn about the beginning of gendered treatments, introduction to the

workforce, and when adulthood began. As a social age category, the ways in which adolescence was experienced, or when it was experienced, will vary across time and space; but the current study demonstrates that there are stories to be told.

CONCLUSION

By using stable carbon and nitrogen isotope analysis of incremental dentine sections and Childhood Social Theory, we were able to explore the period of childhood in a more nuanced way, to identify periods of gendered differences during *adulescentia* and relate these to expected social age changes in the Late Roman life course. The results of this study indicate small increases in stable carbon and nitrogen isotope values as individuals aged, suggesting the gradual incorporation of more protein or higher trophic level foods as individuals matured. The lack of sex-based differences and small effect sizes suggest that, between 4.5 and 15.5 years of age, boys and girls consumed isotopically similar foods, suggesting that diet was not heavily influenced by gender at this point. However, around 16.5 years of age, diets diverged, with men consuming different types, or quantities, of protein than women. Incorporating literary, historical, and archaeological research demonstrates that this difference is the result of changing social roles, as young men took on new positions in their communities, possibly as apprentices or in the military, while young women kept close to the home or continued preparing familiar foods in their spousal home following marriage.

By using permanent dentition from adult skeletal remains to investigate childhood dietary signals, we were able to mitigate issues of non-survivorship and more confidently assess osteological sex by examining post-pubertal skeletal remains. This, in turn, allowed for sex-based results and the analysis of gendered dietary experiences with greater temporal resolution. In doing so, this study contributes to a growing discourse on dietary differences in the post-weaning period, and gendered experiences in childhood and adolescence.

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SUPPLEMENTARY DATA

Available on the following pages.

Table 2-6 (Supplementary Table): Individual, osteological sex and tooth sampled, along with London Atlas development stage and age of corresponding dentine sections ± 1SD, $\delta^{13}C$ and $\delta^{15}N$ values, and sample integrity measures (C:N Ratio, %C, %N and %coll).

Skeleton Number	Sex	Tooth	London Atlas	Age ± 1SD	$\delta^{13}C_{vpdb}$	$\delta^{15}N_{air}$	C:N Ratio	%wt C	%wt N	%coll
MIC 018A	F	ManM3	Coc	11.5 ± 1.09	-19.6	9.2	3.3	42.4	14.9	8.0
			Cr1/2	12.5 ± 1.20	-19.5	9.3	3.3	43.2	15.5	
			Crc	13.5 ± 1.17	-20.3	9.2	3.5	42.4	14.1	
			R1/4	15.5 ± 0.87	-20.0	9.0	3.4	42.5	14.5	
			R1/2	16.5 ± 0.78	-19.6	9.9	3.3	43.2	15.3	
			Ac	23.5 ± 1.12	-19.8	10.2	3.3	39.7	14.1	
MIC 097	F	ManM2	Coc	4.5 ± 0.58	-19.8	8.9	3.3	42.7	15.3	5.6
			Cr1/2	5.5 ± 0.50	-19.7	8.8	3.3	42.1	15.0	
			Crc	7.5 ± 0.49	-19.5	8.8	3.2	42.0	15.1	
			Ri	8.5 ± 0.52	-20.2	8.7	3.4	37.3	12.7	
			R1/2	10.5 ± 0.79	-19.6	8.6	3.2	39.0	14.0	
			R3/4	12.5 ± 1.20	-19.8	8.6	3.3	42.0	14.8	
			Ac	15.5 ± 0.87	-20.5	8.5	3.6	43.4	14.1	
MIC 099	M	MaxM3	Coc	10.5 ± 0.79	-19.4	8.7	3.3	43.0	15.3	5.4
			Cr1/2	11.5 ± 1.09	-19.7	8.5	3.3	42.8	15.3	
			Crc	13.5 ± 1.17	-19.4	8.5	3.2	42.8	15.4	
			R1/4	15.5 ± 0.87	-19.5	8.4	3.3	42.7	15.3	
			R1/2	16.5 ± 0.78	-19.7	8.4	3.3	42.9	15.0	
			Ac	23.5 ± 1.12	-21.0	8.1	3.9*	44.5	13.2	
MIC 112	M	ManM3	Coc	11.5 ± 1.09	-19.9	10.3	3.2	43.3	15.6	8.4
			Cr1/2	12.5 ± 1.20	-19.6	9.3	3.2	43.2	15.7	
			Crc	13.5 ± 1.17	-19.5	9.0	3.2	43.2	15.7	
			R1/4	15.5 ± 0.87	-19.5	9.4	3.2	43.3	15.6	
			R1/2	16.5 ± 0.78	-19.8	9.5	3.3	42.7	15.1	

			Ac	23.5 ± 1.12	-20.2	9.8	3.4	42.4	14.3	
MIC 118	F	ManM2	Coc	4.5 ± 0.58	-20.5	8.5	3.5	41.7	13.9	9.7
			Cr1/2	5.5 ± 0.50	-21.4	8.2	3.9*	46.0	13.8	
			Crc	7.5 ± 0.49	-19.9	8.4	3.3	43.4	15.4	
			Ri	8.5 ± 0.52	-19.7	8.2	3.2	43.3	15.7	
			R1/2	10.5 ± 0.79	-19.6	8.8	3.2	43.0	15.5	
			R3/4	12.5 ± 1.20	-19.5	9.0	3.2	41.7	15.1	
			Ac	15.5 ± 0.87	-19.8	9.1	3.3	42.6	15.1	
MIC 153	M	ManM3	Coc	11.5 ± 1.09	-20.2	7.8	3.4	43.5	15.0	4.8
			Cr1/2	12.5 ± 1.20	-19.9	8.1	3.3	43.3	15.2	
			Crc	13.5 ± 1.17	-20.1	8.6	3.6	44.1	14.3	
			R1/4	15.5 ± 0.87	-20.3	8.6	3.6	43.6	14.2	
			R1/2	16.5 ± 0.78	-19.7	8.8	3.4	39.5	13.4	
			Ac	23.5 ± 1.12	-24.6	7.8	7.2*	46.4	7.6	
MIC 156	M	ManM2	Coc	4.5 ± 0.58	-20.4	8.7	3.2	42.9	15.6	12.8
			Cr1/2	5.5 ± 0.50	-20.6	8.7	3.3	44.3	15.9	
			Crc	7.5 ± 0.49	-20.6	9.0	3.3	42.8	15.3	
			Ri	8.5 ± 0.52	-20.3	9.2	3.2	42.0	15.1	
			R1/4	9.5 ± 0.64	-20.2	9.6	3.3	42.9	15.3	
			R1/2	10.5 ± 0.79	-20.2	9.9	3.3	43.0	15.3	
			R3/4	12.5 ± 1.20	-20.1	10.2	3.3	42.4	15.2	
			Ac	15.5 ± 0.87	-22.5	9.7	4.3*	44.5	12.1	
MIC 299A	F	MaxM3	Coc	10.5 ± 0.79	-20.2	10.8	3.6	43.9	14.4	8.0
			Cr1/2	11.5 ± 1.09	-19.7	10.4	3.4	43.4	14.9	
			Crc	13.5 ± 1.17	-19.4	10.6	3.3	43.5	15.4	
			R1/4	15.5 ± 0.87	-19.3	10.1	3.3	42.8	15.1	
			R1/2	16.5 ± 0.78	-19.0	10.1	3.3	43.1	15.4	
			Ac	23.5 ± 1.12	-19.5	11.5	3.3	40.8	14.5	

MIC 343	F	MaxM2	Coc	4.5 ± 0.58	-19.7	7.6	3.2	38.9	14.0	9.9
			Cr1/2	5.5 ± 0.50	-19.8	7.7	3.2	42.6	15.3	
			Crc	7.5 ± 0.49	-19.5	7.7	3.2	41.3	14.9	
			Ri	8.5 ± 0.52	-19.8	7.9	3.3	42.6	15.2	
			R1/4	9.5 ± 0.64	-20.0	8.4	3.3	42.2	15.1	
			R1/2	10.5 ± 0.79	-19.8	8.3	3.3	42.6	15.2	
			R3/4	12.5 ± 1.20	-20.1	8.6	3.5	42.2	14.2	
			Ac	16.5 ± 0.78	-19.6	9.3	3.3	41.0	14.6	
MIC 359	M	ManM2	Coc	4.5 ± 0.58	-20.1	8.0	3.2	43.1	15.5	7.0
			Cr1/2	5.5 ± 0.50	-20.0	7.5	3.2	42.3	15.2	
			Crc	7.5 ± 0.49	-19.9	7.5	3.2	42.8	15.5	
			Ri	8.5 ± 0.52	-19.9	7.8	3.2	42.3	15.2	
			R1/4	9.5 ± 0.64	-19.8	7.3	3.2	44.5	16.1	
			R3/4	12.5 ± 1.20	-20.3	7.8	3.4	40.5	13.9	
			Ac	15.5 ± 0.87	-20.3	7.8	3.4	40.6	14.0	
MIC 366	M	MaxM3	Coc	10.5 ± 0.79	-19.4	9.7	3.2	42.2	15.2	10.2
			Cr1/2	11.5 ± 1.09	-19.4	8.6	3.2	42.8	15.5	
			Crc	13.5 ± 1.17	-19.4	8.8	3.2	42.3	15.4	
			R1/4	15.5 ± 0.87	-19.3	9.0	3.3	41.8	15.0	
			R1/2	16.5 ± 0.78	-19.4	9.1	3.2	40.9	14.8	
			Ac	23.5 ± 1.12	-19.2	9.1	3.2	40.5	14.6	
MIC 374	M	MaxM2	Coc	4.5 ± 0.58	-20.8	9.6	3.4	41.8	14.2	9.8
			C1/2	5.5 ± 0.50	-20.5	9.1	3.4	43.0	14.9	
			Crc	7.5 ± 0.49	-20.2	10.0	3.3	42.3	15.0	
			Ri	8.5 ± 0.52	-20.1	10.0	3.2	42.2	15.2	
			R1/4	9.5 ± 0.64	-20.0	9.9	3.2	40.2	14.4	
			R1/2	10.5 ± 0.79	-20.1	9.7	3.3	41.5	14.8	
			R3/4	12.5 ± 1.20	-19.9	9.4	3.3	41.1	14.7	

			Ac	16.5 ± 0.78	-20.1	9.0	3.4	41.4	14.3	
MIC 377	F	MaxM2	Coc	4.5 ± 0.58	-20.1	9.6	3.3	41.2	14.8	7.5
			C1/2	5.5 ± 0.50	-20.2	9.3	3.3	41.7	14.8	
			Crc	7.5 ± 0.49	-19.7	9.0	3.3	42.3	15.1	
			Ri	8.5 ± 0.52	-20.0	8.9	3.3	41.9	14.8	
			R1/4	9.5 ± 0.64	-20.7	8.7	3.5	42.1	14.1	
			R1/2	10.5 ± 0.79	-20.1	9.2	3.3	41.5	14.5	
			R3/4	12.5 ± 1.20	-19.8	9.1	3.3	42.1	15.1	
			Ac	16.5 ± 0.78	-19.8	9.4	3.3	35.9	12.9	
MIC 391	F	ManM3	Coc	11.5 ± 1.09	-19.7	10.0	3.3	42.3	14.8	9.5
			Cr1/2	12.5 ± 1.20	-19.7	9.6	3.3	42.9	15.3	
			R1/4	15.5 ± 0.87	-19.4	9.4	3.3	42.7	15.3	
			Ac	23.5 ± 1.12	-19.6	9.6	3.3	41.6	14.9	
MIC 395	M	ManM2	Coc	4.5 ± 0.58	-19.7	9.0	3.2	41.5	14.9	8.9
			Cr1/2	5.5 ± 0.50	-19.7	8.4	3.3	42.9	15.2	
			Crc	7.5 ± 0.49	-19.6	8.3	3.3	42.7	15.2	
			Ri	8.5 ± 0.52	-19.6	8.5	3.3	41.9	14.9	
			R1/2	10.5 ± 0.79	-19.6	9.1	3.3	41.4	14.8	
			R3/4	12.5 ± 1.20	-19.6	9.0	3.2	42.0	15.1	
			Ac	15.5 ± 0.87	-19.6	9.1	3.3	42.2	15.1	
MIC 405	F	ManM2	Coc	4.5 ± 0.58	-19.8	9.4	3.4	42.7	14.5	8.1
			Cr1/2	5.5 ± 0.50	-19.9	9.5	3.5	42.8	14.5	
			Crc	7.5 ± 0.49	-20.3	9.8	3.5	42.4	14.2	
			Ri	8.5 ± 0.52	-19.6	9.4	3.3	42.6	14.9	
			R1/2	10.5 ± 0.79	-19.5	9.2	3.4	42.1	14.6	
			R3/4	12.5 ± 1.20	-19.3	9.6	3.3	41.5	14.6	
			Ac	16.5 ± 0.78	-19.8	9.6	3.5	42.2	14.2	
MIC 458	M	ManM2	Coc	4.5 ± 0.58	-19.6	9.6	3.3	42.5	15.1	7.4

			Cr1/2	5.5 ± 0.50	-19.6	9.8	3.3	42.5	15.1	
			Crc	7.5 ± 0.49	-20.0	8.8	3.4	42.5	14.7	
			Ri	8.5 ± 0.52	-20.0	9.2	3.3	42.8	15.2	
			R1/4	9.5 ± 0.64	-19.7	9.0	3.3	43.0	15.3	
			R1/2	10.5 ± 0.79	-19.4	9.0	3.3	42.6	15.2	
			R3/4	12.5 ± 1.20	-19.4	9.6	3.3	42.0	15.0	
			Ac	15.5 ± 0.87	-20.7	9.7	3.7*	41.9	13.2	
MIC 483	F	MaxM3	Coc	10.5 ± 0.79	-20.4	10.3	3.4	42.7	14.6	2.2
			Cr1/2	11.5 ± 1.09	-20.6	10.6	3.6	43.0	14.0	
			Crc	13.5 ± 1.17	-20.6	10.6	3.5	41.2	13.9	
			R1/2	16.5 ± 0.78	-21.2	10.8	3.8*	40.6	12.6	
			Ac	23.5 ± 1.12	-24.7	8.5	6.5*	47.5	8.6	
MIC 490	M	ManM2	Cr1/2	5.5 ± 0.50	-19.6	9.4	3.2	41.1	14.9	5.2
			Crc	7.5 ± 0.49	-22.1	8.6	4.5*	43.6	11.3	
			Ri	8.5 ± 0.52	-19.8	9.4	3.4	43.8	15.1	
			R1/4	9.5 ± 0.64	-19.7	9.4	3.4	43.6	15.1	
			R1/2	10.5 ± 0.79	-19.6	9.4	3.3	43.1	15.2	
			R3/4	12.5 ± 1.20	-20.0	9.5	3.4	42.1	14.6	
			Ac	15.5 ± 0.87	-20.6	9.5	3.5	42.4	14.1	
MIC 535	F	ManM2	Coc	4.5 ± 0.58	-20.1	8.6	3.2	42.2	15.2	5.5
			Cr1/2	5.5 ± 0.50	-20.1	8.3	3.3	42.5	15.2	
			Crc	7.5 ± 0.49	-20.0	8.7	3.3	43.3	15.5	
			Ri	8.5 ± 0.52	-19.5	9.6	3.2	42.4	15.3	
			R1/4	9.5 ± 0.64	-19.4	9.7	3.2	40.4	14.6	
			R1/2	10.5 ± 0.79	-19.6	9.3	3.3	41.7	14.9	
			R3/4	12.5 ± 1.20	-19.8	9.4	3.3	42.7	15.1	
			Ac	15.5 ± 0.87	-20.5	9.3	3.5	43.3	14.3	
MIC 543	M	MaxM2	Coc	4.5 ± 0.58	-19.9	7.5	3.4	41.2	14.1	7.6

			C1/2	5.5 ± 0.50	-19.4	7.2	3.3	42.7	15.1	
			Crc	7.5 ± 0.49	-19.8	6.7	3.4	42.8	14.8	
			Ri	8.5 ± 0.52	-19.7	7.7	3.4	42.5	14.6	
			R1/4	9.5 ± 0.64	-19.5	8.2	3.4	41.3	14.2	
			R1/2	10.5 ± 0.79	-19.5	8.3	3.4	40.6	14.1	
			R3/4	12.5 ± 1.20	-20.8	8.1	3.9*	38.1	11.4	
			Ac	16.5 ± 0.78	-20.0	8.7	3.5	41.4	13.7	
MIC 564	F	ManM2	Coc	4.5 ± 0.58	-20.7	8.6	3.4	43.8	14.8	9.6
			Cr1/2	5.5 ± 0.50	-20.8	8.6	3.5	43.7	14.7	
			Crc	7.5 ± 0.49	-21.2	8.6	3.7*	44.2	13.9	
			Ri	8.5 ± 0.52	-20.3	8.4	3.6	48.7	16.0	
			R1/4	9.5 ± 0.64	-19.8	8.5	3.4	43.0	14.8	
			R1/2	10.5 ± 0.79	-19.4	8.7	3.3	40.5	14.4	
			R3/4	12.5 ± 1.20	-20.5	9.0	3.6	41.9	13.5	
			Ac	15.5 ± 0.87	-19.8	9.2	3.4	39.5	13.7	
MIC 583	F	ManM2	Coc	4.5 ± 0.58	-21.4	8.8	3.7*	43.1	13.5	12.2
			Cr1/2	5.5 ± 0.50	-21.3	8.6	3.7*	44.6	14.1	
			Crc	7.5 ± 0.49	-20.2	8.3	3.3	43.1	15.2	
			Ri	8.5 ± 0.52	-19.8	8.2	3.3	41.7	14.8	
			R1/4	9.5 ± 0.64	-19.9	8.2	3.3	43.2	15.1	
			R1/2	10.5 ± 0.79	-19.8	8.4	3.4	43.4	15.0	
			R3/4	12.5 ± 1.20	-19.3	8.2	3.3	40.1	14.3	
			Ac	15.5 ± 0.87	-19.5	8.8	3.3	41.1	14.5	
MIC 602	F	MaxM2	Coc	4.5 ± 0.58	-19.6	10.0	3.2	40.8	14.7	8.0
			C1/2	5.5 ± 0.50	-19.6	9.9	3.3	42.1	14.9	
			Crc	7.5 ± 0.49	-19.5	9.7	3.3	41.9	15.0	
			Ri	8.5 ± 0.52	-19.6	9.6	3.2	43.0	15.5	
			R1/2	10.5 ± 0.79	-19.9	9.8	3.3	42.5	14.9	

			R3/4	12.5 ± 1.20	-19.8	10.1	3.4	42.5	14.8	
			Ac	16.5 ± 0.78	-20.2	10.5	3.6	42.7	14.0	
MIC 632	F	ManM2	Coc	4.5 ± 0.58	-20.0	10.3	3.3	42.5	14.8	37.3
			Cr1/2	5.5 ± 0.50	-19.9	9.6	3.4	42.0	14.4	
			Crc	7.5 ± 0.49	-19.3	10.1	3.3	42.9	15.4	
			Ri	8.5 ± 0.52	-19.2	10.3	3.3	42.9	15.3	
			R1/2	10.5 ± 0.79	-19.2	10.7	3.3	43.0	15.4	
			R3/4	12.5 ± 1.20	-19.3	10.7	3.3	42.8	15.2	
			Ac	15.5 ± 0.87	-20.0	10.7	3.5	42.7	14.3	
MIC 653	F	ManM2	Coc	4.5 ± 0.58	-20.7	11.0	3.2	42.4	15.3	9.5
			Cr1/2	5.5 ± 0.50	-20.4	10.2	3.2	42.6	15.3	
			Crc	7.5 ± 0.49	-20.3	9.9	3.3	39.7	14.0	
			Ri	8.5 ± 0.52	-20.2	9.7	3.3	42.5	14.9	
			R1/2	10.5 ± 0.79	-20.3	9.7	3.4	41.4	14.3	
			R3/4	12.5 ± 1.20	-20.4	10.3	3.4	42.2	14.6	
			Ac	15.5 ± 0.87	-21.2	10.2	3.7*	41.9	13.2	
MIC 659	M	MaxM2	Coc	4.5 ± 0.58	-20.0	8.5	3.3	42.6	15.2	12.6
			C1/2	5.5 ± 0.50	-20.0	7.3	3.2	43.4	15.6	
			Crc	7.5 ± 0.49	-20.0	7.2	3.3	42.1	15.0	
			Ri	8.5 ± 0.52	-19.8	7.0	3.2	42.6	15.4	
			R1/2	10.5 ± 0.79	-19.7	6.9	3.2	42.7	15.4	
			R3/4	12.5 ± 1.20	-19.8	7.3	3.2	42.8	15.4	
			Ac	16.5 ± 0.78	-19.4	8.3	3.3	42.8	15.3	
MIC 663	M	ManM2	Coc	4.5 ± 0.58	-20.3	8.3	3.5	43.0	14.4	12.7
			Cr1/2	5.5 ± 0.50	-19.5	7.9	3.3	42.9	15.3	
			Crc	7.5 ± 0.49	-19.4	8.0	3.3	42.1	15.1	
			Ri	8.5 ± 0.52	-19.2	8.6	3.2	41.1	14.8	
			R1/4	9.5 ± 0.64	-19.3	8.1	3.2	42.8	15.5	

			R1/2	10.5 ± 0.79	-19.1	8.4	3.2	42.6	15.5	
			R3/4	12.5 ± 1.20	-19.2	8.7	3.2	43.0	15.5	
			Ac	15.5 ± 0.87	-19.2	8.8	3.3	42.9	15.4	
MIC 690	M	ManM2	Coc	4.5 ± 0.58	-21.5	9.4	3.7*	44.1	14.0	9.5
			Cr1/2	5.5 ± 0.50	-20.0	9.3	3.2	42.5	15.4	
			Crc	7.5 ± 0.49	-20.0	8.9	3.3	43.2	15.1	
			Ri	8.5 ± 0.52	-19.7	9.4	3.3	42.9	15.4	
			R1/2	10.5 ± 0.79	-20.2	9.5	3.4	41.2	14.3	
			R3/4	12.5 ± 1.20	-21.1	9.0	3.8*	42.5	12.9	
			Ac	15.5 ± 0.87	-19.8	9.2	3.4	41.6	14.3	
MIC 704	F	ManM2	Coc	4.5 ± 0.58	-20.2	8.0	3.4	43.2	14.9	13.0
			Cr1/2	5.5 ± 0.50	-19.6	7.7	3.2	42.8	15.4	
			Crc	7.5 ± 0.49	-20.0	7.7	3.4	43.1	14.8	
			Ri	8.5 ± 0.52	-19.4	8.4	3.2	43.4	15.6	
			R1/2	10.5 ± 0.79	-19.4	8.7	3.2	43.0	15.5	
			R3/4	12.5 ± 1.20	-19.3	8.8	3.3	42.4	15.2	
			Ac	15.5 ± 0.87	-19.1	9.4	3.2	42.6	15.3	
MIC 715	M	MaxM2	Coc	4.5 ± 0.58	-21.5	7.6	3.9*	44.5	13.5	10.4
			C1/2	5.5 ± 0.50	-20.3	7.7	3.4	43.0	14.8	
			Crc	7.5 ± 0.49	-19.8	7.7	3.2	42.8	15.4	
			Ri	8.5 ± 0.52	-19.7	7.8	3.2	43.1	15.5	
			R1/2	10.5 ± 0.79	-19.7	8.8	3.2	43.1	15.5	
			R3/4	12.5 ± 1.20	-20.0	8.9	3.3	43.1	15.1	
			Ac	16.5 ± 0.78	-20.5	8.1	3.4	41.8	14.3	
MIC 755	F	MaxM3	Coc	10.5 ± 0.79	-20.1	10.1	3.3	42.9	15.0	13.8
			Cr1/2	11.5 ± 1.09	-20.4	10.2	3.3	42.8	15.0	
			Crc	13.5 ± 1.17	-20.0	10.1	3.2	42.8	15.4	
			R1/4	15.5 ± 0.87	-19.8	9.8	3.3	40.9	14.6	

			R1/2	16.5 ± 0.78	-19.6	9.5	3.3	42.5	15.2	
			Ac	23.5 ± 1.12	-19.6	9.7	3.3	42.4	15.2	
MIC 787	F	MaxM2	Crc	7.5 ± 0.49	-19.6	10.1	3.3	41.1	14.5	6.3
			Ri	8.5 ± 0.52	-19.5	10.5	3.3	41.8	14.6	
			R1/4	9.5 ± 0.64	-19.8	10.6	3.3	41.1	14.4	
			R1/2	10.5 ± 0.79	-20.1	10.9	3.4	41.5	14.2	
			R3/4	12.5 ± 1.20	-20.1	9.8	3.4	42.6	14.4	
			Ac	16.5 ± 0.78	-19.8	9.4	3.4	41.5	14.2	
MIC 790	M	MaxM3	Coc	10.5 ± 0.79	-19.7	9.1	3.3	43.0	15.3	13.4
			Cr1/2	11.5 ± 1.09	-19.6	8.8	3.3	42.9	15.4	
			Crc	13.5 ± 1.17	-19.3	8.9	3.3	43.2	15.5	
			R1/4	15.5 ± 0.87	-19.1	8.8	3.3	42.9	15.2	
			R1/2	16.5 ± 0.78	-19.6	9.0	3.4	42.5	14.7	
			Ac	23.5 ± 1.12	-19.5	9.2	3.3	42.4	15.0	
MIC 818	F	MaxM3	Coc	10.5 ± 0.79	-19.9	8.4	3.4	42.9	14.7	12.8
			Cr1/2	11.5 ± 1.09	-19.5	8.3	3.2	42.8	15.4	
			Crc	13.5 ± 1.17	-19.6	8.2	3.3	42.6	15.2	
			R1/4	15.5 ± 0.87	-19.1	8.1	3.2	42.7	15.4	
			R1/2	16.5 ± 0.78	-18.9	8.4	3.2	42.4	15.3	
			Ac	23.5 ± 1.12	-18.9	8.9	3.3	41.3	14.7	
MIC 822	F	MaxM3	Coc	10.5 ± 0.79	-20.2	8.6	3.5	31.1	10.3	9.0
			Cr1/2	11.5 ± 1.09	-19.5	8.7	3.3	39.5	14.1	
			Crc	13.5 ± 1.17	-19.2	8.5	3.2	42.2	15.3	
			R1/4	15.5 ± 0.87	-19.7	8.5	3.3	32.0	11.3	
			R1/2	16.5 ± 0.78	-19.7	8.6	3.3	38.9	13.7	
			Ac	23.5 ± 1.12	-19.5	8.8	3.3	39.8	14.1	
MIC 824	F	ManM2	Coc	4.5 ± 0.58	-19.4	7.9	3.3	40.9	14.7	8.9
			Cr1/2	5.5 ± 0.50	-19.5	7.7	3.3	43.0	15.0	

			Crc	7.5 ± 0.49	-20.2	7.1	3.5	43.0	14.4	
			Ri	8.5 ± 0.52	-19.8	7.2	3.4	42.5	14.5	
			R1/4	9.5 ± 0.64	-19.3	7.4	3.3	42.7	15.1	
			R1/2	10.5 ± 0.79	-19.3	7.5	3.3	42.3	14.9	
			R3/4	12.5 ± 1.20	-19.3	8.1	3.3	42.5	15.1	
MIC 868	F	MaxM2	Coc	4.5 ± 0.58	-19.9	9.3	3.2	42.2	15.4	13.0
			C1/2	5.5 ± 0.50	-19.8	9.8	3.2	42.5	15.4	
			Crc	7.5 ± 0.49	-19.6	10.1	3.2	42.7	15.6	
			Ri	8.5 ± 0.52	-19.0	10.3	3.2	42.9	15.6	
			R1/2	10.5 ± 0.79	-19.3	10.2	3.2	42.8	15.5	
			Ac	16.5 ± 0.78	-19.4	10.4	3.3	42.6	15.2	
MIC 875	M	ManM3	Coc	11.5 ± 1.09	-19.4	9.8	3.2	42.8	15.5	10.9
			Cr1/2	12.5 ± 1.20	-19.5	9.8	3.2	43.1	15.5	
			Crc	13.5 ± 1.17	-19.8	9.7	3.3	40.6	14.6	
			R1/4	15.5 ± 0.87	-19.6	9.7	3.2	41.3	14.9	
			Ac	23.5 ± 1.12	-19.6	10.5	3.3	42.7	15.3	
MIC 897	M	MaxM2	Coc	4.5 ± 0.58	-20.2	9.3	3.5	42.8	14.4	10.3
			C1/2	5.5 ± 0.50	-19.6	9.0	3.3	42.7	15.1	
			Crc	7.5 ± 0.49	-19.4	9.1	3.3	42.9	15.3	
			Ri	8.5 ± 0.52	-19.0	8.3	3.2	42.6	15.3	
			R1/4	9.5 ± 0.64	-19.6	8.6	3.4	43.2	14.7	
			R1/2	10.5 ± 0.79	-19.2	9.2	3.4	42.7	14.8	
			R3/4	12.5 ± 1.20	-19.1	9.4	3.4	42.2	14.6	
			Ac	16.5 ± 0.78	-21.8	9.1	4.5*	42.7	11.2	
MIC 900	F	MaxM2	Coc	4.5 ± 0.58	-19.8	8.5	3.2	42.4	15.5	11.6
			C1/2	5.5 ± 0.50	-19.6	7.9	3.2	42.3	15.3	
			Crc	7.5 ± 0.49	-20.1	7.8	3.4	43.8	15.1	
			Ri	8.5 ± 0.52	-20.0	8.0	3.3	43.2	15.1	

			R1/2	10.5 ± 0.79	-20.1	8.1	3.3	42.0	14.8	
			R3/4	12.5 ± 1.20	-20.2	9.0	3.3	42.6	15.0	
			Ac	16.5 ± 0.78	-20.0	8.9	3.3	41.5	14.9	
MIC 906	F	MaxM2	Coc	4.5 ± 0.58	-19.9	8.8	3.2	42.0	15.1	10.6
			C1/2	5.5 ± 0.50	-19.7	8.4	3.3	42.0	15.0	
			Crc	7.5 ± 0.49	-19.9	8.6	3.3	43.2	15.1	
			Ri	8.5 ± 0.52	-19.6	8.6	3.3	42.8	15.3	
			R1/2	10.5 ± 0.79	-19.6	9.2	3.3	42.9	15.4	
			R3/4	12.5 ± 1.20	-19.7	9.9	3.3	43.0	15.2	
			Ac	16.5 ± 0.78	-19.6	10.4	3.3	42.8	15.3	
MIC 914	F	ManM3	Coc	11.5 ± 1.09	-19.2	10.2	3.2	42.8	15.4	12.4
			Cr1/2	12.5 ± 1.20	-18.9	9.9	3.2	43.2	15.6	
			Crc	13.5 ± 1.17	-19.1	9.9	3.2	42.8	15.4	
			R1/4	15.5 ± 0.87	-19.9	10.2	3.3	43.9	15.4	
			Ac	23.5 ± 1.12	-19.0	10.5	3.2	41.7	15.0	
MIC 919	M	ManM2	Coc	4.5 ± 0.58	-20.4	10.1	3.4	43.8	15.0	12.3
			Cr1/2	5.5 ± 0.50	-19.8	9.5	3.3	42.9	15.2	
			Crc	7.5 ± 0.49	-19.1	9.5	3.2	43.0	15.5	
			Ri	8.5 ± 0.52	-20.2	10.2	3.4	44.5	15.2	
			R1/4	9.5 ± 0.64	-19.5	10.3	3.2	43.3	15.7	
			R1/2	10.5 ± 0.79	-19.7	10.0	3.3	43.3	15.4	
			R3/4	12.5 ± 1.20	-20.4	10.6	3.5	43.3	14.4	
			Ac	15.5 ± 0.87	-19.5	11.7	3.2	42.9	15.6	
MIC 926	F	ManM3	Coc	11.5 ± 1.09	-19.3	8.3	3.2	41.9	15.3	8.9
			Cr1/2	12.5 ± 1.20	-19.4	8.9	3.2	42.0	15.1	
			Crc	13.5 ± 1.17	-19.5	9.3	3.3	41.5	14.8	
			R1/4	15.5 ± 0.87	-19.7	9.2	3.3	42.5	14.8	
			Ac	23.5 ± 1.12	-19.5	9.4	3.3	41.0	14.6	

MIC 958	M	ManM3	Coc	11.5 ± 1.09	-20.4	9.2	3.4	35.4	12.2	5.9
			Cr1/2	12.5 ± 1.20	-19.6	9.0	3.2	39.8	14.4	
			Crc	13.5 ± 1.17	-20.1	8.7	3.5	40.4	13.7	
			R1/4	15.5 ± 0.87	-19.8	9.5	3.3	39.6	13.8	
			Ac	23.5 ± 1.12	-19.6	10.3	3.3	39.3	13.8	

Sex: F = female, M = male. London Atlas development stage derived from AlQahtani *et al.,* (2010, 2014) and Liversidge *et al.* (2020): Coc – cusp outline complete; Cr1/2 – crown half completed; Cr3/4 – crown three quarters completed; Crc – crown completed with defined pulp root; Ri – initial root formation with diverge edges; R1/4 – root length less than crown length with visible bifurcation area; R1/2 – root length equals crown length; R3/4 – three quarters of root length developed with divergent edges; Ac – apex closed with normal PDL width. Asterisk (*) indicates samples that failed measures of sample integrity and were excluded from statistical analysis.

REFERENCES

Acsádi, G., & Nemeskéri, J. (1970). *History of human life span and mortality*. Akademiai Kiado.

Alberici, L. A., & Harlow, M. (2007). Age and innocence: Female transitions to adulthood in late antiquity. *Hesperia Supplements* 41: 193-203. https://www.jstor.org/stable/20066790.

AlQahtani, S. J., Hector, M. P., & Liversidge, H. M. (2010). Brief communication: The London Atlas of human tooth development and eruption. *American Journal of Physical Anthropology* 142(3): 481-490. https://doi.org/10.1002/ajpa.21258.

AlQahtani, S.J., Hector, M. P., & Liversidge, H. M. (2014). Accuracy of dental age estimation charts: Schour and Massler, Ubelaker, and the London Atlas. *American Journal of Physical Anthropology* 154(1): 70-78. https://doi.org/10.1002/ajpa.22473.

Ambrose, S. (1993). Isotopic analysis of paleodiet: methodological and interpretive considerations. In: J. B. Edward, & R. A. Benfer (Eds.), *Investigations of ancient human tissue: Chemical analyses in anthropology* (pp.59-130). Gordon and Breach Science Pub.

Ariès, P. (1962). *Centuries of childhood: A social history of family life.* Vintage Books.

Avery, L.C., Prowse, T.L., & Brickley, M.B. (2019). Dental health and dietary difference at Late Roman Winchester. *Bioarchaeology International* 3(3): 157-173. https://doi.org/10.5744/bi.2019.1011.

Badel, C. (2012). Alimentation et société dans la Rome classique : bilan historiographique (IIe siècle av. J.-C. – IIe siècle apr. J.-C.). *Dialogues d'histoire ancienne* S& : 133-157. https://doi.org/10.3917/dha.hs71.0133.

Beaumont, J., Montgomery, J., Buckberry, J., & Jay, M. (2015). Infant mortality and isotopic complexity: New approaches to stress, maternal health, and weaning. *American Journal of Physical* Anthropology, 157(3): 441-457. https://doi.org/10.1002/ajpa.22736.

Beaumont, J., & Montgomery, J. (2016). The great Irish famine: Identifying starvation in the tissues of victims using stable isotope analysis of bone and incremental dentine collagen. *PLOS One* 11:e0160065. https://doi.org/10.1371/journal.pone.0160065.

Beerden, K. (2019). Textual evidence: Roman reflections of realities. In P. Erdkamp, & C. Holeran (Eds.), *The Routledge handbook of diet and nutrition in the Roman World* (pp. 17-25). Routledge.

Brickley, M.B., Kahlon, B., & D'Ortenzio, L. (2019). Using teeth as tools: Investigating the mother-infant dyad and developmental origins of health and disease hypothesis using vitamin D deficiency. *American Journal of Physical Anthropology* 171(2): 342-353. https://doi.org/10.1002/ajpa.23947.

Brooks, S., & Suchey, J. (1990). Skeletal age determination based on the os pubis: A comparison of the Acsadi-Nemeskeri and Suchey-Brooks Methods. *Human Evolution* 5: 227-238. https://doi.org/10.1007/BF02437238.

Buchet, L., & Séguy, I. (2008). L'âge au décès des enfants : âge civil, âge biologique, âge social ? In F. Gusi, S. Muriel, O. Carme (Eds.), *Nasciturus, Infans, Puerulus : Vobis master terra* (pp. 25-39). Servicio de Investigaciones Arqueológicas y Prehistóricas.

Caldwell, L. (2015). *Roman girlhood and the fashioning of femininity*. Cambridge University Press.

Cardoso, H. (2008a). Epiphyseal union at the innominate and lower limb in a modern Portuguese skeletal sample, and age estimation in adolescent and young adult male and female skeletons. *American Journal of Physical Anthropology* 135(2):161-170. https://doi.org/10.1002/ajpa.20717.

Cardoso, H. (2008b). Age estimation of adolescent and young adult male and female skeletons II, Epiphyseal union at the upper limb and scapular girdle in a modern Portuguese skeletal sample. *American Journal of Physical Anthropology* 137(1):97-105. https://doi.org/10.1002/ajpa.20850.

D'Ortenzio, L., Brickley, M., Schwarcz, H., & Prowse, T. (2015). You are not what you eat during physiological stress: Isotopic evaluation of human hair. *American Journal of Physical Anthropology* 157(3): 374-388. https://doi.org/10.1002/ajpa.22722.

DeNiro, M. J. (1985). Post-mortem preservation and alteration of in vivo bone collagen isotope ratios in relation to palaeodietary reconstruction. *Nature* 317:806–809. https://doi.org/10.1038/317806a0.

Eerkens, K. W., Berget, A. G., & Bartelink, E. J. (2011). Estimating weaning and early childhood diet from serial micro-samples of dentin collagen. *Journal of Archaeological Science* 38(11): 3101-3111. https://doi.org/10.1016/j.jas.2011.07.010.

Eyben, E. (1993). *Restless youth in ancient Rome*. Routledge.

France, C., Giaccai, J., & Cano, N. (2011). The effect of PVAc treatment and organic solvent removal of $\delta^{13}C$, $\delta^{15}N$, and $\delta^{18}O$ values of collagen and hydroxyapatite in a modern bone. *Journal of Archaeological Science* 38(12): 3387-3393. https://doi.org/10.1016/j.jas.2011.07.024.

Fernandez-Martinez, P., Maurer, A. F., Jiménez-Morillo, N. T., Botella, M., Lopez, B., & Dias, C. B. (2020). Bone stable isotope data of the Late Roman population (4^{th}-7^{th} centuries CE) from Mondragones (Granada): A dietary reconstruction in a Roman villa context of south-eastern Spain. *Journal of Archaeological Science: Reports* 33: 102566. https://doi.org/10.1016/j.jasrep.2020.102566.

Fritz, C. O., Morris, P. E., & Richler, J. J. (2012). Effect size estimates: Current use, calculations, and interpretation. *Journal of Experimental Psychology: General* 141(1): 2-18. https://doi.org/10.1037/a0024338.

Fuller, B. T., Richards, M. P., & Mays, S. A. (2003). Stable carbon and nitrogen isotope variations in tooth dentine serial sections from Wharram Percy. *Journal of Archaeological Science* 30(12): 1673-1684. https://doi.org/10.1016/S0305-4403(03)00073-6.

Garnsey, P. D. A. (1999). *Food and society in classical antiquity.* Cambridge University Press.

Gowland, R. (2000). Playing Dead: Implications of mortuary evidence for the social construction of childhood in Roman Britain. In G. Davies, A. Gardner, K. Lockyear (Eds.), *TRAC 2000: Proceedings of the Tenth Annual Theoretical Roman Archaeology Conference* (pp. 152-168). Oxbow Books.

Gustafson, G., & Koch, G. (1974). Age estimation up to 16 years of age based on dental development. *Odontologisk Revy* 25(3): 297-306.

Halcrow, S. E., & Tayles, N. (2008). The bioarchaeological investigation of childhood and social age: Problems and prospects. *Journal of Archaeological Method and Theory* 15: 190-215. https://doi.org/10.1007/s10816-008-9052-x.

Halsall, G. (2012). *Barbarian migrations and the Roman west, 376-568.* Cambridge University Press.

Harlow, M., & Laurence, R. (2002). *Growing up and growing old in ancient Rome.* Routledge.

Ingram, J. (2015). *Activity and aging in adult males: investigation of entheses and cortical bone from the site of Lisieux-Michelet in Northern France.* Unpublished MA Thesis. McMaster University. https://macsphere.mcmaster.ca/handle/11375/18247.

Katz, D., & Suchey, J. (1986). Age determination of the male os pubis. *American Journal of Physical Anthropology* 69(4): 427-435. https://doi.org/10.1002/ajpa.1330690402.

Kehne, P. (2007). War- and peacetime logistics: Supplying Imperial armies in east and west. In Erdkamp, P. (Ed.), *A companion to the Roman army* (pp. 323-338). Blackwell Publishing.

Laes, C. (2011). *Children in the Roman Empire: Outsiders within.* Cambridge University Press.

Laes, C. (2015). Masters and apprentices. In W. M. Bloom (Ed.), *A companion to ancient education* (pp. 474-482). John Wiley & Sons, Inc.

Laes, C. (2019). Women, children and food. In P. Erdkamp, & C. Holeran (Eds.), *The Routledge handbook of diet and nutrition in the Roman world* (pp177-187). Routledge Press.

Lett, D. (2019). La perception de l'enfance dans l'Antiquité et au Moyen Âge. *Après-demain*, 1: 5-6. https://doi.org/10.3917/apdem.049.0005.

Lewis, M. E. (2019). Children in Bioarchaeology: methods and interpretations. In A. Katzenberg, & A. Grauer (Eds.), *Biological anthropology of the human skeleton* (pp. 119-143). Academic Press.

Liversidge, H. M., AlQahtani, S. J., & Hector, M. P. (2020). *Playback.* The London Atlas: Version 2. http://www.ibossolutions.com/qmul/v3/.

Mion, L., Herrscher, E., Blondiaux, J., Binet, E., & Andre, G. (2016). Comportements alimentaires en Gaule du Nord: étude isotopique du site de l'Îlot de la Boucherie (IIIe–Ve siècles apr. J.-C.) à Amiens. *Bulletins et Mémoires de la Société d'Anthropologie de Paris*, 28:155-175. https://doi.org/10.1007/s13219-016-0164-7.

Munaro, P. (2012). Temps de guerre, temps de paix: Influence du contexte sociologique sur l'état bucco-dentaire au IV^{e} siècle ap. J.-C. à Lisieux, Calvados. Unpublished PhD Thesis. University de Lorraine. https://hal.univ-lorraine.fr/hal-01738929.

Paillard, D., Alduc-Le Bagousse, A., Allen, M. I., Blondiaux, J., Buchet, L., Chapelain de Seréville-Niel, C., Guihard, P. M., Maneuvrier, C., Pacory, J., Pilet, C., Pilet-Lemière, J., & Vipard, P. (Forthcoming). *La nécropole Michelet. Bilan et perspectives des recherches sur la cité*

de Lisieux (Calvados) de ses origines au IX^e siècle, Publications du Craham, Presses Universitaires de Caen.

Paillard, D., Alduc-Le Bagousse, A., Buchet, L., Blondiaux, L., & Niel, C. (2009). Identité sociale ou miroir d'une société en évolution? Les tombes remarquables de la seconde moitié de IV^e siècle dans la nécropole Michelet à Lisieux (Calvados). *Inhumations de prestige ou prestige de l'inhumation?* Université de Caen – CRAHM; 1-22. https://hal/archives-ouvertes.fr/hal-00469526.

Paillard, D., Buchet, L., & Alduc-Le Bagousse, A. (2006). Nombre d'inhumés, nombre d'habitants: Estimations archéologiques et anthropologiques. Lisieux (Calvados), IV^e siècle de notre ère. In L. Buchet, C. Dauphin, I. Séguy (Eds.), *La paléodémogrphie. Mémoire d'os, mémoire* (pp. 209-223). Proceedings from the 8th Anthropology Day of Valbonne.

Paillard, D. (1994). Le quartier artisanal de Michelet. In J. Bergeret (Ed.), *Lisieux avant l'an mil: Essai de reconstitution* (pp. 36-45). Musées de la ville de Lisieux.

Phenice, T. W. (1969). A newly developed visual method of sexing the os pubis. *American Journal of Physical Anthropology* 30(2): 297-301. https://doi.org/10.1002/ajpa.1330300214.

Prowse, T., Nause, C., & Ledger, M. (2014). Growing up and growing old on an Imperial estate: Preliminary paleopathological analysis of skeletal remains from Vagnari. In A. M. Small (Ed.), *Beyond Vagnari: New themes in the study of Roman south Italy* (pp. 111-122). Edipuglia.

Prowse, T. L., Schwarcz, H. P., Saunders, S. R., Macchiarelli, R., & Bondioli, L. (2005). Isotopic evidence for age-related variation in diet from Isola Sacra, Italy. *American Journal of Physical Anthropology* 128(1): 2-13. https://doi.org.10.1002/ajpa.20094.

Redfern, R., Gowland, R., Millard, A., Powell, L., & Gröcke, D. (2018). 'From the mouths of babes': A subadult dietary stable isotope perspective on Roman London (*Londinium*). *Journal of Archaeological Science: Reports* 19: 1030-1040. https://doi.org/10.1016/j.jasrep.2017.08.015.

Scheidel, W. (2007). Roman funerary commemoration and the age at first marriage. *Classical Philology* 102: 389-402.

Schwarcz, H. P., & Schoeninger, M. H. (1991). Stable isotope analyses in human nutritional ecology. *Yearbook of Physical Anthropology* 34(S13): 283-321. https://doi.org/10.1002/ajpa.1330340613.

Sharpe, W. D. (1964). Isidore of Seville: The medical writings. An English translation with an introduction and commentary. *Transactions of the American Philosophical Society* 54(2): 1-75. https://www.jstor.org/stable/10.5938.

Shaw, B. D. (1987). The age of Roman girls at marriage: some reconsiderations. *The Journal of Roman Studies* 77: 30-46. https://doi.org/10.1017/S0075435800008492.

Smith, R. J. (2017). The continuing misuse of null hypothesis significance testing in biological anthropology. *American Journal of Physical Anthropology* 166(1): 236-245. https://doi.org/10.1002/ajpa.23399.

Sullivan, G. M., & Feinn, R. (2012). Using effect size – or why the *p* value is not enough. *Journal of Graduate Medical Education* 4(3): 279-282. https://doi.org/10.4300/JGME-D-12-00156.1.

van Klinken, G. J. (1999). Bone collagen quality indicators for palaeodietary and radiocarbon measurements. *Journal of Archaeological Science* 26(6): 687–695. https://doi.org/10.1006/jasc.1998.0385.

Vuolanto, V. (2015). Children and work: Family strategies and socialization in Roman and Late Antique Egypt. In K. Mustakallio, & J. Hanska (Eds.), *Agents and objects: Children in Pre-Modern Europe* (pp. 97-112). Institutum Romanum Finlandiae.

Waters-Rist, A. L., & Katzenberg, M. A. (2010). The effect of growth on stable nitrogen isotope ratios in subadult bone collage. *International Journal of Osteoarchaeology* 20(2): 172-191. https://doi.org/10.1002/oa.1017.

Wood, J.W., Milner, G. R., Harpending, H. C., & Weiss, K. M. (1992). The osteological paradox: Problems of inferring prehistoric health from skeletal samples [and comments and reply]. *Current Anthropology* 33(4): 343-370. https://doi.org/10.1086/204084.

CHAPTER 3: PUBERTAL TIMING AS A MEASURE OF EARLY LIFE STRESS IN ROMAN ITALY AND ROMAN GAUL

Title: Pubertal Timing as a Measure of Early Life Stress in Roman Italy and Roman Gaul.

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ABSTRACT

Objectives: Puberty is a period of rapid growth and development, and the age of onset and duration of this period may serve as a sensitive measure of developmental stress during childhood. In this study, we compare pubertal timing in two Roman Imperial cemetery sites integrating biological and social factors to better understand pubertal timing differences in relation to Early Life Stress (ELS).

Materials and Methods: Osteological pubertal timing methods were applied to 264 individuals from Roman Imperial Lisieux-Michelet (4-5th centuries CE; France) and *Isola Sacra* (1-4th centuries CE; Italy). Novel peptide analysis of tooth enamel was used to assess sex for a sub-sample of pre-pubertal remains.

Results: Individuals experienced puberty between 9 and 20 years of age, with females experiencing the acceleration stage earlier than males in both samples with large effect sizes ($p<.05$, $g>1.2$). Females exhibited no significant differences in pubertal timing between sites, but males from *Isola Sacra* exhibited younger ages of pre-puberty than males from Lisieux-Michelet. Menarche was experienced around 15 years of age among females in both samples.

Discussion: The inter-site comparisons demonstrate similar patterns of pubertal timing, suggesting similar exposure to ELS. For males, the timing of pubertal development aligns with ancient literary descriptions of key social milestones. Females in the current study entered puberty earlier than literary sources suggest, and experienced puberty for an extended period, pointing to possible gendered exposure to ELS, influenced by social status in the Roman Empire. These results demonstrate how pubertal timing may be considered as a measure of developmental stress in past populations.

INTRODUCTION

Understanding the health and well-being of past populations is a central tenant of biological anthropology (Larsen, 2002). Yet, 'health' is difficult to measure, as it encapsulates aspects of physical, social, and mental well-being, at both individual and community levels, which are difficult to assess for past populations (Reitsema & McIlvaine, 2014). Biological anthropologists investigate indicators of growth disruptions or developmental stress markers as proxies for (poor) health, assessing traits such as: vertebral neural canals and enamel hypoplasia (e.g., Watts, 2015), bone length and cross-sectional properties (e.g., Osipov *et al.*, 2020), and dental fluctuating asymmetry (e.g., Milella, Betz, Knüsel, Larsen & Dori, 2018), among others. However, some of these methods (e.g., bone length) rely on examining the remains of non-survivors, effectively assessing developmental stress for the deceased, rather than the living (Wood, Milner, Harpending & Weiss, 1992). With that in mind, this study uses pubertal timing as a mechanism to infer Early Life Stress (ELS) for those who survived the period of childhood and applies this approach to two skeletal collections from the Roman Imperial period (1-5th centuries CE).

Puberty is a period of rapid growth, defined by the development of secondary sexual characteristics and the pubertal growth spurt (Carswell & Stafford, 2016). When discussing puberty, researchers use a variety of terms. In this paper, pubertal timing reflects the chronological age at which each stage of puberty is reached, while pubertal tempo refers to the time it takes to pass through all stages of puberty (following Mendle, Harden, Brooks-Gunn & Graber, 2010). Menarche refers to the first menstruation experienced by females.

Researchers sub-divide the period of pubertal development into five stages: pre-puberty, acceleration, peak height velocity (PHV), deceleration, and post-puberty (Marshal & Tanner, 1969; 1970). In skeletal remains, pubertal stage-at-death is determined by assessing the mineralization of the mandibular canine, development of the hand and wrist (i.e., hamate, phalanges, radius, ulna), fusion of the distal humerus and iliac crest, and growth of the cervical vertebrae, following Shapland and Lewis (2013, 2014). Additionally, menarcheal stage-at-death (i.e., pre, peri and post) is assessed based on the fusion of the iliac crest and phalanges, as well as pubertal stage-at-death (Buehl & Pyle, 1942).

The pattern of pubertal development through the five stages follows a predictable manner; however, pubertal timing and pubertal tempo for males and females, as well as age at menarche for females, are influenced by a variety of factors, including genetics, nutrition and obesity, social conditions, and disease (Walvoord, 2010; Li *et al.*, 2017). As it is difficult to tease these factors apart, researchers have suggested that pubertal timing and age at menarche may be used as a broad measure of developmental stress, or Early Life Stress (ELS), as it captures early physical and psychosocial experiences (Joos, Wodzinski, Wadsworth & Dorn, 2018). In neurobiology and clinical literature, ELS refers to the exposure to events during childhood that "exceeds the child's coping resources, leading to prolonged periods of stress," and can include various forms of adversity, such as abuse (physical, sexual, emotional, and verbal), neglect, illness, and adverse social conditions (Baker *et al.*, 2013: 196). The connection between ELS and pubertal timing can be understood through the concept of allostatic load, which refers to the cumulative 'wear and tear' individuals experience through increased exposure to physical and psychosocial stressors and resulting stress hormones (Sterling & Eyer, 1988; Allsworth, Weitzen & Boardman, 2005). Allostatic load cannot be observed directly, but is inferred through other variables (i.e., multisystem biomarker composites representing the neuroendocrine, metabolic, cardiovascular,

and immune systems) and calculated using allostatic load indices (ALIs) (Edes & Crews, 2016). Although bioarchaeologists may not be able to calculate ALIs, we can identify long-term health outcomes on bones and teeth, and work to understand the early life conditions that may have contributed to their development.

While the mechanisms behind ELS and altered pubertal timing are not fully understood, it is likely related to the premature activation of hypothalamic-pituitary-adrenal (HPA) and hypothalamic-pituitary-gonadal (HPG) axes during ELS, resulting in early pubertal development (Joos *et al*., 2018). Thus, age at menarche in females, and pubertal timing for males and females may serve as proxies for allostatic load in early development, and function as measures of developmental stress in childhood or ELS, for those who survived that period of life. In particular, chronic ELS and increased allostatic load are believed to contribute to early onset puberty, and early menarche (Joos *et al.,* 2018; Allsworth *et al.,* 2005; Burris & Wiley, 2021).

In biological anthropology, age at menarche has been considered in relation to adverse childhood experiences in living populations (e.g., Holdsworth & Appleton, 2020) and to improved living conditions in archaeological collections (e.g., DeWitte & Lewis, 2021). However, pubertal timing as a measure of ELS has yet to be incorporated into the 'toolkit' used to assess population stress, health, and well-being in the past. The current study investigates patterns of pubertal timing in middle-class populations in Roman Gaul (present-day France) and near Rome itself. We aim to:

1. Identify osteological patterns of pubertal timing in samples from Roman Gaul and Roman Italy.
2. Contextualize the osteological data in relation to ancient literary sources that discuss puberty and adolescence in the Roman world.
3. Investigate osteological patterns of pubertal timing for males and females in relation to developmental stress or ELS, considering biological and social explanations for the patterns observed.

The osteological pubertal data presented here demonstrates the applicability of pubertal timing as a measure of developmental stress in past populations.

MATERIALS AND METHODS

MATERIALS

Two skeletal samples were selected for analysis to allow inter-population comparisons of pubertal timing and age at menarche: *Isola Sacra* (1st-4th centuries CE; Rome, Italy) and Lisieux-Michelet (4-9th centuries CE; Lisieux, France). Both samples represent middle-class populations from the Roman Imperial and Late Roman periods, respectively (Fig. 3-1). From the two collections, all individuals between the ages of 8 and 25 were examined and included in the study (n=320), to ensure that the entire period of puberty was captured, following ages used by Blom and colleagues (2021).

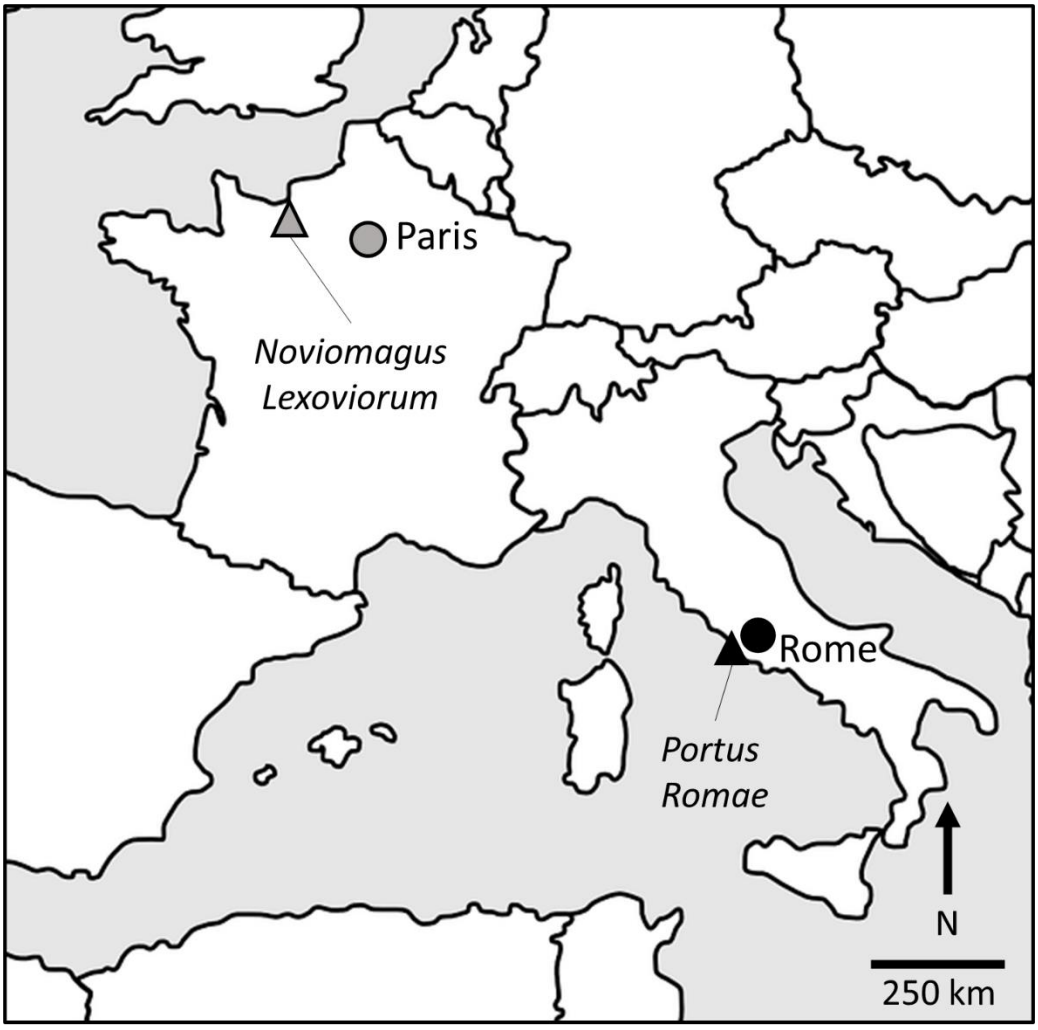

Figure 3-1: Map of western Europe with modern capital cities (circles) and archaeological sites (triangles) in the current study indicated in France (grey) and Italy (black).

The necropolis of *Isola Sacra* is associated with the Roman Imperial town of *Portus Romae,* the main port servicing Rome (Keay, Millett, Paroli, & Strutt, 2005). Construction of the port began in the 1st century CE, under the direction of Emperor Claudius, and the local community quickly grew in response (Keay *et al.,* 2005). Some have suggested that the population of *Portus* may have reached several thousand inhabitants, and, while Keay and colleages (2005: 311) stress there is no specific evidence to support this figure, they acknowledge that a substantial population would have been needed to support the scale of activities at *Portus*. As a port town, the inhabitants of *Portus* relied on the activities of the harbour for their daily living, with evidence for merchants, traders, shopkeepers, craftsmen, and artisans (Sperduti, Bondioli, & Garnsey, 2012). The necropolis of *Isola Sacra* is located between *Portus* and *Ostia Antica*, on an artificial island, and was the main cemetery used by the community of *Portus* between the 1-4th centuries CE (Calza & Becatti, 2008). More than 200 funerary buildings and 2000 individuals have been excavated from the site. Terracotta reliefs and inscriptions suggest the cemetery was used by middle-class individuals, including freedmen and immigrants (Calza & Becatti, 2008).

The second site, Lisieux-Michelet, is associated with the necropolis outside the Late Roman Imperial city of *Noviomagus Lexoviorum* (Paillard *et al.*, forthcoming). *Noviomagus* was a medium-sized urban center with evidence for trade, farming, an artisanal district, and where military presence seems to be present at various times in the Roman period (Paillard, 2006). Following a series of attacks by the Franks and Saxons in the 3rd century, the previously open-urban settlement became a fortified *castrum*, covering eight hectares of land and an estimated population of 400 permanent inhabitants within the city walls (Paillard, 2006; Paillard *et al.* forthcoming). Positioned along major roads, *Noviomagus* connected the northern coast to Roman Gaul (Munaro, 2012). The necropolis at Lisieux-Michelet was used during the Late Roman (4-5th centuries CE) and Merovingian periods (6-9th centuries CE). Archaeological excavations have identified 1156 skeletons from 970 graves (Paillard *et al.*, forthcoming). In the current study, only individuals from the Late Roman period (4-5th centuries CE) were included.

AGE ESTIMATION

Osteological age-at-death was estimated using dental development (Gustafson & Koch, 1974), epiphyseal fusion (Cardoso, 2008a; 2008b), pubic symphysis morphology (Brooks & Suchey, 1990; Katz & Suchey, 1986), and transition analysis (Boldsen, Milner, Konigsber, & Wood, 2002). In instances where age estimations produced conflicting results, dental development and epiphyseal fusion were given greater priority. Features that were used to estimate pubertal stage-at-death (e.g., mineralization of the mandibular canine, fusion of the distal radius, fusion of the iliac crest) were not used to estimate osteological age. From these age estimates, mean age-at-death, to the nearest whole year, was calculated (following Lewis, Shapland & Watts, 2016).

SEX ESTIMATION

Multiple methods were used to estimate sex. Macroscopic analysis of pelvic and cranial morphology was applied to individuals aged 15+ (Phenice, 1969; Buikstra & Ubelaker, 1994), while the unfused ilium and mandible were visually assessed for individuals aged <15 years (Schutkowski, 1993). An adolescent specific method, using the distal humerus, was also used for individuals between the ages of 11 and 20 (Rogers, 2009). When possible, sex was also estimated using dental metrics of the permanent canine and premolars, using the sample mean as the sectioning point between males (> mean) and females (< mean) (Cardoso, 2008c). Intraobserver error tests demonstrate a strong correlation between the first and second measurements, suggesting measurements were performed consistently (ICC = 0.957, $p<.001$). Lastly, for a sub-sample of both Lisieux-Michelet (n= 43) and *Isola Sacra* (n=25), peptides in dental enamel were assessed following Stewart, Gerlach, Gowland, Gron and Montgomery (2017).

For peptide analysis, teeth were cleaned using repeated ultrasonic baths in distilled H_2O until the water remained clear, followed by a 3% H_2O_2 rinse for 30 seconds and, lastly, rinsed with dH_2O. Teeth were air dried, and two acid etches of the enamel were performed, by holding the cusp of the tooth against 5% (vol/vol) HCl, to remove some of the enamel from the tooth and suspend the particles within the liquid (Fig. 3-2). The first etch was completed for two minutes in the cap of a 2mL Eppendorf LoBind Microcentrifuge Tube for protein research to remove any surface contaminants and discarded, while the second etch was completed for three minutes in a Protein Lo-Bind Tube and retained as the etch solution.

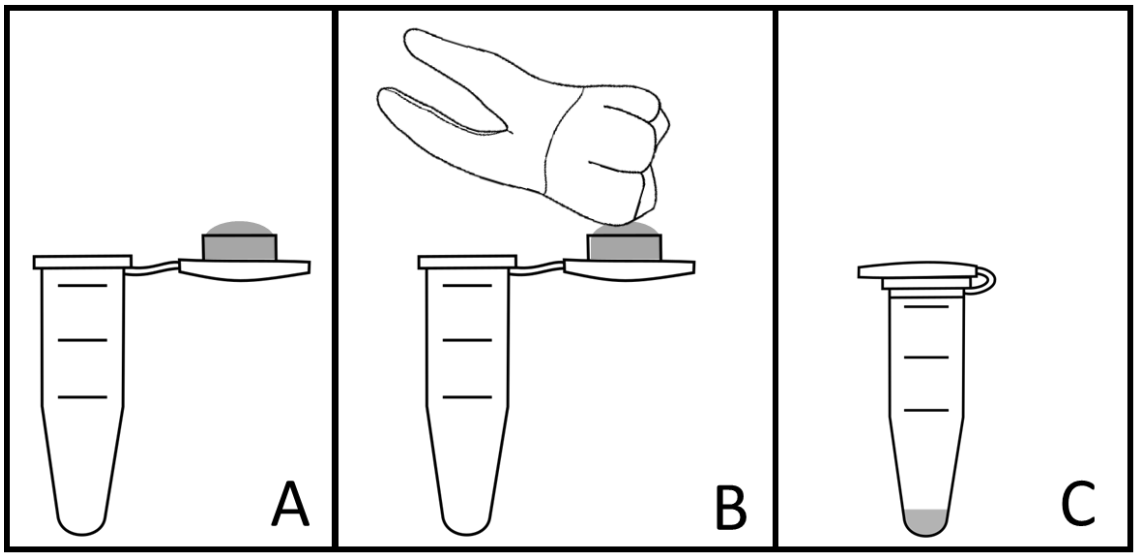

Figure 3-2: Etching process. A: Add 5% (vol/vol) HCl acid (grey) until a convex meniscus in the cap of a 2mL Eppendorf LoBind Microcentrifuge Tube. B: Hold the cusp of the tooth in the acid for two minutes on the initial etch, or three minutes for the second etch. C: Close the cap and turn upright, containing the etch solution in the bottom of the Eppendorf Tube (grey).

A C18 resin-loaded ZipTip was attached to an adjustable 0.5-10uL pipette, set to 10uL, and conditioned using 100% CH_3CN (three times) and 0.1% (vol/vol) CH_2O_2 (three times), with each draw discarded. The sample was then loaded into the ZipTip by pipetting the etch solution up and down ten times, with the last draw discarded back into the Protein-LoBind Tubes. Then, 0.1% (vol/vol) CH_2O_2 was drawn and discarded six times to wash the sample. The adjustable pipette was set to 4uL and the elution buffer (60% CH_3CN /0.1% CH_2O_2) was drawn up, and the final sample was ejected into Thermo Scientific 11mm autosampler vials, to minimize sample loss. Samples were subsequently dried with a Thermo Scientific Speedvac vacuum concentrator at room temperature for 30 minutes.

Prepared samples were dissolved in 12uL of 0.1% trifluoroacetic acid (TFA) in water and centrifuged for five minutes to remove any particulate matter. Following this, 5uL of each sample were injected by reverse-phase nanoLC-MS with liquid chromatograph (Ultiamte RSLCNano 3000; Thermo Fisher Scientific) coupled to a hybrid quadrupole orbitrap mass spectrometer (Q Exactive HG; Thermo Fisher Scientific). Peptides were loaded onto a C18 trapping cartridge (Pepmap100 C18 5µm resin; Thermo Fisher Scientific; 75µm x 5 cm) for 8.5 min at a flow rate of 7.5 µL/min with 0.08% TFA. Separation was achieved at a flow rate of 70 nL/min on a home-made analytical column (Reprosil-Pur 120 C18-AQ 5µm resin; 50 cm × 50 µm) with a gradient starting at 5% acetonitrile (solvent B), increased to 8% B over 2 min, then to 26% B over 30 min, 38% B over 5 min, and 80% B over 2 min, held constant at 80% B for 5 min, returned to 5% B, and equilibrated for 38 min.

The MS was operated in parallel reaction monitoring (PRM) mode. Specifically, the MS performs a cycle of full MS, MS/MS for 540.2796 (SIRPPYPSY, $[M+2H]^{2+}$, the peptide present

in the isoform AMELX), and MS/MS for 440.2233 ($SM_{ox}IRPPY$, $[M+2H]^{2+}$, the peptide present in isoform AMELY). Each full MS scan is collected with 390– 1,200 m/z, resolution 120,000, AGC target 3e6, maximum injection time 200ms. Each MS/MS scan was collected with isolation window at 1.2Da, normalized collision energy (NCE) at 28, AGC target 2e5, resolution 30,000. Total MS acquisition time was 50 min. Data was processed with Skyline v 4.1.0.11714 (64 bit), identifying peak areas for selected fragment ions.

The peptide analysis protocol was first applied to five modern teeth with known biological sex (HiREB ethics approval, project number 4834-T) and four archaeological teeth with clear indicators of osteological sex (2 males; 2 females). Using these controls, thresholds were calculated for the current sample, identifying biological sex based on Y:X ratios (AMEL-Y/AMEL-X). Specifically, females are represented by Y:X ratios of <0.3 and males represented by Y:X ratios of >0.5. Individuals with ratios between 0.3 and 0.5 were categorized as ambiguous, as the data could not provide clear indication regarding their biological sex. These thresholds were then applied to 68 samples to more confidently assess biological sex (Supplementary Table 3-8). Permission for destructive analysis of archaeological dental tissues was granted by Dr. Chapelain de Seréville-Niel at Université de Caen Normandie for Lisieux-Michelet, and by Dr. Bondioli at Museo delle Civiltà di Roma for *Isola Sacra*.

In instances where sex estimations produced conflicting results, enamel peptides were given greatest priority (for all ages, n=65), followed by pelvic and cranial dimorphism (for individuals aged 15+, n=176), dental metrics (for all ages, n=49), and distal humerus (for individuals aged 11-20 years, n=8) and lastly, unfused mandible and ilium (for individuals <15 years old, n=10). For the remaining 12, sex could not be estimated using any of the methods above.

PUBERTAL STAGE

Pubertal stage-at-death was assessed following the methods outlined by Shapland and Lewis (2013, 2014). In this method, development of the mandibular canine, hook of the hamate, and cervical vertebrae maturation (CVM), as well as the fusion of the phalanges, distal radius, distal humerus, proximal ulna, and iliac crest were macroscopically examined and recorded for each individual. Pubertal-stage-at-death was assigned for individuals who had at least three features present and in agreement based on the categories in Table 3-1. For CVM, the third cervical vertebra (C3) was preferentially selected, when available. However, as CVM has produced inconsistent results in medical and bioarchaeological studies, it was not considered problematic if CVM was one stage ahead or behind other features (Santiago *et al.,* 2012; Arthur, Gowland & Redfern, 2016). In these instances, priority was given to other features, provided there were enough to properly assess pubertal stage. Individuals with less than three observable features, or conflicting features, were assigned an undetermined pubertal stage.

Menarche occurs approximately one year after PHV, and coincides with the ossification of the iliac crest, making this feature the best osteological indicator of menarche (Buehl & Pyle, 1942). As ossified but unfused iliac crests are infrequently recovered from archaeological contexts, menarche can also be estimated to occur after PHV but before the fusion of the phalangeal epiphyses and fusion of the iliac crest (Buehl & Pyle, 1942). Based on this, females were divided into three categories: pre-menarcheal, menarcheal (i.e., around the time of menarche), and post-menarcheal (Table 3-2).

Table 3-1: Pubertal stages and their osteological features. The criteria for each stage were compiled from Shapland and Lewis (2013, 2014).

Feature	**Pubertal Stage**				
	Pre-Puberty	Acceleration	PHV	Deceleration	Post-Puberty
Canine	Stage F	Stage G	Stage H	Stage H	Stage H
Hamate	Stage G	Stage H/H.5	Stage I	Stage I	Stage I
Phalanges	UF	UF	UF/PF	PF/F	F
Radius	UF	UF	UF	PF	F
Ulna	UF	UF	PF	F	F
Humerus	UF	UF	PF	F	F
Iliac Crest	UF	UF	UF	Ossified and UF	PF/F
Cervical Vertebra	Stage 1	Stage 2	Stage 3	Stage 4/5	Stage 6

PHV – Peak Height Velocity. Canine development based on Demirjian stages: Stage F = Apex ends in a funnel shape, root length is ≥ crown height; Stage G = Apical end is still partially open; Stage H = Apical end of the root canal is completely closed. Hamate development: Stage G = hook undeveloped; Stage H = hook appearing; Stage H.5 = hook developing; Stage I = hook complete. UF – unfused, PF – partially fused, F – fused. Cervical Vertebra maturation based on: Stage 1 = inferior border flat, vertebral body wedge shaped; Stage 2 = Concavity appearing in inferior border, body nearly rectangular in shape; Stage 3 = Concavity developing in inferior border, body rectangular in shape; Stage 4 = Distinct concavity in inferior border, body shape nearly square in shape; Stage 5 = Accentuated concavity in inferior border, body square in shape; Stage 6 = Deep concavity in inferior border, body taller than it is wide.

Table 3-2: Menarcheal stages and their osteological features based on Buehl and Pyle (1942).

	Pre-Menarcheal	**Menarcheal**	**Post-Menarcheal**
Pubertal stage	Before PHV	At/After PHV	At/After PHV
Phalanges	Unfused	Unfused	Fused
Iliac Crest	Unfused	Ossified but unfused	Fusing/Fused

PHV – Peak Height Velocity

STATISTICAL TESTING

As assumptions of normality were not met for the data, non-parametric tests were used (e.g., Mann-Whitney-U). Following DeWitte and Lewis (2021), we adopt a significance threshold of 90% ($p<.10$) to mitigate issues of small sample sizes. As statistical power is directly tied to sample size, using a more conservative approach (e.g., $p<.05$) would prevent the ability for the statistical tests to identify small and moderate effects (Morgan, 2017). We also employ Hedge's G effect sizes which describe the size of the observed difference. When interpreting these tests in tandem, effects that are large ($g>0.8$) and nonsignificant ($p>.10$) may suggest that differences are present, but sample sizes were too small to detect them (Fritz, Morris & Richler, 2012).

Meanwhile, effects that are small ($g<0.3$) but significant ($p<.10$) can help warn researchers against possibly overvaluing statistical tests (Fritz *et al.*, 2012). Together, the significance and substantive tests help strengthen statistical interpretations, particularly when confronted with issues of small sample sizes.

RESULTS

DEMOGRAPHIC RESULTS

From the two collections, 320 individuals were estimated to be between the ages of 8 and 25 and were included in the study. For these, pubertal stage-at-death could be confidently identified for 264 individuals (127 from *Isola Sacra*, 137 from Michelet), or 82.5% of the original sample, and were included in the current study (Table 3-3; Supplementary Table 3-9). Of these, 47.0% (n=124) were estimated as male/probable male, while 51.1% (n=135) were estimated as female/probable female. For the remaining 1.9% (n=5) sex could not be estimated.

Table 3-3: Sample size by pubertal stage at death, sex and site.

	Lisieux-Michelet (MIC)				*Isola Sacra* (SCR)				Total			
	M	F	UD	Total	M	F	UD	Total	M	F	UD	Total
Pre-Puberty	10	7	2	19	8	10	0	18	18	17	2	37
Acceleration	11	6	1	18	7	9	0	16	18	15	1	34
PHV	9	7	0	16	9	9	2	20	18	16	2	36
Deceleration	13	8	0	21	17	14	0	31	30	22	0	52
Post-Puberty	22	41	0	63	18	24	0	42	40	65	0	105
Total	65	69	3	137	59	66	2	127	124	135	5	264

M – male/probable male. F – female/probable female. UD – undetermined. PHV – Peak Height Velocity.

PUBERTAL TIMING

In the Lisieux-Michelet sample, pubertal stage-at-death was assessed for 65 males and 69 females. All 8-year-old males were pre-pubertal (no 9 or 10-year-old males were identified at Lisieux-Michelet), while all males aged 20 or older were post-pubertal. For females, all individuals aged 8 or 9 were pre-pubertal, and all individuals aged 19 or older were post-pubertal. Mann-Whitney U and Hedge's G analysis demonstrates that males and females from Lisieux-Michelet began and ended puberty around the same time; while females reached acceleration earlier than males, differences at acceleration exhibit a large effect size (Table 3-4).

In the *Isola Sacra* sample, pubertal stage was assessed for 59 males, with all individuals aged 10 years and younger assessed as pre-pubertal, and individuals aged 20 or older assessed as post-pubertal. Pubertal stage was assessed for 66 females, with all individuals aged 8 years assessed as pre-pubertal and all individuals aged 20 or older defined as post-pubertal. Males exhibit a younger mean age of pre-puberty, but older ages than females during acceleration, with very large effect sizes (Table 3-4). No differences were noted for later phases of pubertal development, and males and females reached post-puberty at the same age.

Table 3-4: Mean age and standard deviation at each pubertal stage, for males and females at Lisieux-Michelet and *Isola Sacra*, with statistical test results for sex-based differences (males versus females) for each pubertal stage.

	Mean Age (yrs) ± 1SD		Mann-Whitney U		Hedge's G
	Males	Females	U=	p=	G=
Lisieux-Michelet (MIC), France					
Pre-Puberty	10.7 ± 2.1	9.4 ± 1.3	22.0	.187	0.713
Acceleration	12.9 ± 1.6	11.0 ± 0.6	10.0	.016	1.406
PHV	14.8 ± 1.6	13.9 ± 1.7	20.5	.232	0.548
Deceleration	16.9 ± 1.2	16.8 ± 1.4	50.0	.879	0.078
Post-Puberty	20.2 ± 1.8	20.2 ± 1.8	426.0	.706	0.000
Isola Sacra (SCR), Italy					
Pre-Puberty	8.9 ± 1.1	10.0 ± 1.3	21.0	.081	0.904
Acceleration	13.1 ± 1.8	11.0 ± 1.7	10.5	.024	1.204
PHV	15.0 ± 1.1	14.2 ± 1.3	26.5	.198	0.664
Deceleration	16.9 ± 0.8	16.7 ± 1.7	106.0	.594	0.156
Post-Puberty	20.1 ± 1.9	20.1 ± 1.8	208.5	.841	0.000

SD – Standard Deviation. PHV – Peak Height Velocity. U = Mann-Whitney U test, p= significance test (significant at p<.10; values shaded), G = Hedge's G effect size (small effect size ≤ 0.2; 0.3 ≤ medium effect size ≤ 0.7; large effect size ≥ 0.8).

When testing between sites, no significant differences were noted for age at each pubertal stage for females (Table 3-5). For males, those buried at *Isola Sacra* exhibited lower ages at pre-puberty than those buried at Lisieux-Michelet, with large effect sizes; no differences were noted for the other stages of puberty.

Menarche was assessed in 62 females from Lisieux-Michelet and 52 females from *Isola Sacra*. Osteological indicators suggest that 11 individuals between the ages of 12 and 19 had recently begun to menstruate, with a mean age of 15.4 ± 2.3 years. Mann-Whitney U and Hedge's G statistical tests indicate no significant differences in menarcheal ages between the two samples, although this may be due to small sample sizes (Table 3-6).

As there were no significant differences between males at the two sites (with the exception of pre-puberty), nor females at the two sites, samples were collapsed to facilitate comparisons between sex-based groups, as well as between osteological and literary evidence (Table 3-7).

Table 3-5: Mann-Whitney U statistical tests and Hedge's G for age at each pubertal stage for males (MIC vs. SCR) and females (MIC vs. SCR).

	Males (MIC vs. SCR)			Females (MIC vs. SCR)		
	U=	P=	G=	U=	P=	G=
Pre-Puberty	20.0	.063	1.038	26.5	.384	0.461
Acceleration	36.0	.816	0.119	22.5	.582	0.000
PHV	36.5	.717	0.146	24.5	.447	0.202
Deceleration	108.0	.907	0.000	55.0	.944	0.062
Post-Puberty	187.0	.755	0.054	488.5	.959	0.056

MIC – Lisieux-Michelet. SCR – *Isola Sacra*. PHV – Peak Height Velocity. U = Mann-Whitney U test, p= significance test (significant at p<.10; values shaded), G = Hedge's G effect size (small effect size ≤ 0.2; 0.3 ≤ medium effect size ≤ 0.7; large effect size ≥ 0.8).

Table 3-6: Menarcheal ages (years) for females at MIC and SCR with statistical results.

	MIC Females		SCR Females		Statistics		
	N=	Mean ± 1SD	N=	Mean ± 1SD	U=	P=	G=
Pre-Menarcheal	10	10.8 ± 1.6	15	10.5 ± 1.7	66.0	.609	0.181
Menarcheal	7	14.9 ± 2.5	4	15.8 ± 2.4	9.5	.387	0.365
Post- Menarcheal	45	19.8 ± 2.1	33	19.2 ± 2.4	641.0	.283	0.269

MIC – Lisieux-Michelet. SCR – *Isola Sacra*. N= sample size. SD – Standard Deviation. Significant values (p<.10) shaded. U = Mann-Whitney U test, p= significance test (significant at p<.10; values shaded), G = Hedge's G effect size (small effect size ≤ 0.2; 0.3 ≤ medium effect size ≤ 0.7; large effect size ≥ 0.8).

Table 3-7: Mean age (years) ± 1SD by sex and pubertal/menarcheal stage (sites combined).

	Males (SCR and MIC combined)	Females (SCR and MIC combined)
Pre-Puberty	*	9.8 ± 1.3
Acceleration	13.0 ± 1.6	11.0 ± 1.3
PHV	14.9 ± 1.4	14.1 ± 1.4
Deceleration	16.9 ± 1.0	16.7 ± 1.6
Post-Puberty	20.2 ± 1.8	20.1 ± 1.8
Pre-Menarcheal	NA	10.6 ± 1.7
Menarcheal	NA	15.1 ± 2.3
Post-Menarcheal	NA	19.6 ± 2.2

*Results not reported as statistical analysis indicate a significant difference between the two sites for this category (see Table 3-5).

DISCUSSION

OSTEOLOGICAL PATTERNS OF PUBERTAL TIMING IN ROMAN GAUL AND ROMAN ITALY

Our analysis demonstrates that individuals at Lisieux-Michelet and *Isola Sacra* experienced puberty between 9 and 20 years of age, with PHV achieved around 15 years of age for males, and 14 years of age for females (Table 3-7). When comparing pubertal timing patterns between the two archaeological sites, females at Lisieux-Michelet and *Isola Sacra* exhibited no significant differences in ages at any pubertal stage (Table 3-5). Males at *Isola Sacra* display younger ages at pre-puberty than males from Lisieux-Michelet; however, this is not an active stage of puberty, so the difference in age reflects sample composition rather than meaningful differences related to pubertal timing. Differences in the active stages of puberty (i.e., acceleration, PHV, deceleration) were not statistically significant for males between the two sites. Thus, pubertal timing for males and females, during the active stages of acceleration, PHV, and deceleration exhibit no significant differences between archaeological sites. Therefore, the similar patterns of pubertal timing and development at *Isola Sacra* and Lisieux-Michelet point to comparable exposure to ELS at the two sites.

Previous studies of subadult long bone length at *Isola Sacra* and Lisieux-Michelet also point to similar patterns of chronic stress at the two sites. For the Lisieux-Michelet sample, comparisons of long bone lengths (femora, tibiae, humeri, radii and ulnae) to published data from the 19th century Belleville collections (Saunders, Hoppa & Southern, 1993) indicate that individuals aged 6-12 years from *Noviomagus Lexoviorum* exhibited prominent femoral stunting, the result of "sustained or repeated nutritional or environmental stresses" (Timmins, 2016: 107). Comparison of femoral diaphyseal lengths at *Isola Sacra* to the Belleville collection also revealed that children from *Portus Romae* exhibited shorter statures by 8 years of age, likely due to chronic stress experiences affecting growth (Prowse, Saunders, Fitzgerald, Bondioli & Macchiarelli, 2010). Both studies of long bone lengths point to chronic stress during childhood at Lisieux-Michelet and *Isola Sacra*, when compared to 19th century samples, manifesting by 6-8 years of age. However, both studies were not able to differentiate between males and females, and thus, sex-specific results are not currently possible.

The previous studies of long bone length, and pubertal data presented in the current study suggest that children at the two sites experienced similar exposure to ELS. While there are many differences between *Portus Romae* and *Noviomagus Lexoviorum*, including the time period, geographical location, economic activities, and settlement size/population density, their status as middle-class populations with access to goods and food, likely contributed to these results.

COMPARISON OF OSTEOLOGICAL DATA AND LITERARY SOURCES

Here we contextualize the osteological data with what we know about puberty based on ancient literary sources, recognizing that these ancient sources likely represent the experiences of higher social status individuals in the Roman world (Garnsey, 1999). Additionally, as most literary sources were written by men, their knowledge of female pubertal timing patterns may be limited. Nevertheless, such comparison can provide greater context about altered pubertal timing within the Roman Empire.

In the Roman Empire, puberty was interpreted as the result of increased heat and moisture in the body (Caldwell, 2015). According to writers such as Macrobius, females entered puberty earlier than males because they were "naturally hotter" (*Saturnalia* 7.7.6, as quoted in Alberici & Harlow, 2007: 196). We also see this pattern in the osteological evidence, as females reached the acceleration stage two years earlier than their male counterparts at Lisieux-Michelet (U=10.0, p=.016, g=1.406) and *Isola Sacra* (U=10.5, p=.024, g=1.204) (Table 3-4).

When discussing male puberty, ancient literary sources (e.g., Aristotle and Hippocrates) place spermatogenesis and *gallulascere* ("to crow", interpreted as the breaking of the male voice) around 14-15 years of age (Eyben, 1972: 688; Amundsen & Diers, 1969). Clinically, spermatogenesis and the breaking of the male voice occurs during PHV (Sadler, 2017). In the current study, males reached PHV at 14.9 years, corresponding with these literary depictions (Table 3-7).

For females, Roman medical writers like Aristotle state that puberty began at 12 years of age, as indicated by breast budding, a defining characteristic of the acceleration stage (Pilkington, 2013). In the current study, females experienced the acceleration stage at 11 years of age, one year earlier than the literary sources suggest (Carswell & Stafford, 2016; Table 3-7). A more clearly defined pubertal event for females is that of menarche. The osteological evidence in this study demonstrates that females at Lisieux-Michelet and Isola began to menstruate at 14.9 and 15.8 years of age, respectively, one to two years after literary descriptions, which tie menarche to 14 years of age (Amundsen & Diers, 1969; Caldwell, 2015; Table 3-7). While an earlier pubertal onset and delayed age at menarche for those at Lisieux-Michelet and *Isola Sacra* compared to literary sources may seem at odds with one another, similar patterns have been found in clinical literature. For example, in a longitudinal study of 1,069 adolescents, Hiatt and colleagues (2021) found that girls from lower socioeconomic families exhibited earlier onset of puberty, but not menarche. Similarly, Negriff, Blankson and Tricket (2015) found that females with earlier pubertal onset exhibited slower tempo, and vice versa. This suggests that females in the current study, with both early onset and delayed menarche, experienced greater exposure to ELS than higher status females, as represented in the ancient literary sources.

The differences between literary accounts and the osteological evidence from the Lisieux-Michelet and *Isola Sacra* females, but not males, may be a reflection of the biases present in ancient literary sources. As these were typically written by men, they likely better understood male pubertal timing, having experienced it themselves. Meanwhile, their knowledge regarding female puberty may be based on a more limited perspective. The differences between literary sources and osteological evidence for females and not males may also point to biological differences in how ELS affects the HPA axis for males and females. In experimental studies of rats and longitudinal studies of humans, researchers have shown that programming of the HPA axis in response to ELS is sex specific (Brydges, Best & Thomas, 2020; Elgar, Gariépy, Torsheim & Currie, 2017). In particular, females exhibit increased HPA axis reactivity compared to males, suggesting that the female HPA axis is more vulnerable to physical and psychological stressors in the pre-pubertal period (Carpenter, Grecian & Reynolds, 2017). This implies that females may be a more sensitive measure of developmental stress than males, despite experiencing the same exposure to ELS. Applying this concept to the current study, the differences between the osteological and literary evidence for females, but not males, may indicate that there are subtle differences in exposure to ELS between these middle-class populations, versus those generally depicted in the literary sources who we expect to be upper class, that was *socially experienced* by both males and females,

but only *biologically detected* in females. However, in a study of sex-based patterns of development stress around the Black Death, DeWitte (2017) found that males, not females, were more sensitive to environmental and social conditions contributing to physiological stress during childhood. Consequently, social explanations must also be considered.

Investigating female experiences of childhood in the past is difficult, as it sits at the intersection of two underrepresented topics in both ancient literary sources and bioarchaeological studies: women, and children. Bioarchaeological studies are well suited to address this gap, but investigations of gendered experiences in childhood are only beginning to develop (e.g., Avery, Brickley, Findlay, Chapelain de Seréville-Niel & Prowse, 2021; Minozzi *et al.*, 2019). Roman literary sources often depict women as inferior to men, suggesting that their needs and contributions were second to men within their families and households (Garnsey, 1999). However, bioarchaeological research has shown that gendered experiences in the Roman Empire depended, in part, on one's social status (Avery, Prowse & Brickley, 2019). Thus, it may be that females in the higher social status families (as inferred through literary sources) were less exposed to ELS than females in lower social status families, perhaps due to economic capacity to provide food, shelter and stability to their children. Meanwhile, in middle social status groups, like those at *Portus* and *Noviomagus Lexoviorum*, preferential access may have been given to the males in the household, to ensure their survival and ability to contribute to the family, resulting in greater exposure to ELS for females but not males.

Future studies focused on identifying pubertal timing patterns in lower status groups would help identify the relationships between ELS and pubertal timing across the social spectrum in the Roman Empire. By incorporating peptide analysis of dental enamel to confidently sex non-adult remains, additional research focused on gendered experiences in childhood would also provide further contextual data with which pubertal data could be better understood.

CONCLUSIONS

When added to the toolkit of methods used to explore stress in past populations, pubertal timing provides a unique way to measure sex- or gender-based experiences and more subtle changes in response to psychosocial stressors in the pre-pubertal period of the life course. The results of this study demonstrate that the two middle class populations, although separated by space and time, exhibited similar patterns of pubertal timing, with puberty occurring between 9 and 20 years of age, and menarche occurring around 15 years of age. Together, these results suggest that individuals at the two sites experienced similar exposure to ELS. These results are supported by studies of long bone length and evidence of chronic stunting at Lisieux-Michelet and *Isola Sacra*.

When assessing the osteological results in relation to ancient literary sources, it appears that males in these middle-class populations in France and Italy experienced similar patterns of pubertal timing as described by Roman medical writers. Meanwhile, females from *Portus* and *Noviomagus Lexoviorum* experienced a younger age of pubertal onset, as well as a longer pubertal tempo than literary sources, suggesting greater exposure to ELS than those represented in the ancient literature. By working to understand lived experiences for women based on literary and archaeological evidence, the differences between females but not males, is likely due to different

social conditions experienced by women in middle and higher status groups, whereby women in higher status groups were better protected against ELS due to their economic and social position.

By incorporating archaeological and literary evidence, alongside osteological analysis, this study demonstrates how pubertal timing may be incorporated into bioarchaeological studies as a measure of developmental stress in past populations, specifically through the consideration of allostatic load and ELS.

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SUPPLEMENTARY DATA

Available on the following pages.

Table 3-8 (Supplementary Table): Peptide data including AMEL-X, AMEL-Y and Y:X ratio for each individual analyzed, including final sex estimation.

Tooth	AMEL-X	AMEL-Y	Y:X	Peptide Sex Estimation	Bio/Osteo Sex
HAM01	41906	6216	0.148331981	F	F*
HAM03	96500	216227	2.240694301	M	M*
HAM04	355256	80449	0.2264536	F	F*
HAM11	1068261	5555	0.00520004	F	F*
HAM19	1979955	2547045	1.2864156	M	M*
SCR0086	70438520	59241560	0.84103925	M	M^+
SCR0444	154775360	66703	0.000430967	F	F^+
SCR0839	354358228	42952	0.000121211	F	F^+
SCR5065	167624752	163241632	0.973851594	M	M^+
MIC001	41009352	42847756	1.044828897	M	
MIC016	33146592	12663108	0.382033483	AM	
MIC114	57635760	126780	0.002199676	F	
MIC116	11919959	194910	0.016351566	F	
MIC129	32812164	31151706	0.949395048	M	
MIC141	47698	45945	0.963247935	M*	
MIC143	45643096	1141751	0.025014758	F	
MIC148	30095568	17964396	0.596911678	M	
MIC164	2992610	3711609	1.240258169	M	
MIC238	14970635	6637	0.000443335	F	
MIC319	37181868	15784382	0.424518263	AM	
MIC368	27563298	14790970	0.536618296	M	
MIC371	11040708	5817373	0.52690217	M	
MIC387	6876804	6776052	0.985349008	M	
MIC389	56990584	42399938	0.743981462	M	
MIC404	10269158	81723	0.007958101	F	
MIC414	47611668	537297	0.011284986	F	
MIC437	57081616	857389	0.015020405	F	
MIC439	31312038	119008	0.003800711	F	
MIC443	15361906	134537	0.008757833	F	
MIC450	27801228	25319202	0.910722433	M	
MIC468	25662672	37076404	1.444760078	M	
MIC473	21187008	22452736	1.059740762	M	
MIC511	20032796	826798	0.041272222	F	
MIC548	24416848	126098	0.005164385	F	
MIC607	15402676	10162884	0.659812879	M	
MIC616	30425596	12335686	0.405437777	AM	
MIC622	6562977	5688405	0.866741572	M	

MIC627	598730	1338277	2.235192825	M	
MIC664	34580404	32802058	0.948573591	M	
MIC665	32132220	18854046	0.5867645	M	
MIC667	29324744	24638326	0.840188954	M	
MIC675	48645440	273220	0.005616559	F	
MIC687	17404196	14220206	0.817056186	M	
MIC713	13246196	9941198	0.750494557	M	
MIC742	7230679	16180	0.002237687	F	
MIC769	26966600	27362736	1.014689876	M	
MIC810	45273864	29157012	0.644014215	M	
MIC861	33653820	503324	0.014955925	F	
MIC899	32329698	901946	0.027898374	F	
MIC929	14396340	36623	0.00254391	F	
MIC960	7442914	228087	0.030644852	F	
MIC565	10213614	20122172	1.970132413	M	
SCR0009	15656122	27032	0.001726609	F	
SCR0080	40108720	63751672	1.589471616	M	
SCR0126	57064320	65923	0.00115524	F	
SCR0209	8970948	70756	0.007887238	F	
SCR0247	38712864	1197358	0.030929202	F	
SCR0249	9257746	128975	0.013931577	F	
SCR0259	10576458	240944	0.022781162	F	
SCR0428	8433846	93409	0.011075493	F	
SCR0446	60647928	365089	0.00601981	F	
SCR0512	81729984	89188816	1.09126188	M	
SCR0810	18427306	761802	0.041340932	F	
SCR5069	299400352	625381	0.002088778	F	
SCR5073	76123296	71886312	0.944340508	M	
SCR6025	24278196	67277	0.002771087	F	
SCR0115	211253824	171768592	0.813091043	M	
SCR0176	52010792	55282968	1.062913405	M	
SCR0812	819978	39610	0.048306174	F	
SCR5058	122127264	133968680	1.096959644	M	
SCR0024	115754352	382426	0.003303772	F	
SCR0103	78302464	98502128	1.257969711	M	
SCR0683	25601036	6379	0.00024917	F	
SCR6005	91770616	49592600	0.540397375	M	
SCR6032	53477704	35072676	0.655837356	M	
SCR0474	69390848	43096724	0.621072162	M	
SCR0538	94537984	55021468	0.582003822	M	

Samples estimated to be female if Y:X ratio <0.3. Samples estimated to be male if Y:X ratio >0.5. Samples left as ambiguous if Y:X ratio fell between 0.3 and 0.5. *Biologically known sex as reported from modern individuals. [+]Osteologically estimated sex, based on clearly defined osteological features associated with pelvic and cranial dimorphism.

Table 3-9 (Supplementary Table): Pubertal data, including age range, mean, estimated sex, pubertal stage at death and menarcheal stage at death for each individual in the current study.

	Age Range	Age (Mean)	Sex	Pubertal Stage	Menarcheal Stage
MIC 001A	12-14	13	Male	Acceleration	
MIC 005B	17-25	21	Male	UD (<3)	
MIC 008	18-21	19	Female	Post-Puberty	Post-Menarche
MIC 016	12-14	13	Undetermined	Acceleration	
MIC 018A	18-27	22	Female	Post-Puberty	Post-Menarche
MIC 020	11-12	11	Female	Acceleration	Pre-Menarche
MIC 036	19-25	22	Male	Post-Puberty	
MIC 048	18-20	19	Female	Post-Puberty	Post-Menarche
MIC 050	15-20	17	Female	PHV	Undetermined
MIC 075	7-9	8	Undetermined	Pre-Puberty	
MIC 083	7-9	8	Male	Pre-Puberty	
MIC 087	18-20	19	Female	UD (<3)	Undetermined
MIC 096	18-22	20	Male	Post-Puberty	
MIC 097	18-19	18	Female	Deceleration	Post-Menarche
MIC 099	17-21	19	Male	Deceleration	
MIC 104	18-21	19	Female	Post-Puberty	Post-Menarche
MIC 112	17-25	21	Male	Post-Puberty	
MIC 114	12-13	12	Female	Acceleration	Pre-Menarche
MIC 116	14-15	14	Female	PHV	Menarcheal
MIC 117	17-18	17	Male	Deceleration	
MIC 118	18-20	19	Female	Post-Puberty	Post-Menarche
MIC 124	18-20	19	Female	Post-Puberty	Post-Menarche
MIC 129	12-13	12	Male	Acceleration	
MIC 136	18-27	22	Female	Post-Puberty	Post-Menarche
MIC 141	10-12	11	Male	Acceleration	
MIC 143	10-12	11	Female	Pre-Puberty	Undetermined
MIC 148	11-12	11	Male	Pre-Puberty	
MIC 153	19-21	20	Male	Post-Puberty	
MIC 155A	18-22	20	Female	Post-Puberty	Post-Menarche
MIC 156	19-20	19	Male	Post-Puberty	
MIC 164	15-16	15	Male	PHV	

MIC 190	17-18	17	Male	Deceleration	
MIC 192	9-10	9	Female	Pre-Puberty	Pre-Menarche
MIC 202	16-18	17	Male	UD (<3)	
MIC 206	17-18	17	Male	Deceleration	
MIC 207	17-20	18	Male	UD (<3)	
MIC 222	22-26	24	Female	Post-Puberty	Post-Menarche
MIC 228	17-21	19	Male	Deceleration	
MIC 230	18-19	18	Male	UD (Post-PHV)	
MIC 238	10-12	11	Female	Pre-Puberty	Pre-Menarche
MIC 244	17-18	17	Male	Post-Puberty	
MIC 245	8-10	9	Undetermined	UD (<3)	
MIC 248A	18-25	21	Female	Post-Puberty	Post-Menarche
MIC 249A	17-21	19	Male	Post-Puberty	
MIC 249B	12-17	14	Female	UD (Pre-PHV)	Pre-Menarche
MIC 257	7-9	8	Male	Pre-Puberty	
MIC 261	18-19	18	Male	Post-Puberty	
MIC 269	17-34	25	Male	UD (<3)	
MIC 274	12-14	13	Female	UD (<3)	Undetermined
MIC 282	19-25	22	Male	Post-Puberty	
MIC 284	19-25	22	Male	Post-Puberty	
MIC 303	17-18	17	Male	Deceleration	
MIC 307B	12-14	13	Female	UD (<3)	Undetermined
MIC 309	12-15	13	Male	UD (<3)	
MIC 319	10-12	11	Undetermined	Pre-Puberty	
MIC 322	17-18	17	Male	Post-Puberty	
MIC 330	12-14	13	Male	Pre-Puberty	
MIC 341	16-18	17	Female	Post-Puberty	Post-Menarche
MIC 343	16-17	16	Female	Deceleration	Post-Menarche
MIC 349	15-19	17	Undetermined	UD (<3)	
MIC 355	18-21	19	Female	Post-Puberty	Post-Menarche
MIC 356	16-19	17	Female	Deceleration	Undetermined
MIC 359	15-16	15	Male	PHV	
MIC 361	19-25	22	Male	Post-Puberty	
MIC 366	19-25	22	Male	Post-Puberty	
MIC 368	10-12	11	Male	Pre-Puberty	
MIC 370	18-19	18	Female	Post-Puberty	Post-Menarche
MIC 371	15-16	15	Male	Deceleration	
MIC 374	17-21	19	Male	Post-Puberty	
MIC 377	13-14	13	Female	PHV	Menarcheal
MIC 387	14-16	15	Male	Acceleration	
MIC 389	12-14	13	Male	Pre-Puberty	

MIC 391	18-27	22	Female	Post-Puberty	Post-Menarche
MIC 394	22-30	25	Female	Post-Puberty	Post-Menarche
MIC 397	18-21	19	Female	Post-Puberty	Post-Menarche
MIC 404	8-9	8	Female	Pre-Puberty	Pre-Menarche
MIC 405	18-27	22	Female	Post-Puberty	Post-Menarche
MIC 414	10-11	10	Female	Acceleration	Pre-Menarche
MIC 418	10-12	11	Male	Acceleration	
MIC 437	12-14	13	Female	PHV	Undetermined
MIC 439	12-13	12	Female	PHV	Menarcheal
MIC 443	17-18	17	Female	Deceleration	Post-Menarche
MIC 450	14-15	14	Male	PHV	
MIC 455	15-16	15	Male	Acceleration	
MIC 458	19-20	19	Male	Post-Puberty	
MIC 459	18-26	22	Female	Post-Puberty	Post-Menarche
MIC 463	18-20	19	Female	Post-Puberty	Post-Menarche
MIC 468	12-14	13	Male	Acceleration	
MIC 472	17-18	17	Male	Deceleration	
MIC 473	15-16	15	Male	Acceleration	
MIC 479	12-13	12	Female	UD (<3)	Undetermined
MIC 480	6-16	11	Female	UD (Pre-PHV)	Undetermined
MIC 483	18-25	21	Female	Post-Puberty	Post-Menarche
MIC 486	14-16	15	Male	PHV	
MIC 493	9-10	9	Female	UD (<3)	Undetermined
MIC 502	19-25	22	Male	Post-Puberty	
MIC 509	18-21	19	Female	Post-Puberty	Post-Menarche
MIC 511	14-15	14	Female	Deceleration	Post-Menarche
MIC 512	17-18	17	Male	Deceleration	
MIC 535	18-27	22	Female	Post-Puberty	Post-Menarche
MIC 537	18-27	22	Female	Post-Puberty	Post-Menarche
MIC 543	16-17	16	Male	Deceleration	
MIC 564	18-20	19	Female	Post-Puberty	Post-Menarche
MIC 565	15-16	15	Male	Deceleration	
MIC 575	19-25	22	Male	Post-Puberty	
MIC 583	18-27	22	Female	Post-Puberty	Post-Menarche
MIC 600	12-14	13	Female	UD (<3)	Undetermined
MIC 602	19-20	19	Female	Post-Puberty	Post-Menarche
MIC 607	11-13	12	Male	PHV	
MIC 608	16-18	17	Undetermined	UD (<3)	
MIC 614	18-20	19	Female	Post-Puberty	Post-Menarche
MIC 616	9-13	11	Undetermined	Pre-Puberty	
MIC 622	7-9	8	Male	Pre-Puberty	

MIC 627	12-13	12	Male	Acceleration	
MIC 629	18-21	19	Female	Post-Puberty	Post-Menarche
MIC 631	19-25	22	Male	Post-Puberty	
MIC 653	16-17	16	Female	Deceleration	Menarcheal
MIC 663	17-21	19	Male	Post-Puberty	
MIC 664	15-16	15	Male	PHV	
MIC 665	16-18	17	Male	PHV	
MIC 667	12-14	13	Male	Pre-Puberty	
MIC 675	15-16	15	Female	PHV	Undetermined
MIC 687	10-12	11	Male	Pre-Puberty	
MIC 690	17-18	17	Male	PHV	
MIC 691	17-21	19	Male	UD (Post-PHV)	
MIC 704	18-20	19	Female	Post-Puberty	Post-Menarche
MIC 713	12-14	13	Male	PHV	
MIC 715	16-17	16	Male	Deceleration	
MIC 727	17-21	19	Male	UD (Post-PHV)	
MIC 742	10-13	11	Female	Acceleration	Pre-Menarche
MIC 761	18-25	21	Female	Post-Puberty	Post-Menarche
MIC 769	10-12	11	Male	Pre-Puberty	
MIC 778	18-24	21	Female	Post-Puberty	Post-Menarche
MIC 782	12-13	12	Male	UD (Pre-PHV)	
MIC 784	18-19	18	Female	Deceleration	Menarcheal
MIC 787	18-27	22	Female	Post-Puberty	Post-Menarche
MIC 810	14-15	14	Male	Acceleration	
MIC 818	18-19	18	Female	Post-Puberty	Post-Menarche
MIC 822	18-21	19	Female	Post-Puberty	Post-Menarche
MIC 824A	18-21	19	Female	Post-Puberty	Post-Menarche
MIC 830	10-11	10	Female	Pre-Puberty	Undetermined
MIC 833	18-19	18	Female	Deceleration	Menarcheal
MIC 861	9-10	9	Female	Pre-Puberty	Undetermined
MIC 868	18-20	19	Female	Post-Puberty	Post-Menarche
MIC 875	19-25	22	Male	Post-Puberty	
MIC 881	18-20	19	Female	Post-Puberty	Post-Menarche
MIC 897	17-18	17	Male	Deceleration	
MIC 899	11-12	11	Female	Acceleration	Pre-Menarche
MIC 900	17-21	19	Female	Post-Puberty	Post-Menarche
MIC 903B	17-19	18	Undetermined	UD (<3)	
MIC 904	12-15	13	Female	UD (<3)	Undetermined
MIC 906	17-27	22	Female	Post-Puberty	Post-Menarche
MIC 914	17-18	17	Female	Post-Puberty	Post-Menarche
MIC 919	18-25	21	Male	Post-Puberty	

MIC 921	14-15	14	Female	UD (<3)	Undetermined
MIC 926	18-27	22	Female	Post-Puberty	Post-Menarche
MIC 929	13-14	13	Female	PHV	Menarcheal
MIC 955	11-12	11	Male	Acceleration	
MIC 958	17-20	18	Male	Post-Puberty	
MIC 960	10-12	11	Female	Acceleration	Pre-Menarche
SCR 005	18-19	18	Female	Deceleration	Post-Menarche
SCR 009	9-10	9	Female	Acceleration	Pre-Menarche
SCR 024	9-11	10	Female	Acceleration	Pre-Menarche
SCR 029	14-15	14	Female	PHV	Post-Menarche
SCR 032	18-21	19	Female	Post-Puberty	Post-Menarche
SCR 036	17-21	19	Male	Post-Puberty	
SCR 052	18-21	19	Female	UD (Post-PHV)	Post-Menarche
SCR 068	18-27	22	Female	Post-Puberty	Post-Menarche
SCR 072	8-10	9	Male	Pre-Puberty	
SCR 075	19-25	22	Male	Post-Puberty	
SCR 080	15-16	15	Male	Acceleration	
SCR 086	17-25	21	Male	Post-Puberty	
SCR 098	18-21	19	Female	Post-Puberty	Post-Menarche
SCR 100	14-15	14	Female	PHV	Menarcheal
SCR 103	8-9	8	Male	Pre-Puberty	
SCR 106	18-19	18	Female	Post-Puberty	Post-Menarche
SCR 111	6-12	9	Undetermined	UD (Pre-PHV)	
SCR 112	10-12	11	Male	Acceleration	
SCR 115	8-9	8	Male	Pre-Puberty	
SCR 116	18-19	18	Female	Deceleration	Post-Menarche
SCR 121	15-17	16	Female	Deceleration	Undetermined
SCR 124	12-15	13	Male	UD (<3)	
SCR 126	15-17	16	Female	Deceleration	Undetermined
SCR 129	14-16	15	Female	UD (Post-PHV)	Undetermined
SCR 133	17-18	17	Male	Post-Puberty	
SCR 138	16-17	16	Male	Deceleration	
SCR 144	19-25	22	Male	Post-Puberty	
SCR 146	12-13	12	Female	Acceleration	Pre-Menarche
SCR 149	15-16	15	Male	PHV	
SCR 157	18-19	18	Female	Post-Puberty	Post-Menarche
SCR 166	12-16	14	Male	UD (Pre-PHV)	
SCR 176	7-9	8	Male	Pre-Puberty	
SCR 196	17-21	19	Male	Post-Puberty	
SCR 197	18-27	22	Female	Post-Puberty	Post-Menarche
SCR 203	18-21	19	Female	Deceleration	Post-Menarche

SCR 209	8-9	8	Female	Pre-Puberty	Pre-Menarche
SCR 216	18-20	19	Female	Deceleration	Menarcheal
SCR 218	6-12	9	Female	UD (<3)	Undetermined
SCR 219	15-20	17	Male	UD (Post-PHV)	
SCR 226	18-20	19	Female	Post-Puberty	Post-Menarche
SCR 237	14-15	14	Male	Acceleration	
SCR 240	8-9	8	Male	Pre-Puberty	
SCR 247	8-11	9	Female	Pre-Puberty	Pre-Menarche
SCR 249	9-11	10	Female	Acceleration	Pre-Menarche
SCR 259	8-9	8	Female	Pre-Puberty	Pre-Menarche
SCR 268	16-17	16	Female	PHV	Post-Menarche
SCR 271	16-17	16	Female	PHV	Menarcheal
SCR 279	9-10	9	Male	UD (Pre-PHV)	
SCR 290	8-12	10	Female	Acceleration	Undetermined
SCR 305	18-27	22	Female	Post-Puberty	Post-Menarche
SCR 306	21-24	22	Female	Post-Puberty	Post-Menarche
SCR 310	17-18	17	Male	Deceleration	
SCR 313	10-11	10	Female	Acceleration	Undetermined
SCR 317	17-20	18	Male	Deceleration	
SCR 319	17-18	17	Male	Deceleration	
SCR 320	18-21	19	Female	Post-Puberty	Post-Menarche
SCR 322	15-16	15	Male	PHV	
SCR 325	19-25	22	Male	Post-Puberty	
SCR 330	18-21	19	Female	Post-Puberty	Post-Menarche
SCR 332	18-27	22	Female	Post-Puberty	Post-Menarche
SCR 333	10-12	11	Male	Acceleration	
SCR 337	17-18	17	Male	Deceleration	
SCR 343	17-18	17	Male	Deceleration	
SCR 352	18-21	19	Female	Post-Puberty	Post-Menarche
SCR 354	16-17	16	Male	Deceleration	
SCR 357	10-12	11	Female	Pre-Puberty	Pre-Menarche
SCR 360	17-18	17	Male	Deceleration	
SCR 361	17-21	19	Male	Post-Puberty	
SCR 368	16-17	16	Male	PHV	
SCR 389	16-17	16	Male	Deceleration	
SCR 391	16-17	16	Male	UD (<3)	
SCR 393	12-13	12	Female	PHV	Undetermined
SCR 396	14-15	14	Male	UD (<3)	
SCR 398	12-16	14	Undetermined	PHV	
SCR 404	17-21	19	Male	Post-Puberty	
SCR 406	18-21	19	Female	Post-Puberty	Post-Menarche

SCR 411	18-27	22	Female	Post-Puberty	Post-Menarche
SCR 413	17-27	22	Female	UD (<3)	Undetermined
SCR 416	18-30	24	Female	Post-Puberty	Post-Menarche
SCR 420	17-19	18	Female	Deceleration	Post-Menarche
SCR 428	10-12	11	Female	Pre-Puberty	Undetermined
SCR 444	18-21	19	Female	Post-Puberty	Post-Menarche
SCR 446	10-11	10	Female	Pre-Puberty	Pre-Menarche
SCR 450	17-29	23	Male	UD (<3)	
SCR 451	12-16	14	Male	UD (Pre-PHV)	
SCR 464	19-25	22	Male	UD (Post-PHV)	
SCR 474	14-15	14	Male	PHV	
SCR 484	18-27	22	Female	Post-Puberty	Post-Menarche
SCR 512	16-18	14	Male	Acceleration	
SCR 517	17-19	16	Male	PHV	
SCR 519	17-21	10	Female	Pre-Puberty	Pre-Menarche
SCR 530	10-12	11	Female	Pre-Puberty	Undetermined
SCR 538	15-16	11	Male	Pre-Puberty	
SCR 539	12-15	13	Male	UD (<3)	
SCR 540	13-15	13	Female	UD (Pre-PHV)	Undetermined
SCR 557	18-27	12	Female	Pre-Puberty	Pre-Menarche
SCR 563	14-16	17	Male	Post-Puberty	
SCR 571	18-21	15	Male	UD (<3)	
SCR 574	17-18	17	Male	Deceleration	
SCR 575	16-17	18	Male	Post-Puberty	
SCR 577	11-14	19	Male	Deceleration	
SCR 579	16-18	15	Female	PHV	Undetermined
SCR 605	18-21	15	Female	Deceleration	Undetermined
SCR 606	16-19	13	Male	UD (<3)	
SCR 609	17-18	14	Female	PHV	Menarcheal
SCR 611	18-27	22	Female	Post-Puberty	Post-Menarche
SCR 615	14-16	15	Female	UD (<3)	Undetermined
SCR 618	14-16	19	Female	Post-Puberty	Post-Menarche
SCR 633	16-17	16	Male	Deceleration	
SCR 638	10-14	16	Undetermined	UD (<3)	
SCR 643	11-14	12	Female	UD (<3)	Undetermined
SCR 645	14-15	17	Male	Deceleration	
SCR 648	12-17	12	Male	UD (<3)	
SCR 663	16-17	16	Male	UD (<3)	
SCR 665	14-15	16	Male	Deceleration	
SCR 666	10-11	18	Undetermined	UD (<3)	
SCR 667	16-18	14	Male	PHV	

SCR 674	15-16	16	Male	PHV	
SCR 677	19-25	19	Female	Deceleration	Undetermined
SCR 679	18-20	19	Female	Post-Puberty	Post-Menarche
SCR 683	17-25	13	Female	PHV	Undetermined
SCR 689	18-22	17	Female	UD (<3)	Undetermined
SCR 693	18-19	14	Female	PHV	Undetermined
SCR 694	12-13	16	Male	UD (<3)	
SCR 712	19-25	17	Male	Deceleration	
SCR 713	10-12	16	Female	Deceleration	Undetermined
SCR 723	11-12	15	Female	Deceleration	Undetermined
SCR 732	14-16	15	Undetermined	UD (<3)	
SCR 753	17-21	15	Female	UD (<3)	Undetermined
SCR 764	17-20	12	Male	UD (<3)	
SCR 783	16-18	10	Female	Pre-Puberty	Undetermined
SCR 792	10-11	14	Female	Deceleration	Post-Menarche
SCR 796	12-17	14	Female	UD (<3)	Undetermined
SCR 810	12-14	14	Female	Acceleration	Pre-Menarche
SCR 812	12-14	14	Female	PHV	Menarcheal
SCR 815	10-11	10	Female	UD (<3)	Undetermined
SCR 824	16-18	17	Undetermined	UD (<3)	
SCR 831	19-25	15	Female	Deceleration	Post-Menarche
SCR 838	19-25	22	Male	Post-Puberty	
SCR 839	19-25	19	Female	Post-Puberty	Post-Menarche
SCR 5005	18-24	21	Male	Post-Puberty	
SCR 5033	18-22	20	Female	Post-Puberty	Post-Menarche
SCR 5034	18-19	18	Male	Post-Puberty	
SCR 5058	10-12	12	Male	Acceleration	
SCR 5065	11-12	22	Male	Post-Puberty	
SCR 5066	12-15	11	Female	UD (Pre-PHV)	Pre-Menarche
SCR 5069	12-14	11	Female	Acceleration	Pre-Menarche
SCR 5073	8-10	9	Male	Pre-Puberty	
SCR 5079	17-21	19	Male	Post-Puberty	
SCR 5083	15-16	18	Female	Post-Puberty	Post-Menarche
SCR 6002B	11-14	17	Male	Deceleration	
SCR 6005	16-17	10	Male	Pre-Puberty	
SCR 6008	17-18	17	Male	Deceleration	
SCR 6012	17-20	13	Female	PHV	Undetermined
SCR 6025	13-14	13	Female	Acceleration	Pre-Menarche
SCR 6032	15-16	15	Male	Acceleration	
SCR 6047	18-20	16	Male	PHV	

SCR 6053	12-14	22	Male	Post-Puberty	
SCR 6074	14-15	16	Female	Deceleration	Undetermined
SCR 6076	19-25	22	Male	Post-Puberty	

MIC: Lisieux-Michelet (France), SCR: *Isola Sacra* (Italy). PHV = Peak Height Velocity. UD = undetermined. <3 = less than three features of puberty present, and cannot be assessed.

REFERENCES

Alberici, L. A., & Harlow, M. (2007). Age and innocence: Female transitions to adulthood in late antiquity. *Hesperia Supplements* 41: 193-203. https://www.jstor.org/stable/20066790.

Allsworth, J. E., Weitzen, S., & Boardman, L. A. (2005). Early age at menarche and allostatic load: Data from the third national health and nutrition examination survey. *Annals of Epidemiology* 15(6): 438-444. https://doi.org/10.1016/j.annepidem.2004.12.010.

Amundsen, D. W., & Diers, C. J. (1969). The age of menarche in Classical Greece and Rome. *Human Biology* 41(1): 125-132. https://www.jstor.org/stable/41448952.

Arthur, N. A., Gowland, R., & Redfern, R. (2016). Coming of age in Roman Britain: Osteological evidence for pubertal timing. *American Journal of Physical Anthropology* 159(4): 698-713. https://doi.org/10.1002/ajpa.22929.

Avery, L. C., Brickley, M. B., Findlay, S., Chapelain de Seréville-Niel, C., & Prowse, T. L. (2021). Child and adolescent diet in Late Roman Gaul: An investigation of incremental dietary stable isotopes in tooth dentine. *International Journal of Osteoarchaeology* 31(6): 1226-1236. https://doi.org/10.1002/oa.3033.

Avery, L.C., Prowse, T.L., & Brickley, M.B. (2019). Dental health and dietary difference at Late Roman Winchester. *Bioarchaeology International* 3(3): 157-173. https://doi.org/10.5744/bi.2019.1011.

Baker, L. M., Williams, L. M., Korgaonkar, M. S., Cohen, R. A., Heaps, J. A., & Paul, R. H. (2013). Impact of early vs. late childhood early life stress on brain morphometrics. *Brain Imaging and Behavior* 7: 196-203. https://doi.org/10.1007/s11682-012-9215-y.

Blom, A. A., Schats, R., Hoogland, M. L. P., & Waters-Rist, A. (2020). Coming of age in the Netherlands: An osteological assessment of puberty in a rural Dutch post-medieval community. *American Journal of Physical Anthropology* 174(3): 463-478. https://doi.org/10.1002/ajpa.24161.

Boldsen, J., Milner, G., Konigsber, L., & Wood, K. (2002). Transition Analysis: A new method for estimating age from skeletons. In: R. D. Hoppa, & R. W. Vaupel (Eds.), *Paleodemography: Age distributions from skeletal samples* (pp. 73-106). Cambridge University Press.

Brooks, S., & Suchey, J. (1990). Skeletal age determination based on the os pubis: A comparison of the Acsadi-Nemeskeri and Suchey-Brooks Methods. *Human Evolution* 5: 227-238. https://doi.org/10.1007/BF02437238.

Brydges, N. M., Best, C., & Thomas, K. L. (2020). Female HPA axis displays heightened sensitivity to pre-pubertal stress. *The International Journal on the Biology of Stress* 23(2): 190-200. https://doi.org/10.1080/10253890.2019.1658738.

Buehl, C., & Pyle, S. (1942). The use of age at first appearance of three ossification centers in determining the skeletal status of children. *The Journal of Pediatrics* 21(3): 335-342. https://doi.org/10.1016/S0022-3476(42)8026-8.

Buikstra, J., & Ubelaker, D. (1994). *Standards for data collection from human skeletal remains*. Proceedings of a Seminar at the Field Museum of Natural History (Arkansas Archaeology Research Series 44). Fayetteville Arkansas Archaeological Survey.

Burris, M. E., & Wiley, A. S. (2021). Marginal food security predicts earlier age at menarche among girls from the 2009-2014 national health and nutrition examination survey. *Journal of Pediatric and Adolescent Gynecology* 34(4): 462-470. https://doi.org/10.1016.j.jpag.2021.03.010.

Caldwell, L. (2015). *Roman girlhood and the fashioning of femininity*. Cambridge University Press.

Calza, G., & Becatti, G. (2008). *Ostia: Itineraries of the museums, galleries and monuments in Italy*. Instituto Poligrafico e Zecca Dello Stato S.P.A.

Cardoso, H. (2008a). Epiphyseal union at the innominate and lower limb in a modern Portuguese skeletal sample, and age estimation in adolescent and young adult male and female skeletons. *American Journal of Physical Anthropology* 135(2):161-170. https://doi.org/10.1002/ajpa.20717.

Cardoso, H. (2008b). Age estimation of adolescent and young adult male and female skeletons II, Epiphyseal union at the upper limb and scapular girdle in a modern Portuguese skeletal sample. *American Journal of Physical Anthropology* 137(1):97-105. https://doi.org/10.1002/ajpa.20850.

Cardoso, H. (2008c). Sample specific (universal) metric approaches for determining the sex of immature human skeletal remains using permanent tooth dimensions. *Journal of Archaeological Science* 35(1): 158-168. https://doi.org/10.1016/j.jas2007.02.013.

Carpenter, T., Grecian, S. M., & Reynolds, R. M. (2017). Sex differences in early-life programming of the hypothalamic-pituitary-adrenal axis in humans suggest increased vulnerability in females: a systematic review. *Journal of Developmental Origins of Health and Disease* 8(2): 244-255. https://doi.org/10.1017/S204017441600074X.

Carswell, J. M., & Stafford, D. E. (2016). Normal physical growth and development. In: L. S. Neinstein, D. K. Katzman (Eds.), *Adolescent and young adult health care: A practical guide. Sixth Edition* (pp. 22-37). Wolters Kluwer.

DeWitte, S. N. (2017). Stress, sex, and plague: Patterns of developmental stress in pre- and post-Blak Death London. *American Journal of Human Biology* 30(1): e23073. https://doi.org/10.1002/ajhb.23073.

DeWitte, S. N., & Lewis, M. (2021). Medieval menarche: changes in pubertal timing before and after the Black Death. *American Journal of Human Biology* 33(2): e23439. https://doi.org/10.1002/ajhb.23439.

Edes, A. N., & Crews, D. E. (2016). Allostatic load and biological anthropology. *American Journal of Physical Anthropology* 162(S63): 44-70. https://doi.org/10.1002/ajpa.23146.

Elgar, F. J., Gariépy, G., Torsheim, T., & Currie, C. (2017). Early-life income inequality and adolescent health and well-bring. *Social Science & Medicine* 174: 197-208. https://doi.org/10.1016/j.socscimed.2016.10.014.

Eyben, E. (1972). Antiquity's view of puberty. *Latomus* 31(3): 677-697. https://www.jstor.org/stable/41529266.

Fritz, C. O., Morris, P. E., & Richler, J. J. (2012). Effect size estimates: Current use, calculations, and interpretation. *Journal of Experimental Psychology: General* 141(1): 2-18. https://doi.org/10.1037/a0024338.

Garnsey, P. D. A. (1999). *Food and society in classical antiquity.* Cambridge University Press.

Gustafson, G., & Koch, G. (1974). Age estimation up to 16 years of age based on dental development. *Odontologisk Revy* 25(3): 297-306.

Hiatt, R. A., Stewart, S. L., Deardorff, J., Danial, E., Abdiwahab, E., Pinney, S. M., Teitelbaum, S. L., Windham, G. C., Wolff, M. S., Kushi, L. H., & Biro, F. M. (2021). Childhood socioeconomic status and menarche: a prospective study. *Journal of Adolescent Health* 69(1): 33-40. https://doi.org/10.1016/j.jadohealth.2021.02.003.

Holdsworth, E. A., & Appleton, A. A. (2020). Adverse childhood experiences and reproductive strategies in a contemporary U.S. population. *American Journal of Physical Anthropology* 171(1): 37-49. https://doi.org/10.1002/ajpa.23967.

Joos, C. M., Wodzinski, A. M., Wadsworth, M. E., & Dorn, L. D. (2018). Neither antecedent nor consequence: Developmental integration of chronic stress, pubertal timing, and conditionally adapted stress response. *Developmental Review* 48: 1-23. https://doi.org/10.1016/j.dr.2018.05.001.

Katz, D., & Suchey, J. (1986). Age determination of the male os pubis. *American Journal of Physical Anthropology* 69(4): 427-435. https://doi.org/10.1002/ajpa.1330690402.

Keay, S., Millett, M., Paroli, L., & Strutt, K. (2005). *Portus: An archaeological survey of the port of Imperial Rome*. The British School at Rome.

Larsen, C. S. (2002). Bioarchaeology: The lives and lifestyles of past people. *Journal of Archaeological Research* 10: 119-166. https://doi.org/10.1023/A:1015267705803.

Lewis, M., Shapland, F., & Watts, R. (2016). On the threshold of adulthood: A new approach for the use of maturation indicators to assess puberty in adolescents from Medieval England. *American Journal of Human Biology* 28(1): 48-56. https://doi.org/10.1002/ajhb.22761.

Li, W., Liu, Q., Deng, X., Chen, Y., Liu, S., & Story, M. (2017). Association between obesity and pubertal timing: A systematic review and meta-analysis. *International Journal of Environmental Research and Public Health.* 14(10): 1266. https://doi.org/10.3390éijerph14101266.

Marshall, W. A., & Tanner, J. M. (1969). Variations in pattern of pubertal changes in girls. *Archives of Disease in Childhood* 44(235): 291-303. https://doi.org/10.1136/adc.44.235.291.

Marshall, W. A., & Tanner, J. M. (1970). Variations in the pattern of pubertal changes in boys. *Archives of Disease in Childhood* 45(239): 13-23. https://doi.org/10.1136/adc.45.239.13.

Mendle, J., Harden, K. P., Brooks-Gunn, J., & Graber, J. A. (2010). Development's tortoise and hare: pubertal timing, pubertal tempo, and depressive symptoms in boys and girls. *Developmental Psychology* 46(5): 1341-1353. https://doi.org/10.1037/a0020205.

Milella, M., Betz, B. J., Knüsel, C. J., Larsen, C. S., & Dori, I. (2018). Population density and developmental stress in the Neolithic: A diachronic study of dental fluctuating asymmetry at Çatalhöyük (Turkey, 7,100-5,950 BC). *American Journal of Physical Anthropology* 167(4) :737-749. https://doi.org/10.1002/ajpa.23700.

Minozzi, S., Caldarini, C., Pantano, W., di Giannantonio, S., Catalano, P., & Giuffra, V. (2019). Enamel hypoplasia and health conditions through social status in the Roman Imperial age (first to

third centuries, Rome, Italy). *International Journal of Osteoarchaeology* 30(1): 53-64. https://doi.org/10.1002/oa.2830.

Morgan, C. J. (2017). Use of proper statistical techniques for research studies with small samples. *American Journal of Physiology- Lung Cellular and Molecular Physiology* 313(5): L873-877. https://doi.org/10.1152/ajplung.00238.2017.

Munaro, P. (2012). *Temps de guerre, temps de paix : Influence du contexte sociologique sur l'état bucco-dentaire au IV^e^ siècle ap. J.-C. à Lisieux, Calvados*. Unpublished PhD Thesis. University de Lorraine. https://hal.univ-lorraine.fr/hal-01738929

Negriff, S., Blankson, A. N., & Tricket, P. K. (2015). Pubertal timing and tempo: Associations with childhood maltreatment. *Journal of Research* on Adolescence 25(2): 201-213. https://doi.org/10.1111/jora.12128.

Osipov, B., Alaica, A. K., Pickard, C., Garcia-Donas, J. G., Marquez-Grant, N., & Kranioti, E. F. (2020). The effect of diet and sociopolitical change on physiological stress and behavior in late Roman-Early Byzantine (300-700 AD) and Islamic (902-1,235 AD) populations from Ibiza, Spain. *American Journal of Physical Anthropology* 172(2): 189-213. https://doi.org/10.1002/ajpa.24062.

Paillard, D. (2006). *The Michelet site*. Unpublished site report. Archaeology department, University of Caen, France.

Paillard, D., Alduc-Le Bagousse, A., Allen, M. I., Blondiaux, J., Buchet, L., Chapelain de Seréville-Niel, C., Guihard, P. M., Maneuvrier, C., Pacory, J., Pilet, C., Pilet-Lemière, J., & Vipard, P. (Forthcoming). *La nécropole Michelet. Bilan et perspectives des recherches sur la cité de Lisieux (Calvados) de ses origines au IX^e^ siècle*, Publications du Craham, Presses Universitaires de Caen.

Phenice, T. W. (1969). A newly developed visual method of sexing the os pubis. *American Journal of Physical Anthropology* 30(2): 297-301. https://doi.org/10.1002/ajpa.1330300214.

Pilkington, N. (2013). Growing up Roman: Infant mortality and reproductive development. *Journal of Interdisciplinary History* 44(1): 1-35. https://doi.org/10.1162/JINH_a_00499.

Prowse, T., Saunders, S., Fitzgerald, C., Bondioli, L., & Macchiarelli, R. (2010). Growth, morbidity, and mortality in antiquity: A case study from Imperial Rome. In: T. Moffat, T. Prowse (Eds.) *Human diet and nutrition in biocultural perspective* (pp173-196). Berghahn Books.

Reitsema, L. J., & McIlvaine, B. K. (2014). Reconciling "stress" and "health" in physical anthropology: What can bioarchaeologists learn from other subdisciplines? *American Journal of Physical Anthropology* 155(2): 181-185. https://doi.org/10.1002/ajpa.22596.

Rogers, T. L. (2009). Sex determination of adolescent skeletons using the distal humerus. *American Journal of Physical Anthropology* 140(1): 143-148. https://doi.org/10.1002/ajpa.21060.

Sadler, K. (2017). Pubertal development. In M. A. Goldstein (Ed.), *The MassGeneral Hospital for Children adolescent medicine handbook* (pp. 19-26). Springer. https://doi.org/10.1007/978-3-319-45778-9_3.

Santiago, R. C., Costa, L. F. M., Vitral, R. W. F., Fraga, M. R., Bolognese, A. M., & Maia, L. C. (2012). Cervical vertebral maturation as a biological indicator of skeletal maturity: A systematic review. *The Angle Orthodontist* 82(6): 1123-1131. https://doi.org/10.2319/103111-673.1.

Saunders, S., Hoppa, R., & Southern, R. (1993). Diaphyseal growth in a nineteenth century skeletal sample of subadults from St Thomas' church, Belleville, Ontario. *International Journal of Osteoarchaeology* 3(4): 265-281. https://doi.org/10.1002/oa.1390030405.

Schutkowski, H. (1993). Sex determination of infant and juvenile skeletons. I. Morphognostic features. *American Journal of Physical Anthropology* 90(2): 199-205. https://doi.org/10.1002/ajpa.1330900206.

Shapland, F., & Lewis M. E. (2013). Brief communication: A proposed osteological method for the estimation of pubertal stage in human skeletal remains. *American Journal of Physical Anthropology* 151(2): 302-310. https://doi.org/10.1002/ajpa/22268.

Shapland F., & Lewis, M. E. (2014). Brief communication: A proposed method for the assessment of pubertal stage in human skeletal remains using cervical vertebrae maturation. *American Journal of Physical Anthropology* 153(1): 144-153. https://doi.org/10.1002/ajpa.22416.

Sperduti A., Bondioli L., & Garnsey P. (2012). Skeletal evidence for occupational structure at the coastal towns of Portus and Velia (1st – 3rd c. AD). In I. Schrufer-Kolb (Ed.), *More than just numbers? The role of science in Roman archaeology* (pp. 53-70). Journal of Roman Archaeology Supplementary Series Number 91.

Sterling, P., & Eyer, J. (1988). Allostasis: A new paradigm to explain arousal pathology. In: Fisher, S., Reason, J. (Eds.). *Handbook of life stress, cognition, and health* (pp. 629-649). John Wiley & Sons Ltd.

Stewart, N. A., Gerlach, R. F., Gowland, R., Gron, K., & Montgomery, J. (2017). Sex determination of human remains from peptides in tooth enamel. *Proceedings of the National Academy of Sciences of the United States of America* 114(52): 13649-13654. https://doi.org/10.1073/pnas.1714926115.

Timmins, S. (2016). *Subadult growth and rickets from a Late Roman and Merovingian Period context in Lisieux, France.* Unpublished Masters thesis. McMaster University. https://macsphere.mcmaster.ca/handle/11375/20504

Walvoord, E. D. (2010). The timing of puberty: Is it changing? Does it matter? *Journal of Adolescent Health* 47(5): 433-439. https://doi.org/10.1016/j.jadohealth.2010.05.018.

Watts, R. (2015). The long-term impact of developmental stress. Evidence from later medieval and post-medieval London (AD 1117-1853). *American Journal of Physical Anthropology* 158(4): 569-580. https://doi.org/10.1002/ajpa.22810.

Wood, J.W., Milner, G. R., Harpending, H. C., & Weiss, K. M. (1992). The osteological paradox: Problems of inferring prehistoric health from skeletal samples [and comments and reply]. *Current Anthropology* 33(4): 343-370. https://doi.org/10.1086/204084.

CHAPTER 4: EATING LIKE ADULTS

Title: Eating like adults: An investigation of dietary change in childhood, adolescence, and adulthood at *Portus Romae* (Italy, 1st-4th centuries CE)

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ABSTRACT

Previous isotopic studies of Roman diet for individuals buried at *Isola Sacra* (1^{st}-4^{th} centuries CE; Italy) have focused on variation in adult diet or the critical stages of breastfeeding and weaning during infancy and childhood; however, little is known about the characteristics of diet when a child transitioned through adolescence to adulthood. This paper uses dietary stable isotope analysis of incremental tooth dentine from 9 individuals (15 teeth, 52 incremental dentine sections) to investigate the transition between childhood and adult diet, and sex-specific dietary patterns for people buried in the necropolis of *Isola Sacra* in the early Roman Empire. The incremental dentine isotope data demonstrate that males and females consumed different diets as early as 4.5 years of age. Additionally, females exhibit a positive correlation between $\delta^{15}N$ and age (r_s=.41, p=.026), suggesting the greater inclusion of higher trophic level foods as they aged. However, no discernable pattern of dietary change could be identified for males, suggesting sex-based patterns of dietary variation. For males, isotopic evidence of protein insufficiency around 15 years of age for two individuals raises questions about the effects of pubertal development on protein requirements, as well as changing social roles for young men during *adulescentia*. This research highlights the importance of considering diet in a longitudinal fashion and working to understand the biological and social changes occurring during adolescence in the past.

INTRODUCTION

In the Roman Empire (1st century BCE – 5th century CE), dietary recommendations were based, in part, on one's gender and age. These guidelines were influenced by medical theories of the time relating to the four humors (i.e., hot, cold, wet, dry), and diet was viewed as a way to maintain balance of the humors in order to influence overall health (Garnsey, 1999). For example, men and the elderly, who were seen as hot and dry, were encouraged to consume wet and cold foods, like eel, sturgeon, and other marine resources to balance their humors (Garnsey, 1999). In contrast, Athenaeus of Attaleia (1st century CE) writes that "the cold and wet constitution of the body of the woman has to be corrected by a regime which is weighted towards the hot and the dry" and, as a result, they were encouraged to "choose foods that are drying rather than moistening" (as quoted in Oribasius 21.1-3, in Garnsey 1999: 105).

Bioarchaeologists have investigated these claims and demonstrated that diets in archaeological samples are rarely as straightforward as the written sources suggest, with variable patterns found between adult males and females (Rissech *et al.,* 2016; Soncin *et al.,* 2021) and between non-adults and adults (Milella *et al.,* 2019; Craig *et al.,* 2009) and between social age categories (Avery *et al.,* 2021). At the Roman Imperial necropolis of *Isola Sacra* (1st to 4th centuries CE, associated with the coastal town of *Portus Romae*) stable isotope analysis of bone collagen and apatite demonstrates that men and women consumed different diets, and that non-adults ate a more restricted diet than adults (Prowse *et al.,* 2005; 2008). Yet, descriptions of the Roman life course not only differentiate between childhood (*pueritia*) and multiple stages of adulthood (*iuvenis, senior, senex*), but also identified a transitional period between the two, often called *adulescentia* (Eyben, 1993; Laes & Strubbe, 2014). To date, bioarchaeological research at *Isola Sacra* has not focused on this stage of the life course, and as a result, we are unsure what the diet looked like during this period, or how diets transitioned from a "child" to an "adult" type.

Stable isotope analysis of diet has traditionally used collagen (and carbonate) obtained from bone samples. This method, however, has proved problematic for the analysis of infant and child diets. In particular, such an approach relies on the analysis of individuals who died during the period of childhood and may not reflect the living population. Additionally, bone samples provide a cross-sectional approach to diet, rather than producing longitudinal datasets, limiting analysis of dietary *change*. Finally, sex-specific analyses are usually not possible, due to methodological limitations of sex estimation in pre-pubertal individuals (Lewis, 2019). Recent developments in dietary stable isotopes, focused on incremental analysis of tooth dentine, now allow researchers to examine dietary change in a longitudinal fashion within an individual (Beaumont *et al.,* 2015; Eerkens *et al.,* 2011). By examining teeth that develop during childhood/adolescence, but are extracted from adult remains, we can circumvent the issues that exist with bone collagen samples, and examine sex-specific patterns of dietary intake and change for those who survived this period of the life course.

This study uses stable isotope values of $\delta^{13}C$ and $\delta^{15}N$ obtained from incremental dentine sections to explore dietary change in childhood and adolescence in the *Isola Sacra* sample (Italy, 1-4th centuries CE). Incorporating osteological evidence for sex, we also explore sex-specific patterns of dietary intake and change. Based on previous bioarchaeological studies of diet for individuals buried at *Isola Sacra*, and descriptions of *adulescentia,* we hypothesize that (1) sex-specific diets emerged during *adulescentia*, in relation to the beginning of gendered roles and

behaviours, and (2) the dietary transition between childhood and adulthood occurred gradually for males and females during the period associated with *adulescentia*.

ROMAN ADULESCENTIA

Ancient descriptions of the Roman life course identify between three and seven stages (see Harlow & Laurence, 2002; Laes & Strubbe, 2014; Rawson, 2003 for more information). Most of these depictions include a transitional period between childhood and adulthood, named *adulescentia* or *iuvenis*, both roughly translating to "a period of youth" (Eyben, 1993). The most well-known and widely used Roman life course model is that described by Varro (117-27 BCE), dividing the life course into five stages, including *adulescentia* between approximately 15 and 30 years of age (Eyben, 1993; Franschetti, 1997). Yet, the mere inclusion of this transitional period does not explain what it looked like and determining precisely what this period of the life course meant is still debated by modern researchers (Laes & Strubbe, 2014). It is likely that, as the Roman Empire consisted of diverse groups of individuals, *adulescentia* took on many different forms, depending on one's gender, social status, regionality, and religious beliefs (e.g., Rawson, 1966; Bradley, 1991; Arthur *et al.*, 2016; Moore, 2009).

For higher status boys, this period of the life course seems to have been an enjoyable and extended period of life, where they were introduced to brothels, heavy drinking, and sports, and received a formal education (Eyben, 1993). This period began when the boy removed the *toga praetexta* (childhood toga) and *bulla* (a protective amulet) and put on the *toga virilis* (adult toga) for the first time (Laes & Strubbe, 2014). Ancient writers are very clear that these boys, as youths, were not yet adults (Laurence, 2000). Rather, these young men were viewed as impulsive and inexperienced, and needed some form of protection from themselves and others (Harlow & Laurence, 2002). Full adulthood was only achieved once individuals had undergone biological and social maturation (Eyben, 1993; Rawson, 2003). Descriptions of this process vary but within the Roman upper classes, entrance into the senate at the age of 30 may serve as an appropriate ending point (Laes & Strubbe, 2014). For lower status boys, who could not afford to participate in the same activities, *adulescentia* was likely a vocationally based period, focused on developing the necessary skills and capabilities to help provide for themselves and their families (Bradley, 1991; Dixon, 1992). However, historians caution that *adulescentia* in the Roman Imperial period was not always a well-defined or demarcated period and was likely a more fluid conceptualization of the aging process (Rawson, 2003).

Relative to the male life course, comparatively little is known about the female life course in Roman society, as ancient literary sources are often silent regarding the experiences of girls and lower status individuals (Laurence, 2000; Eyben, 1993). On the rare occasion that these sources discuss the lives of women, we must be cognisant of the fact that this is how their life course was perceived by men in Roman society, and not necessarily how women perceived their own life course or how they viewed the experience of becoming an adult.

Building on various literary passages, a woman's position in the life course was dependent on how she was perceived by – or interacted with – the male figures in her life. Even terminology used to describe women emphasizes this point, as women went from being *virgines* (virgins) to *uxores* (wives) to *matronae* (matrons) once they had children (Fraschetti, 1997). Based on these

terms, it seems that young women simply went from childhood to adulthood on their wedding day, without a defined period of *adulescentia* (Laes & Strubbe, 2014; Revel, 2005).

Legally, girls could be married as early as 12 years old, and literary evidence indicates that marriage at such a young age was common in higher status families, sometimes even occurring before a girl reached puberty (Eyben, 1993). For example, at nearby *Ostia Antica* (Italy, 1st century BCE – 5th century CE), an epitaph on a cinerary urn reports the name (*Onesime*), the age (*vxit annis XIII*; she lived 13 years), and role (*uxori dulcissimae;* sweetest wife) of a deceased woman, indicating that marriage did occur at these ages; bioarchaeological analysis of the burnt skeletal remains confirmed the young age of the individual (Bondioli *et al.*, 2018). In middle and lower status families, like those buried at *Isola Sacra*, analyses of epitaphs suggest most women married in their late teens or early twenties (Saller, 1987; Shaw, 1987; Revel, 2005).

Although there is no explicit discussion of a transitional period in the female life course, historians suggest that a period of social transition likely existed (Caldwell, 2015). This interpretation is supported by Rufus of Ephesus' (1st century CE; cited in Oribasius, 4th century CE) *Regimen for Young Girls* and Soranus' (1st-2nd century CE) *Gynecology*, which both treat puberty as an important transitional step to adulthood (Caldwell, 2015). For higher status girls, Rufus and Soranus suggest that puberty (as indicated by breast budding) began when a girl was 12 years old, and menarche occurred at 14 years (Pilkington, 2013).

During this, potentially brief, period between menarche and marriage, scarce evidence suggests that this transition for young women likely took place within the domestic space, focused on preparing these young women for marriage and motherhood (Caldwell, 2015; Nathan, 2021). However, once again, we must consider the biases present in literary sources, and that we may be missing key features of a women's experiences, particularly for young women in middle and lower status families, like those buried at *Isola Sacra*.

For young men in higher and lower social status groups, *adulescentia* appears to have been a transitional period between childhood (*pueritia*) and young adulthood (*juventus)*, with individuals taking on new roles and responsibilities in their communities and households. For young women, the period seems to be less well defined, and may have included skill development within the natal household. However, when these transitions occurred, or the ways in which this was achieved varied greatly, and this variation needs to be considered when analysing and interpreting the lived experiences of adolescents in the past.

MATERIALS AND METHODS

THE NECROPOLIS OF *ISOLA SACRA*

Located 23km southwest of Rome, the necropolis of *Isola Sacra* is associated with the Roman Imperial town of *Portus Romae*, the main port servicing Rome (Keay *et al.*, 2005; fig. 4-1). Construction of the port began under Emperor Claudius in the 1st century CE and expanded in the 2nd century CE under Emperor Trajan (Keay *et al.*, 2005:1). At its peak, the port and the surrounding community was one of the most important trading centres in the Mediterranean, supporting the population of Rome with daily shipments of food, goods, and people (Keay *et al.*, 2005; Hoover *et al.*, 2005).

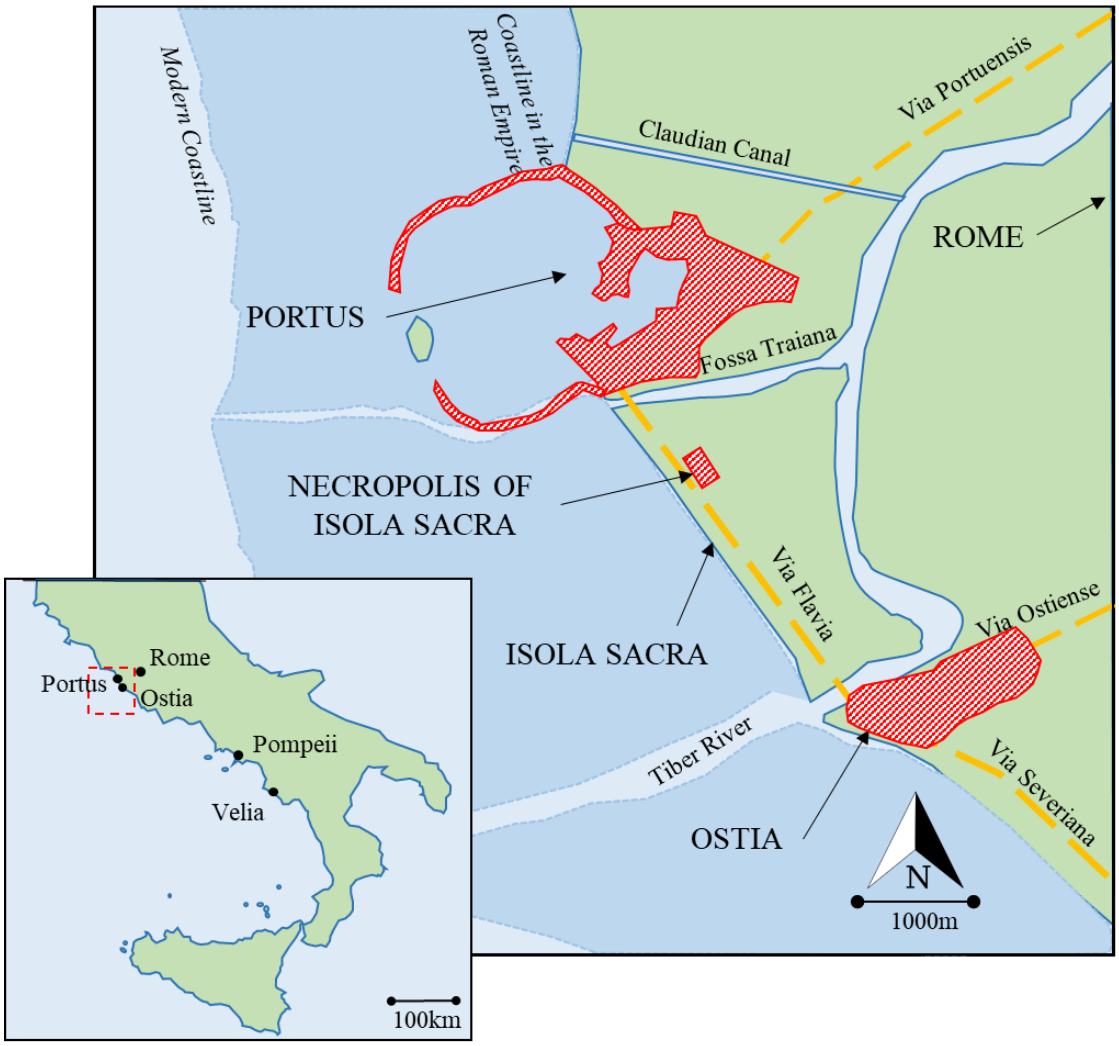

Figure 4-1: Map of *Portus*, *Isola Sacra*, and *Ostia* (Italy). Yellow long dash lines – Roman roads; Red areas with diagonal lines– archaeological areas. Adapted from Germoni et al. (2011: 232) and Talbert (2000: 43).

As a port town, the inhabitants of *Portus* relied on the activities of the harbour for their daily living. As a result, the community included merchants, traders, shopkeepers, carpenters, craftsmen, and artisans (Cho & Stout, 2003; Sperduti *et al.*, 2012). Reliefs within the necropolis also point to a wide range of occupations, including a doctor and midwife, a smith, a watercarrier, and a grain merchant. Residents of *Portus* likely exploited marine resources and further from the port cultivation and farming were certainly possible, although space for these activities seems limited (Crowe *et al.*, 2010; Sperduti *et al.*, 2012). Rather, as a port town with diverse peoples and varied trade goods, it is likely that individuals at *Portus* would have consumed a wide range of foodstuffs brought through the community, contributing to diverse dietary patterns (Erdkamp, 2015).

At *Portus*, little evidence remains of an elite class living within the community; rather, it seems that rich landowners and aristocrats lived in their estates closer to *Ostia* (Keay & Millett, 2005). As a result, *Portus* is interpreted to be a middle-class community (Manzi *et al.*, 1999).

Additionally, the frequency with which freedmen are mentioned in the surrounding cemeteries suggests that *Portus* had a large population of enslaved individuals, freedmen, or their descendants (Hermansen, 1981). Epigraphic evidence also demonstrates that the people in *Portus* were diverse, with immigrants coming from Tunisia, Egypt, Palestine, France, Greece, Asia Minor, and throughout Italy (Hermansen, 1981: 46). Bioarchaeological studies using strontium and oxygen isotope analyses further demonstrate that approximately one third of individuals sampled exhibited isotope values outside the expected local range, including women and children (Prowse *et al.*, 2007; Stark, 2016).

The necropolis of *Isola Sacra*, located along the *Via Flavia* between *Portus* and *Ostia*, was the primary necropolis used by the inhabitants of *Portus* between the 1st and 4th centuries CE (Germoni *et al.*, 2011; Calza & Becatti, 2008) (fig. 4-1). The necropolis was rediscovered as early as 1699, with systematic excavations beginning in 1918, and continuing throughout the 20th century. More than 200 funerary buildings have been excavated, although Calza and Becatti (2008) suspect that only a small portion of the necropolis has been identified and excavated. Much of the chronology of the necropolis is poorly understood, largely due to its lack of systematic use (Meiggs, 1973). Determining when the necropolis was abandoned is also difficult, but Calza and Becatti (2008) suggest that there were no new tombs constructed after the middle of the third century CE, and by the end of the fourth century CE, the cemetery "ceased to grow" (Meiggs, 1973: 466). Eventually the necropolis was abandoned and covered by encroaching sand. The remains of more than 2000 individuals recovered from the necropolis are now housed at the Museo della Civiltà in Rome, Italy. Most of the individuals analyzed in the current study come from the so-called "campo dei poveri" (poor people's field), a large area where over 600 ground sepulchres of diverse typology were scattered in the spaces between the monumental tombs (Olivanti & Spanu, 2018).

METHODOLOGY

Terminology. In the current study, biological age refers to patterns of growth and development of the human body, while social age relates to culturally constructed categories of age (e.g., *pueritia*), that encapsulate appropriate behaviours and attitudes. When discussing biological age, we use numerical values (e.g., 4.5 ± 0.48 years) or "non-adult" and "adult". When discussing social age, we use culturally specific categories for the Roman period where appropriate (e.g., *adulescentia*) rather than standard western categories (e.g., adolescence), to better capture the social construction of the life course and the process of aging during this particular time period.

In anthropology, sex and gender are understood as biological and social constructs, respectively, that exist along a spectrum rather than in binary opposition (Joyce, 2017). However, ancient Roman authors identify and discuss two primary groups (i.e., man/woman or male/female) (Grubbs, 2002). Consequently, in the context of this study, we use these two groups when discussing gendered experiences (man/woman) or sex-based results (male/female). We acknowledge, however, that lived experiences were likely more diverse than ancient authors represent, and that other gender identities beyond this binary likely existed.

Sample selection. To explore dietary intake and change during the period of childhood and adolescence, paired second (M2) and third molars (M3) were selected from individuals that met the following criteria:

- Aged 18 years or older, based on dental development (Gustafson & Koch, 1974), epiphyseal fusion (Cardoso, 2008a; 2008b), and pubic symphysis morphology (Brooks & Suchey, 1990; Katz & Suchey, 1986).
- Clear osteological indicators of sex using standard pelvic and cranial morphology (Acsádi & Nemeskéri, 1970; Phenice, 1969).
- Present and loose M2 and M3, to avoid damage associated with manual extraction, that were confidently attributable to the skeletal remains (based on refitting and dental wear patterns).
- Skeletal remains were not previously sampled for bioarchaeological studies.

Sample Preparation. Clean and dry teeth were embedded in Buehler EpoThin epoxy, sectioned mesio-distally using a Buehler IsoMet1000 slow-speed saw with a diamond blade, and then removed from the epoxy using 100% acetone (France *et al.,* 2011). One half of the tooth was retained for future research, while the other half was prepared for isotope analysis. Enamel was removed with a diamond bit on a Dremel drill, and the remaining dentine sample was demineralized using 0.5M hydrochloric acid (HCl), changing the acid daily until demineralization occurred (following Beaumont & Montgomery, 2016). Once demineralized, teeth were sectioned following dentine formation patterns for second and third molars, as illustrated by Brickley *et al.* (2019: fig. 4-2), using landmarks within the tooth (e.g., pulp chamber, bifurcation of the roots), rather than overall length. Using oblique, rather than horizontal, cuts provide a more accurate chronological representation of changes in diet over time, as it takes into account the directionality and pace of incremental growth structures (fig. 4-7). However, even this approach is imperfect, and some blending between age points is expected, as dentine develops in cone-like structures (Eerkens *et al.,* 2011). The incremental samples were subsequently heated for 48 hours in 0.001M HCl at 70º Celsius. The liquid collagen was dried at 60º Celsius for 24 hours and weighed to determine the percent yield.

Prepared samples were sent to the Ján Veizer Stable Isotope Laboratory (University of Ottawa, Canada) for analysis on a Vario EL Cube Elemental Analyser connected to a Delta Advantage isotope ratio mass spectrometer, coupled with a Conflo IV interface. Duplicates were run on seven samples. The analytical precision is better than 0.2‰ for both $\delta^{13}C$ and $\delta^{15}N$. Analytical precision is based on the internal check standard C-55 (glutamic acid) ($\delta^{15}N$, $\delta^{13}C$ in ‰): -4.0, -28.5. Internal laboratory calibration standards are ($\delta^{15}N$, $\delta^{13}C$ in ‰): C-51 Nicotinamide (0.1, -23.0); C-52 mix of ammonium sulphate + sucrose (16.6, -11.9), and C-54 caffeine (-16.6, -34.5). Using the standard C-55, the mean and standard deviation for $\delta^{13}C$ (‰, VPDB) is -28.5 ± 0.03 (n=3), and $\delta^{15}N$ (‰, AIR) is -4.0 ± 0.04 (n=3). The calibration standards are as good as, or better than, the check standard. In each case, the calibration is R^2 = 0.999x or better.

Nitrogen isotope data are reported as ‰ vs. AIR and normalized to internal standards that are calibrated to international standards IAEA-N1(+0.4‰), IAEA-N2(+20.3‰), USGS-40(-4.5‰) and USGS-41(47.6‰). All carbon isotope data are reported as ‰ vs. VPDB and normalized to internal standards calibrated to international standards IAEA-CH-6(-10.4‰), NBS-22(-29.9‰), USGS-40(-26.2‰) and USGS-41(37.8‰). A multipoint calibration (using all three calibration standards) was used to normalize the data.

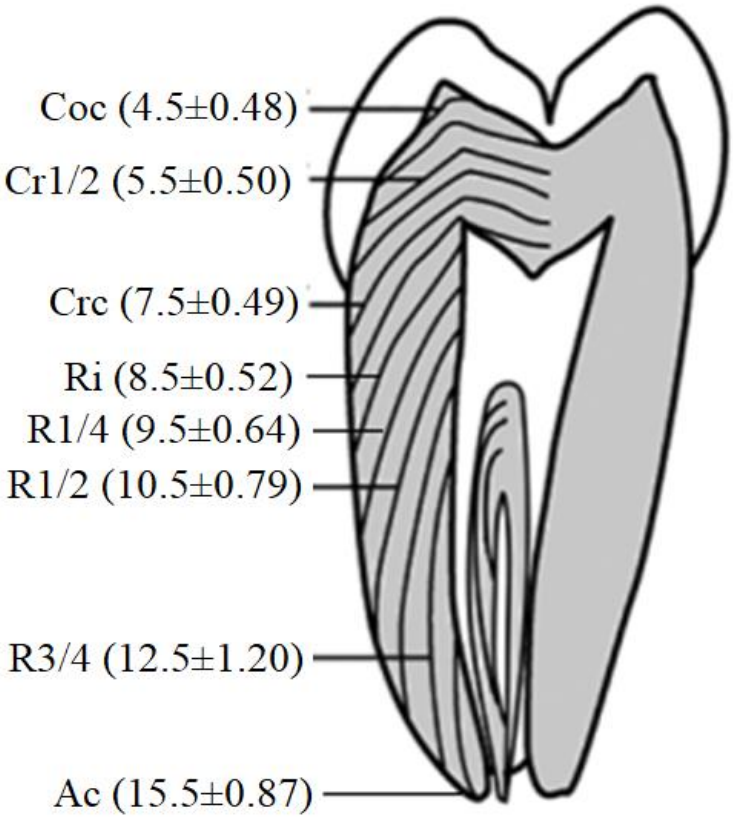

Figure 4-2: Schematic of the mandibular second molar with oblique cutting protocol indicated (adapted from Brickley et al., 2019, AlQahtani et al., 2010; 2014; Liversidge et al., 2020). Details for maxillary second molar and third molars can be found in figure 4-4 (supplementary figure). Coc = coalescence of cusps; Cr1/2 = crown half completed; Crc = crown completed with defined pulp root; Ri = initial root formation with diverging edges; R1/4 = root length less than crown length; R1/2 = root length equals crown length; R3/4 = root length more than crown length with diverging ends; Ac = apex closed with normal periodontal ligament width.

Sample integrity was assessed using C:N ratios (acceptable range: 2.9-3.6), collagen yields (>1.0‰ *coll*), and percent carbon and nitrogen by weight (>3%C, >1%N) (DeNiro, 1985; Schwarcz & Schoeninger, 1991; van Klinken, 1999; Ambrose, 1993). Samples that met these limits were included in the analysis. Age estimation of each dentine section was completed by comparing the sample's anatomical location to the stage of dental development following The London Atlas, including mean ages and standard deviations (AlQahtani *et al.*, 2010; 2014; Liversidge *et al.*, 2020).

STATISTICAL ANALYSIS

A Shapiro-Wilk's test and assessment of skewness and kurtosis show that $\delta^{13}C$ values are approximately normally distributed for males, females, and the sexes combined; consequently, parametric tests are used (e.g., Pearson's Correlation, r) (Table 4-4, supplementary table). For $\delta^{15}N$, however, non-parametric tests are used (e.g., Spearman's correlation, r_s), as values are

skewed and kurtotic, and the Shapiro-Wilk's test demonstrates that values are not normally distributed for males, females, nor the sexes combined. When analyzing $\delta^{13}C$ and $\delta^{15}N$ values simultaneously, non-parametric tests are used, as they do not make assumptions about the dataset, and thus, are more conservative and appropriate when some of the datasets are not normally distributed (Kaur & Kumar, 2015). A significance threshold of 95% ($p<.05$) was selected for all statistical tests. Statistical tests were calculated using IBM SPSS v.26.

RESULTS

A total of 97 sections were obtained from the 20 teeth selected for analysis. Fifty-two sections from 15 teeth (9 individuals) met the necessary collagen yields for mass spectrometry and all thresholds of sample integrity (Table 4-1, Table 4-5 supplementary table). Carbon isotope ratios range from -20.2‰ to -17.9‰ (mean: -19.3‰ ± 0.5) and nitrogen isotope ratios range from 6.7‰ to 12.9‰ (mean: 11.1‰ ± 1.6) (fig. 4-3).

Table 4-1: Sample size by age of dentine section and osteological sex.

Age ± 1SD	Males	Females	Total
4.5 ± 0.58	2	2	4
5.5 ± 0.50	2	2	4
7.5 ± 0.49	2	4	6
8.5 ± 0.52	2	2	4
9.5 ± 0.64	2	1	3
10.5 ± 0.79	1	6	7
11.5 ± 1.09	3	2	5
12.5 ± 1.20	2	2	4
13.5 ± 1.17	3	3	6
15.5 ± 0.87	2	3	5
16.5 ± 0.78	1	2	3
23.5 ± 1.12	1	0	1
Total	23 (44.2%)	29 (55.8%)	52 (100%)

Spearman's correlation indicates that $\delta^{15}N$ values are positively correlated with age for females ($r_s=.41$, $p=.026$; fig. 4-4) and for sexes combined ($r_s=0.28$, $p=.042$), but not for males (Table 4-2). Meanwhile, $\delta^{13}C$ values are not correlated with age (sexes combined: $r=-0.17$, $p=.218$; fig. 4-5). For males, $\delta^{13}C$ and $\delta^{15}N$ values are correlated ($r_s=.47$, $p=.025$), but the stable isotope values are not correlated with each other for females or sexes combined.

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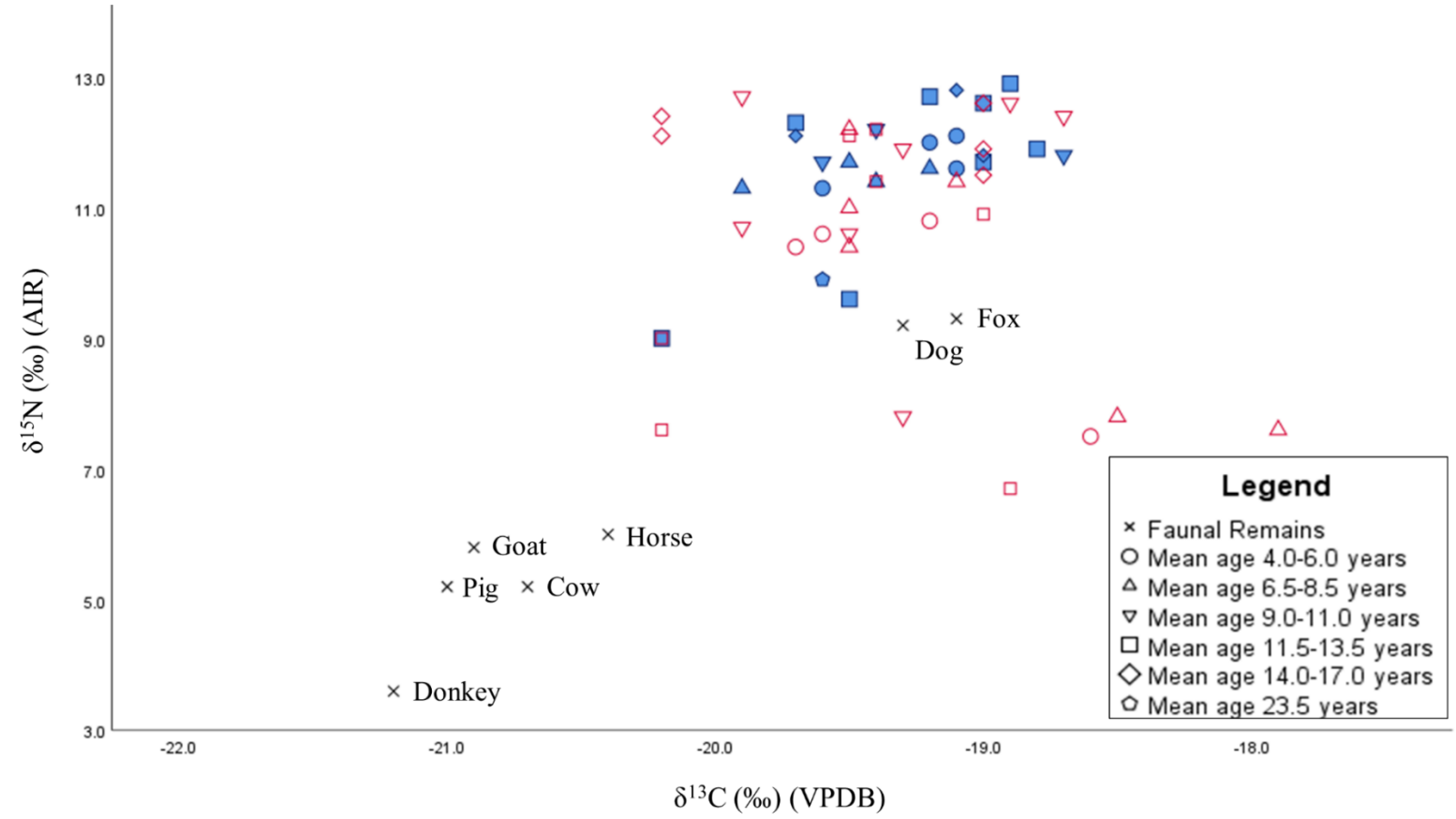

Figure 4-3: Stable carbon and nitrogen isotope values by age and sex. Markers for males (solid blue shapes) and females (outlined red shapes) represent a single dentine section from one of 15 individuals. Markers for faunal remains (×, labeled by animal) represent average values reported by Prowse *et al.* (2004). Shape indicates the age of the sample, to demonstrate how stable isotopes values change with age.

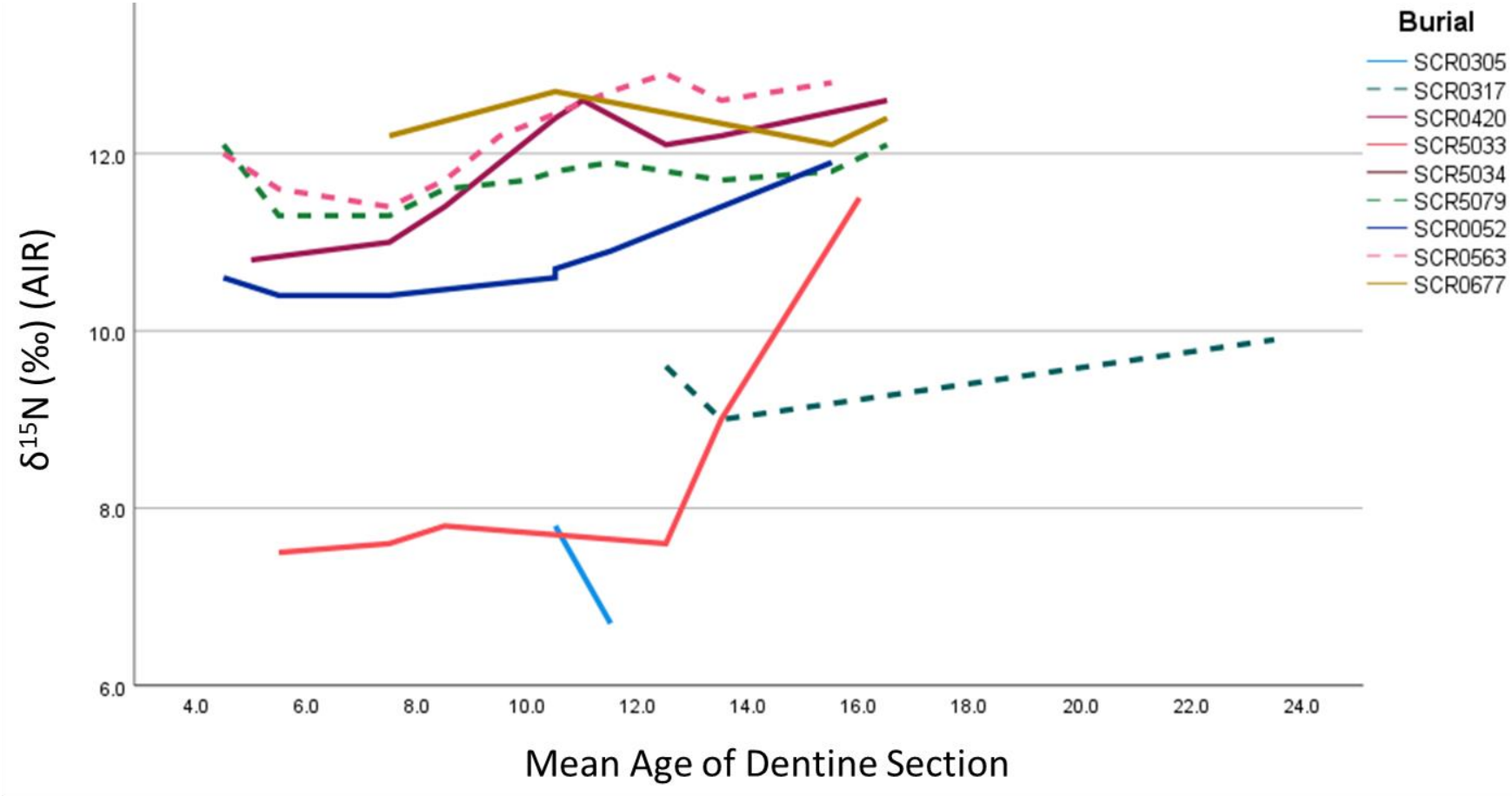

Figure 4-4: Stable nitrogen isotope values by individual (by colour). Males = dotted lines, Females = solid lines. Colour represents different burials, as indicated in legend (SCR 5034 not shown as it is a single datapoint).

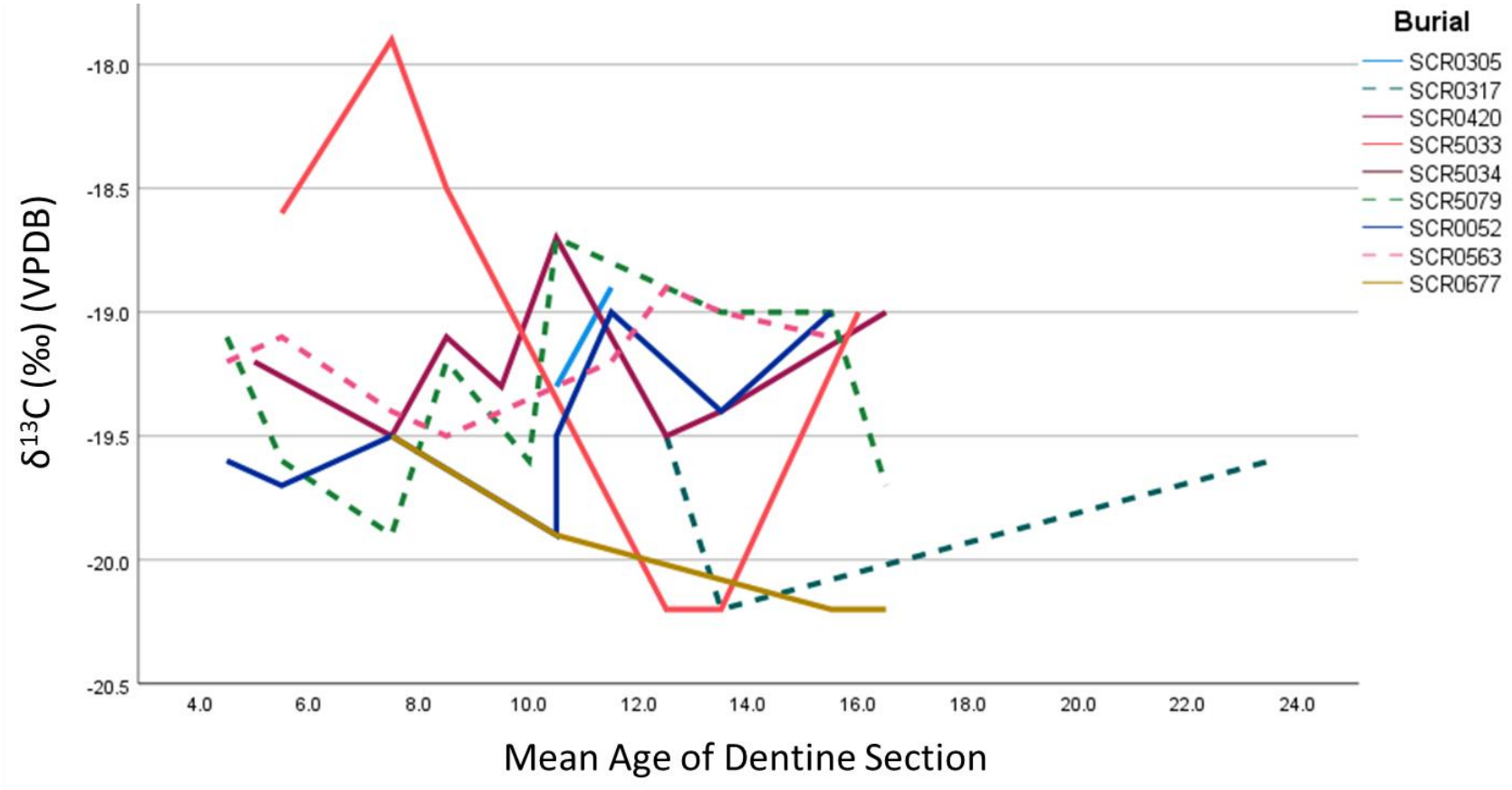

Figure 4-5: Stable carbon isotope values by individual (by colour). Males = dotted lines, Females = solid lines. Colour represents different burials, as indicated in legend (SCR 5034 not shown as it is a single datapoint).

Table 4-2: Spearman's correlation by age and $\delta^{13}C$ & $\delta^{15}N$ values.

	Males	Females	Sexes Combined
Age & $\delta^{13}C$	r= -.07, p=.746	r=--.26, p=.179	r= -.17, p=.218
Age & $\delta^{15}N$	r_s=.15, p=.490	r_s=.41, p=.026	r_s=.28, p=.042
$\delta^{13}C$ & $\delta^{15}N$	r_s=.47, p=.025	r_s=-.12, p=.549	r_s=.11, p=.448

r= Pearson's correlation coefficient; r_s= Spearman's correlation coefficient, p= statistical significance. Significant values (p<.05) shaded. Correlation coefficient also indicates effect size, with r =0.1 indicating a small effect size, r=0.3 indicating a medium effect size, and r=0.5 indicating a large effect size.

DISCUSSION

Compared to herbivore bone samples recovered from *Isola Sacra* (e.g., cow, goat) analyzed by Prowse *et al.* (2004), the mean $\delta^{13}C$ and $\delta^{15}N$ values for human samples in the current study are higher by 1.5‰ and 5.0‰, respectively, for dentine sections aged 4.5 to 23.5 years (fig. 4-3). This is greater than the expected trophic level increase of 1‰ for $\delta^{13}C$, and 3‰ for $\delta^{15}N$, suggesting the consumption of the flesh or by-products of these animals, as well as the incorporation of marine resources. These results are consistent with the known composition of the site of *Portus Romae*, as a major trade centre and known marine resource extraction that took place at the site (e.g., Manzi *et al.,* 1991).

When compared to non-adult (5-15 years of age) femoral samples, published by Prowse *et al.* (2005), individuals in the current study display mean $\delta^{15}N$ values that are 0.7‰ higher, and $\delta^{13}C$ values that are 0.3‰ lower. While the sample sizes in the current study are small, it suggests that there are no marked differences in dietary intake for those that died during childhood compared to those that survived this portion of the life course (table 4-3). The dentine samples do, however, show greater standard deviations. Initially, these results may suggest greater dietary variation within the current sample, however, these differences are likely a result of the different tissues sampled between the two studies, with bone collagen representing longer-term averages than dentine sections. As a result, the bone collagen results by Prowse *et al.* (2005) may mask some of the variation in diet experienced by people buried at *Isola Sacra*, demonstrating further benefits of using incremental analysis of dentine sections to learn about dietary difference and change in the past.

Table 4-3: Comparative $\delta^{13}C$ and $\delta^{15}N$ data from dentine (current study) and femora (Prowse *et al.,* 2005).

Tissue	Age	Sex	$\delta^{13}C$ (‰)			$\delta^{15}N$ (‰)			Source
			N=	Mean	SD	N=	Mean	SD	
Dentine	4.5-23.5	M, F	52	-19.3	0.5	52	11.1	1.6	Current study
Dentine	4.5-23.5	M	23	-19.3	0.4	23	11.7	1.0	Current study
Dentine	4.5-3.5	F	29	-19.3	0.6	29	10.6	1.9	Current study
Femora	5-15	M, F	14	-19.0	0.3	13	10.4	0.8	Prowse *et al.,* 2005

M= male, F = female. N= sample size, SD = standard deviation.

EMERGENCE OF SEX-SPECIFIC DIETS

Previous stable isotope research analyzing bone collagen and apatite demonstrated that adult males and females buried at *Isola Sacra* consumed different diets, with females consuming more terrestrial-based proteins, and males consuming more marine-based proteins (Prowse *et al.*, 2005). The current dataset is unable to determine when gendered diets emerged for those buried at *Isola Sacra*, but visual examination of $\delta^{15}N$ values by individual (fig. 4-4) demonstrates that males exhibited higher stable nitrogen values than females as early as 4.5 years of age. These results fit well with dietary recommendations, that encouraged women to avoid wet and cold foods, like marine resources (Garnsey, 1999).

Although sample sizes are small, these results suggest that dietary intake at *Isola Sacra* was sex-specific or gender-based during the period under consideration (4.5 to 23.5 years of age). Garnsey (1999) suggests that food distribution within the family unit was often dictated by social hierarchy, with men and older boys receiving a more generous share of the family resources than women. In part, because, as a patriarchal society, males were often valued more than females in the Roman Empire (Garnsey, 1999). The isotopic results of the current study show that dietary intake was different for males and females buried at *Isola Sacra* during childhood and adolescence.

Between 4.5 and 23.5 years of age, statistical correlation shows that males and females buried at *Isola Sacra* exhibited different patterns of dietary change, with females exhibiting a moderate positive correlation between $\delta^{15}N$ values and age, while males do not, further supporting the idea that males and females consumed different diets during childhood and adolescence (Table 4-2).

TRANSITION FROM CHILD TO ADULT DIETS

One of the strengths of incremental dentine analysis is the ability to explore longitudinal patterns of dietary change at the individual level, rather than strictly cross-sectional data from a sample. The longitudinal data demonstrate a gradual increase in $\delta^{15}N$ for six of the nine individuals between 4.5 and 23.5 years of age (fig. 4-4); while $\delta^{13}C$ values show more variability with age and no consistent pattern (fig. 4-5). This pattern is confirmed by the Spearman's correlation, which demonstrates a weak positive correlation between $\delta^{15}N$ values and age for females and sexes combined, whereas Pearson's correlations for $\delta^{13}C$ were not statistically significant (table 4-2). Examining individual longitudinal profiles (fig. 4-6 and fig. 4-8), the overall increase in $\delta^{15}N$ within any one individual is less than 2‰ (with the exception of SCR5033, discussed below), indicating that the change was due to the increased incorporation and consumption of marine resources and/or higher trophic level foods, rather than the result of a radically different dietary regimen.

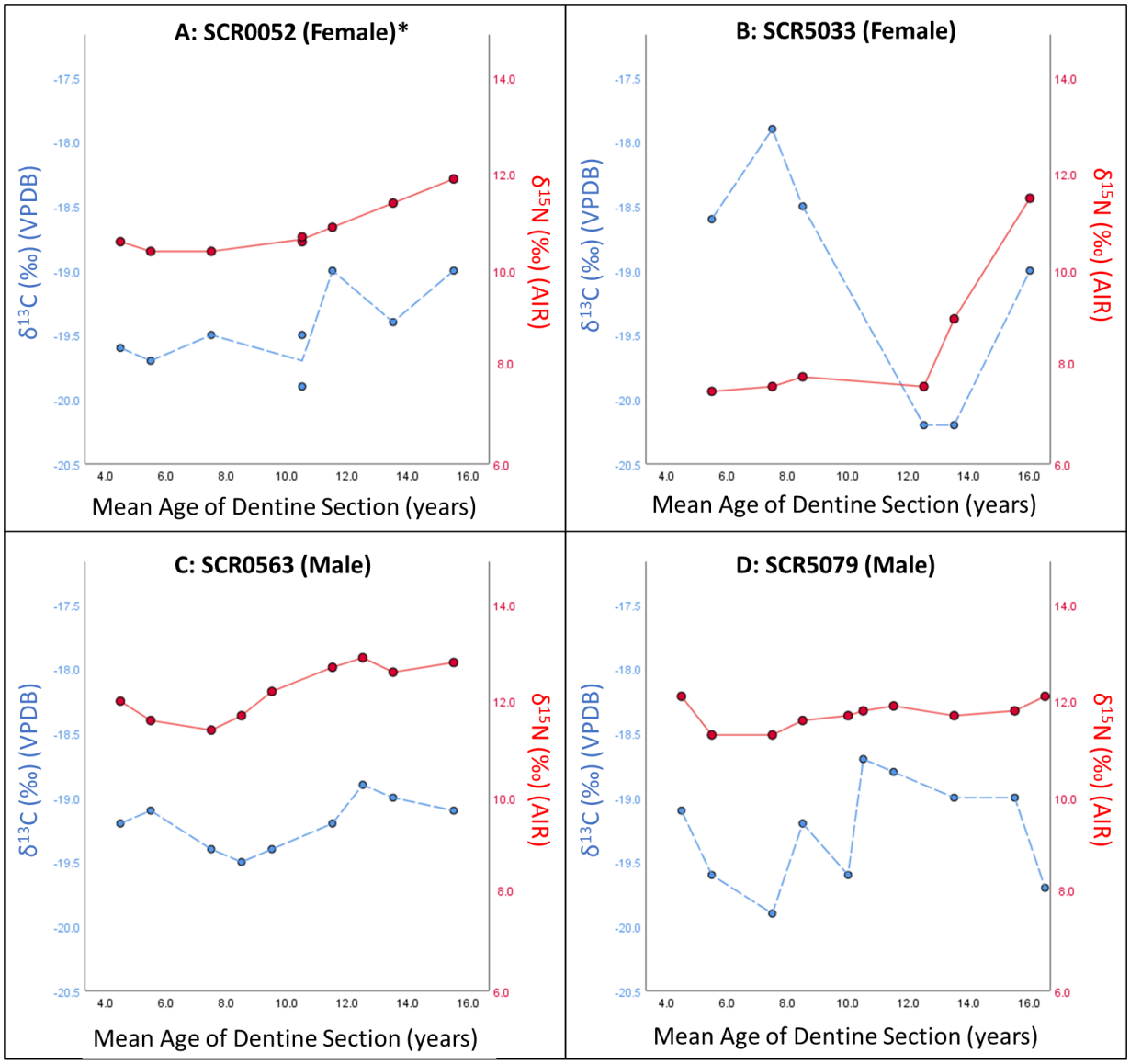

Figure 4-6: Select longitudinal isotopic profiles of dentine sections by individual for stable carbon (dotted blue lines) and nitrogen (solid red lines) isotope values. Each dot represents a dentine section from the M2 or M3. Additional longitudinal profiles available in Figure 4-8. *Two points at age 10.5 for SCR0052 reflection dentine section from the M2 and a similarly aged dentine section from the M3.

The presentation of the longitudinal data also allows us to identify outliers. For example, SCR5033 (fig. 4-6b, female; 20-25 years old at death) exhibits $\delta^{15}N$ values almost a full trophic level lower (3‰) than other profiles between 5.5 and 12.5 years of age, and a 4‰ increase between 12.5 and 16.0 years of age. Stable carbon isotope values for SCR5033 are also anomalous, exhibiting values that are 1‰ higher than others between 5 and 9 years of age. When the $\delta^{15}N$ and $\delta^{13}C$ isotope values are considered in tandem, SCR5033 appears to have consumed a different diet during *pueritia* (roughly 7-15 years, according to Varro; Laes & Strubbe, 2014), possibly with the

inclusion of some C_4-based proteins (e.g., millet) and freshwater fish resource consumption. Around 15 years of age, however, she began to consume higher trophic level foods, including marine resources, and increased consumption of meat and/or animal by-products. On their own, these results do not explain why these changes occurred. The shift in $\delta^{13}C$ and $\delta^{15}N$ values between 9 and 14 years of age may be due to a marked social age change during this period or may hint at migration occurring during this period, with the individual consuming foods with a different isotopic baseline and reduced access to marine foods prior to moving to the area around *Portus Romae*. Previous isotopic research of samples from *Isola Sacra* demonstrates high rates of mobility at the site, including migration during childhood (Prowse *et al.*, 2007; Stark, 2016). While the mobility of young women is often attributed to marriage or position as slaves, researchers have highlighted that women may have also moved to seek out new employment opportunities (Stark, 2016; Bruun, 2016; Holleran, 2016). Further consideration of $\delta^{18}O$ or strontium isotope data for SCR5033 may help us understand her unique dietary patterns further, by providing information on the geographic origins of this individual.

Females. The Spearman's correlation and longitudinal profiles of the five individuals (nine teeth; 29 dentine sections) suggest that, between 4.5 and 16 years of age, diet changed gradually and subtly for women, with small increases in both $\delta^{13}C$ and $\delta^{15}N$, possibly also reflecting a gradual social age change (e.g., fig. 4-6a). These results appear to challenge literary writers who suggest that girls simply transitioned from childhood to adulthood on their wedding day, and instead support historians, who argue in favour of a transitional period of the female life course (Laes & Strubbe, 2014; Caldwell, 2015).

The gradual increase in $\delta^{13}C$ and $\delta^{15}N$ values with age may reflect medical recommendations at the time, to monitor and control the diets of young women. Rufus of Ephesus (1st century CE) writes:

> *"When they are older and growth has all but stopped, and when young girls out of modesty no longer want to play childish games to the full, then one must give much more continuous attention to their regimen, regulate and moderate their intake of food, and not let them touch meat at all, or other foods that are very nourishing"* (Rufus of Ephesus quoted in Oribasius (4th century CE), *Liber Incertus* 18.10, cited in Garnsey, 1999: 101).

The isotopic data, however, suggest women at *Portus Romae* continued to consume animal proteins at this point in their life course, contradicting these recommendations. The recommendations from Rufus and other medical writers may have acted as guidelines for higher status women, but may also reflect more common notions of restricted or controlled diets at the beginning of puberty for young women of other social classes.

The gradual dietary change for females (except for SCR5033), however, does not negate the possibility of a sudden social age change during this period. It may be that, without data for the late teen years, we are missing the period during which middle-class women in Roman Italy would be marrying and experiencing a sudden social age transition which, in turn, may have resulted in a pronounced dietary shift (Shaw, 1987). The lack of noticeable dietary shift may also suggest that diet is not an appropriate proxy or indicator of social age changes for women buried at *Isola Sacra*. According to Laes (2019), food production within the family was often under the supervision or control of women in middle-class families. Therefore, even as women transitioned from childhood to adulthood, they likely would have continued to have agency over the foods

produced and consumed in their daily lives, resulting in small and relatively consistent changes. Consequently, methods beyond stable isotopes may be needed to investigate social age changes for females buried at *Isola Sacra*.

Males. The ancient Roman writer, Varro, suggests that *adulescentia* began around 15 years of age for young men (Laes & Strubbe, 2014). Examination of the longitudinal profiles of SCR0563 and SCR5079 (fig. 4-6c, d; males) demonstrate a very slight increase in $\delta^{15}N$ (<1‰) and concurrent decrease in $\delta^{13}C$ (<1‰) between 14 and 16 years of age, coinciding with this period. There is no stable isotope data available after this point to determine if this is the start of a trend (i.e., if $\delta^{15}N$ continues to increase while $\delta^{13}C$ continues to decrease) or if this is a very subtle shift that does not continue as individuals age. Although these changes are slight, similar patterns were reported by Prowse *et al.* (2004; all ages), with high and varied $\delta^{15}N$ values, but low and restricted $\delta^{13}C$ values, which they interpret as a reflection of an inadequate protein supply for individuals buried at *Isola Sacra*. During protein insufficiency, the body receives less nitrogen than required for proper maintenance, and as a result, the body can turn to catabolizing its own tissues (Reitsema, 2013). This 'recycling' of body tissues leads to repeat fractionation processes, resulting in elevated $\delta^{15}N$ values and decrease in $\delta^{13}C$ if the body pulls resources from stored body fat (Reitsema, 2013; Waters-Rist & Katzenberg, 2010; Walter *et al.,* 2020).

A protein-deficient diet between 14 and 16 years of age for SCR0563 and SCR5079 may be the result of changing social roles, as these young men took on new roles and responsibilities, particularly if they began apprenticeships or new occupations that took them away from their natal home (which may or may not have been in the region of *Portus Romae*) and put them into a more vulnerable position. Vuolanto (2015) suggests that apprenticeships were similar to the experiences of enslaved children, with food provided by the apprentice's master. Thus, while it is unclear what the dietary regimen for an apprentice would encompass, we may look to rations provided to enslaved peoples as a possible interpretation. In *de Agricultura*, Cato the Elder (234-149 BCE) states that slaveholders should provide each farmhand with wheat, olive oil, salt, and wine (White, 1976). To this base, vegetables, legumes, fruits, and nuts should also be added, which would have provided some protein to their diets (Garnsey, 1999). If these young men were consuming a protein-deficient diet, it is possible that they would have entered a catabolic state to make up for this deficit.

The dietary patterns noted for SCR0563 and SCR5079 may also reflect periods of famine or food shortages, which were common in the Roman Empire, due to environmental conditions (e.g., excessive heat, limited rainfall) or trade disruptions (e.g., war, trade disputes) (Erdkamp, 2015). During these periods of food insecurity, Erdkamp (2015) suggests that in urban environments, the prices of basic foodstuffs would dramatically increase, which would limit options for lower- or middle-class individuals, like those buried at *Isola Sacra*. Males, who may have been expected to provide for themselves through labour and work, would be particularly vulnerable to these changing markets and variable prices, whereas females may have been better protected in their family homes. The slight changes in $\delta^{13}C$ and $\delta^{15}N$ likely suggest that males were consuming enough calories, but not enough protein to meet their biological needs. Thus, during periods of food shortages and increased prices, young men may have turned to lower cost items that resulted in lower protein consumption. However, we must be cautious with this interpretation as the differences in the current dataset are small (<1‰ difference in $\delta^{15}N$) and cannot be considered conclusive.

While adolescence is often a period of social change, we must also consider that adolescence encompasses biological changes. Thus, a diet that failed to meet protein needs for the two males between 14 and 16 years of age may be influenced by puberty. Puberty is a period of rapid growth and development, characterized by the development of secondary sexual characteristics and the pubertal growth spurt (Sadler, 2017). During Peak Height Velocity (PHV), modern adolescents experience an average height increase of approximately 9 cm/year for girls and 13 cm/year for boys, as well as soft tissue changes and changes to circadian rhythm patterns (Anderson, 2020: 75). Along with these rapid biological changes, energy requirements increase, and those who do not meet their nutritional requirements during this period of development, risk delayed or stunted growth, or even "protein-energy malnutrition" (Anderson, 2020: 75).

Aristotelian writings and writings in the Hippocratic corpus (4th century BCE) place spermatogenesis and the breaking of the male voice at 14 and 15 years of age, respectively, features now associated with PHV (Eyben, 1972; Amundsen & Diers, 1969). While these literary sources pre-date those living at *Portus*, bioarchaeological analysis of osteological indicators for pubertal stage at death, based on the methods proposed by Shapland and Lewis (2013, 2014) also suggest that males buried at *Isola Sacra* experienced PHV at 15.0 ± 1.1 years of age (Avery *et al.*, forthcoming), coinciding with the changing stable isotope values. The possible evidence of protein insufficiency in the current sample may therefore be caused by the increased nutritional requirements during puberty rather than a specific change in diet. Females buried at *Isola Sacra* would also be experiencing puberty around this age, as bioarchaeological analysis of the *Isola Sacra* samples indicates that females entered puberty at 11.0 ± 1.7 years, and experienced menarche at an average age of 15.8 ± 2.4 years (Avery *et al.*, forthcoming). Yet, the isotopic results in the current study do not demonstrate the same pattern of an increase in $\delta^{15}N$ and concurrent decrease in $\delta^{13}C$ for females, suggesting that these females did not experience protein-deficiency to the same extent.

These sex-specific patterns may be due to sex-specific hormones released during puberty. Specifically, testosterone released in males facilitates an increase in lean body mass and concurrent decreased in percent body fat during puberty, while increased estrogen and progesterone in females leads to the preferential deposition of body fat rather than lean body mass (Anderson, 2020). As a result, females store body fat more efficiently than males, even when males consume more calories than females (O'Sullivan, 2009). The physical changes during puberty also increase energy and nutritional demand, with males needing higher protein, zinc and calcium than females (Anderson, 2020). Thus, it may be that the two males exhibiting stable isotope patterns consistent with protein-insufficiency or other stressors at *Isola Sacra* (SCR0563 and SCR5079) did not change their diet, but that their biological requirements changed due to puberty. The lack of protein-insufficiency seen in females, therefore, may be interpreted as the result of sex-specific hormones released as part of puberty (or that they were eating a different diet). As the differences are small, this interpretation is perhaps the most likely, although additional research may help elucidate the causes of these stable isotope changes. For example, examining amino acids to help identify cases of nutritional stress and disruptions in protein consumption, or paleopathological analyses may provide insights into nutritional deficiencies or other disease processes, although we acknowledge that not all disease conditions will result in skeletal manifestations (Reitsema & Holder, 2018).

CONCLUSIONS

When returning to our first hypothesis, the stable isotope analysis of incremental dentine of individuals buried at *Isola Sacra* point to sex-specific patterns of dietary intake as young as 4.5 years of age, suggesting that boys and girls likely consumed different diets during childhood. Different correlations between stable isotope values and age also suggest different patterns of change as males and females aged, with females exhibiting positive correlation between age and $\delta^{15}N$, while males exhibit no statistically significant correlations.

Ultimately, this research was unable to identify the emergence of gendered or sex-based diets based on the analysis of second and third molars. Future research should re-examine weaning patterns in the *Isola Sacra* sample by incorporating peptide analysis (e.g., Stewart *et al.*, 2017) to more confidently assess biological sex, and determine if experiences of weaning were also sex-specific, or if gendered treatments began after the weaning period in this Roman Imperial sample. Future research should also continue to expand the life course, by incorporating third molars into stable isotope analyses, to investigate dietary intake and change into early adulthood. By investigating dietary change in late teens/early twenties, researchers may be able to explore the transition from *adulescentia* to adulthood, including changes around the time of marriage, to further understand changing gendered roles.

In relation to our second hypothesis, the statistical correlations and longitudinal stable isotope data suggest that dietary change occurred gradually between 4.5 and 23.5 years of age in this small sample from *Isola Sacra*, through the incorporation of higher trophic levels foods and/or marine resources, possibly reflecting the gradual social age changes these individuals were experiencing at these ages. For females, the gradual but subtle change in diet for six individuals points to an extended transitional period as proposed by historians, rather than a sudden change from childhood to adulthood suggested by literary sources. However, we must consider that social age changes for women may not have encompassed dietary changes, as they had greater control over food production and consumption, and additional research is needed to further consider social age changes at this site using methods beyond stable isotopes.

For males, no clear dietary pattern emerged across the time period under consideration, however, the subtle increase in $\delta^{15}N$ and concurrent decrease in $\delta^{13}C$ for SCR0563 and SCR5079 may indicate a protein-deficient diet between 14 and 16 years of age. While the changes in $\delta^{13}C$ and $\delta^{15}N$ were small (<1‰) and based on two individuals, they may reflect changing social roles, changing patterns of food (in)security, or the result of unmet protein needs during pubertal development. Additional studies are needed to explore this pattern further, and better understand the impact of puberty on dietary stable isotope values.

Ultimately, this research contributes to a growing discussion related to gendered experiences during childhood and adolescence for individuals buried at *Isola Sacra*, although additional research is needed to explore whether these patterns are unique, or part of a larger trend during the Roman Empire. By using incremental analysis of dentine sections, this study also emphasizes the utility of examining markers of childhood and adolescence captured in adult skeletal remains, to circumvent issues related to inaccurate sex estimation methods, poor preservation of the burial environment, and demonstrates the value of examining diet in a longitudinal fashion to identify dietary changes over the life course.

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SUPPLEMENTARY DATA

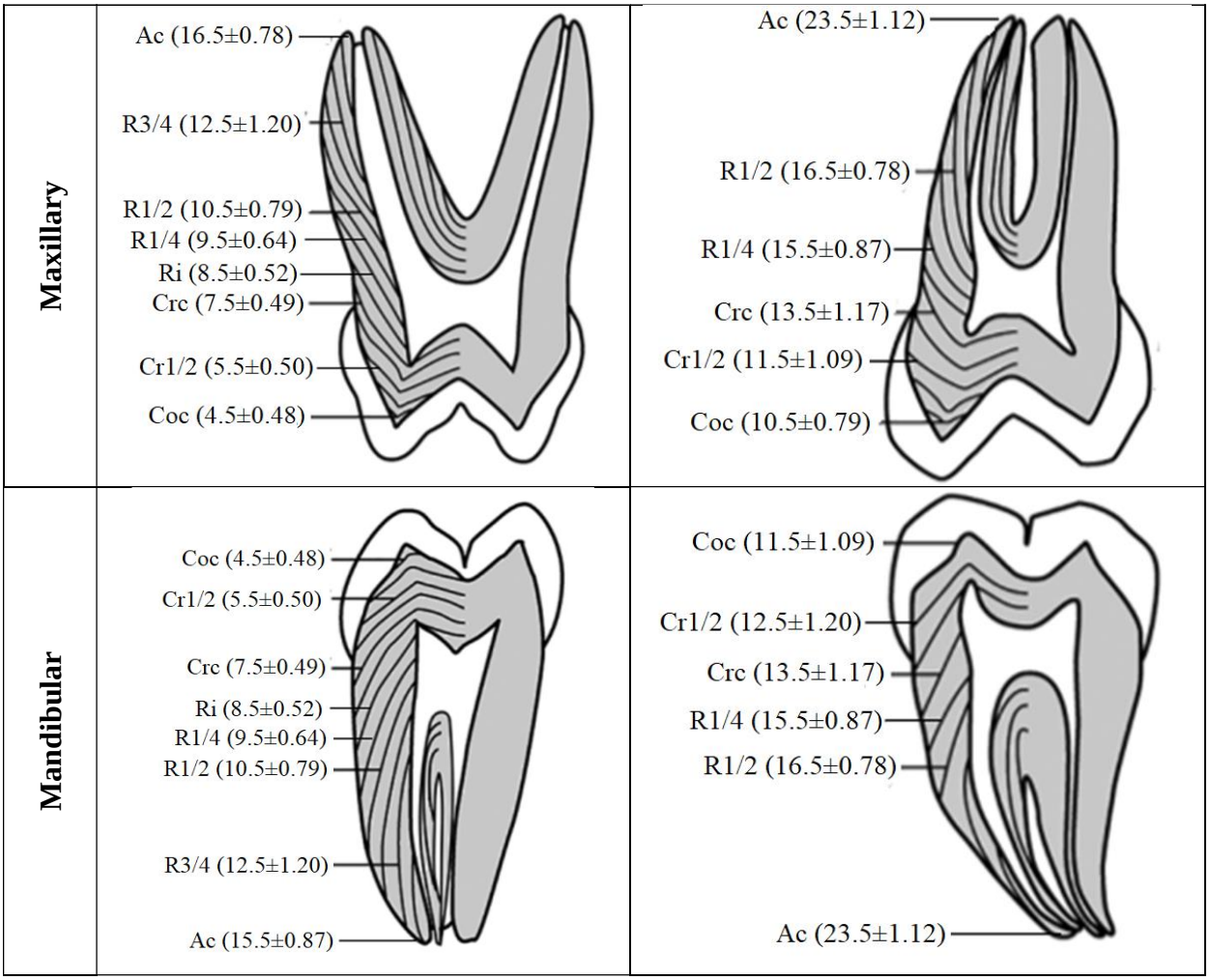

Figure 4-7 (Supplementary Figure): Schematics identifying oblique cuts corresponding to dentine lines, and corresponding developmental ages. Schematics adapted from Brickley et al. (2019). Ages and terminology of landmarks derived from the London Tooth Atlas (AlQahtani et al., 2010; 2014; Liversidge et al., 2020) .Coc = coalescence of cusps; Cr1/2 = crown half completed; Crc = crown completed with defined pulp root; Ri = initial root formation with diverging edges; R1/4 = root length less than crown length; R1/2 = root length equals crown length; R3/4 = root length more than crown length with diverging ends; Ac = apex closed with normal periodontal ligament width.

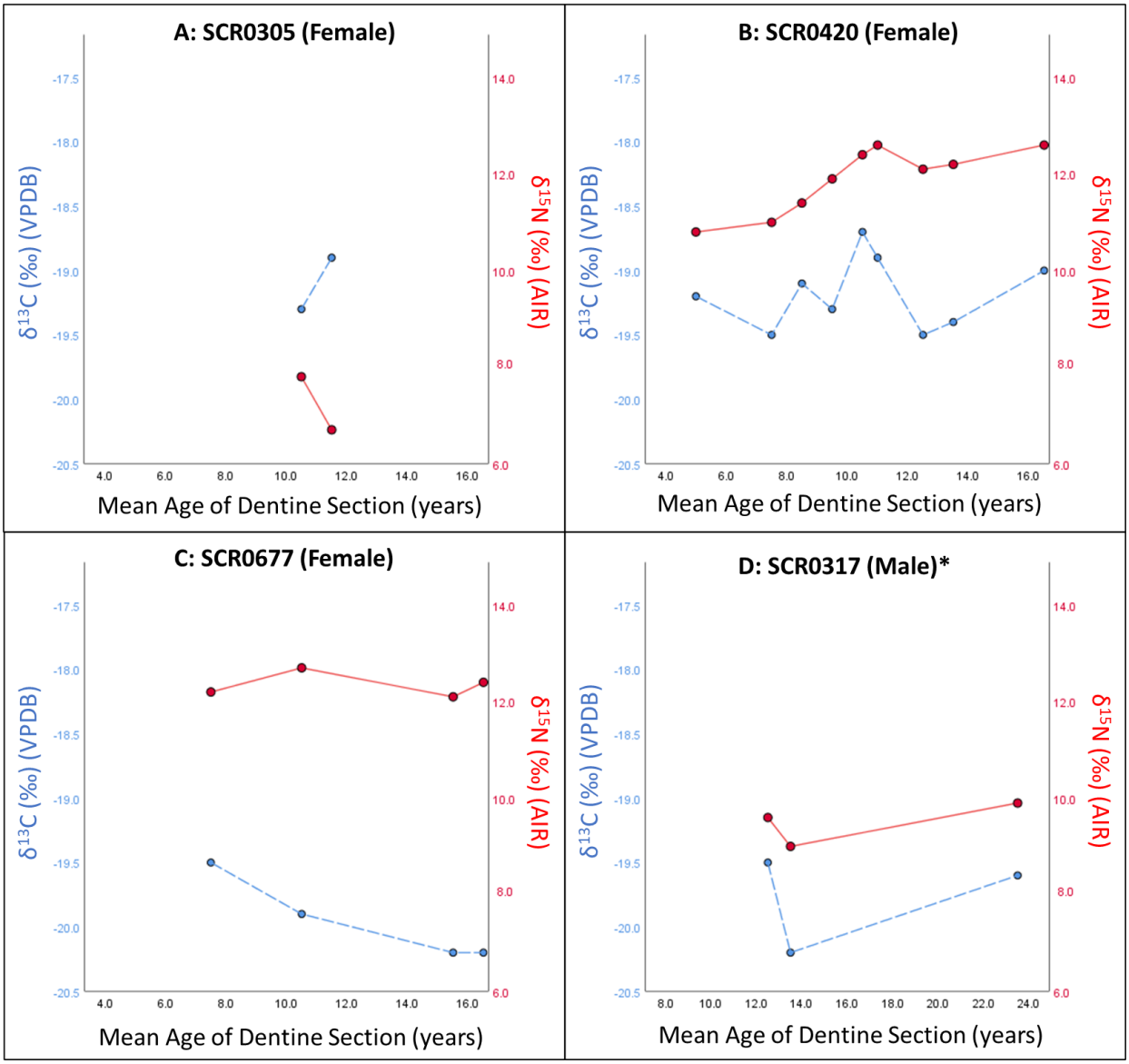

Figure 4-8 (Supplementary Figure): Longitudinal isotopic profiles of dentine sections by individual for stable carbon (dotted blue lines) and stable nitrogen (solid red lines) isotope values. Each dot represents a dentine section from the M2 or M3. Asterik (*) indicates different age scale used, to capture last dentine section. Data for SCR5034 (male) not shown, as it includes a single data point.

Table 4-4 (Supplementary table): Assumptions of normality tests including skewness and kurtosis values, and Shapiro-Wilk's test by sex and stable isotope.

Independent Variable	Dependent Variable	Skewness (SE)	Kurtosis (SE)	Shapiro-Wilk's Test
Males	$\delta^{13}C$	-.447 (SE= .481)	-.129 (SE= .935)	W(23)=.968, p=.642
Females	$\delta^{13}C$	.312 (SE= .434)	.302 (SE= .845)	W(29)=.961, p=.349
Sexes Combined	$\delta^{13}C$	.161 (SE=.330)	.546 (SE=.650)	W(52)=.968, p=.167
Males	$\delta^{15}N$	-1.437 (SE= .481)	2.074 (SE= .935)	W(23)=.848, p=.002
Females	$\delta^{15}N$	-.896 (SE= .434)	-.507 (SE= .845)	W(29)=.855, p<.001
Sexes Combined	$\delta^{15}N$	-1.336 (SE=.330)	.891 (SE=.650)	W(52)=.835, p<.001

SE = Standard error. Data is considered normally distributed when the skewness and kurtosis values divided by their standard errors is between -1.96 and 1.96, and when p>.05 for the Shapiro-Wilk's test; in these instances, parametric tests are used. Data is considered not normally distributed when skewness and kurtosis values divided by their standard errors is less than -1.96 or greater than 1.96, and when p<.05 for Shapiro-Wilk's test; in these instances, non-parametric tests are used.

Table 4-5 (Supplementary table): Burial number, osteological sex and tooth sampled, along with London Atlas development stage and mean age of corresponding dentine section(s) ± 1SD, collagen weight (mg), $\delta^{13}C_{vpdb}$ and $\delta^{15}N_{air}$ values, and sample integrity measures (%wt C, %wt N, C:N ratio, and % collagen yield), and if the sample was excluded from analysis.

Burial	Sex	Tooth	London Tooth Atlas	Age Mean ± 1 SD	Collagen (mg)	$\delta^{13}C_{vpbd}$	$\delta^{15}N_{air}$	%wt C	%wt N	C:N Ratio	%Coll yield	Exc.
SCR0052	F	MaxLM2	Coc	4.5 ± 0.48	3.3	-19.56	10.55	42.80	14.91	3.35	5.45	
			Cr1/2	5.5 ± 0.50	4.8	-19.72	10.43	43.70	14.90	3.42		
			Crc	7.5 ± 0.49	5.5	-19.52	10.35	37.10	13.19	3.28		
			Ri & R1/4	9.0 ± 1.00	1.6	-21.33	10.21	44.60	12.76	4.08		*
			R1/2	10.5 ± 0.79	5.8	-19.53	10.60	43.90	15.00	3.41		
			R3/4	12.5 ± 1.20	3.6	-20.06	10.51	44.20	14.08	3.66		*
			Ac	16.5 ± 0.78	0.5	-	-	-	-	-		+
		MaxLM3	Coc	10.5 ± 0.79	5.7	-19.86	10.72	44.00	14.51	3.54	4.87	
			Cr1/2	11.5 ± 1.09	4.5	-18.96	10.85	42.90	15.50	3.23		
			Crc	13.5 ±1.17	6.0	-19.40	11.36	44.40	15.40	3.36		
			R1/4	15.5 ± 0.87	9.0	-18.98	11.92	44.20	15.30	3.37		
			R1/2	16.5 ± 0.78	4.4	-20.95	11.80	45.10	12.74	4.13		*
			Ac	23.5 ± 1.12	0.0	-	-	-	-	-		NP
SCR0100	M	ManLM2	All	All	1.7	-26.27	8.13	53.00	6.94	8.91	0.55	*
		ManLM3	All	All	0.3	-	-	-	-	-	0.14	+*
SCR0305	F	MaxRM2	Coc to Crc	6.0 ± 2.00	0.9	-	-	-	-	-	0.00	+*
			Ri-Ac	8.5 ± 0.52	0.0	-	-	-	-	-		DND
		MaxRM3	Coc	10.5 ± 0.79	2.2	-19.28	7.77	43.00	15.10	3.32	2.57	
			Cr1/2	11.5 ± 1.09	3.3	-18.85	6.70	42.50	15.00	3.30		
			Crc	13.5 ± 1.17	2.2	-22.77	7.09	45.00	11.05	4.75		*
			R1/4, R1/2	16.0 ± 1.50	1.6	-24.17	8.12	48.10	9.73	5.76		*
			Ac	23.5 ± 1.12	0.0	-	-	-	-	-		NP
SCR0317	M	ManRM2	Coc to Crc	6.0 ± 2.00	2.8	-20.70	9.81	44.20	13.04	3.95	2.28	*
			Ri to R1/2	9.5 ± 1.50	4.7	-21.31	9.98	45.60	12.69	4.19		*
			R3/4, Ac	14.0 ± 2.50	0.2	-	-	-	-	-		+
		ManRM3	Coc	11.5 ± 1.09	2.0	-21.83	9.94	41.10	11.31	4.24	2.40	*

			Cr1/2	12.5 ± 1.20	1.4	-19.54	9.61	40.00	13.78	3.39		
			Crc	13.5 ±1.17	2.6	-20.18	9.02	40.60	13.38	3.54		
			R1/4	15.5 ± 0.87	2.2	-20.83	9.27	41.60	12.80	3.79		*
			R1/2	16.5 ± 0.78	2.2	-20.24	9.30	39.80	12.82	3.62		*
			Ac	23.5 ± 1.12	5.3	-19.60	9.94	39.00	13.38	3.40		
SCR0420	F	MaxRM2	Coc, Cr1/2	5.0 ± 1.00	2.8	-19.22	10.80	40.70	14.46	3.28		
			Crc	7.5 ± 0.49	2.7	-19.46	11.04	41.70	14.10	3.45		
			Ri	8.5 ± 0.52	5.5	-19.10	11.36	42.30	14.70	3.36		
			R1/4	9.5 ± 0.64	4.5	-19.30	11.86	40.90	13.95	3.42	4.65	
			R1/2	10.5 ± 0.79	2.3	-18.65	12.35	37.40	13.38	3.26		
			R3/4	12.5 ± 1.20	2.0	-19.46	12.13	41.30	13.60	3.54		
			Ac	16.5 ± 0.78	3.6	-19.00	12.58	40.60	13.96	3.39		
		MaxRM3	Coc	10.5 ± 0.79	0.0	-	-	-	-	-		NP
			Cr1/2	11.5 ± 1.09	2.3	-18.88	12.57	42.00	14.87	3.29		
			Crc	13.5 ± 1.17	2.0	-19.44	12.21	36.80	12.07	3.56		
			R1/4	15.5 ± 0.87	3.5	-21.56	11.60	32.10	8.70	4.30	2.39	*
			R1/2	16.5 ± 0.78	0.0	-	-	-	-	-		NP
			Ac	23.5 ± 1.12	0.0	-	-	-	-	-		NP
SCR0563	M	ManLM2	Coc	4.5 ± 0.48	3.7	-19.23	12.04	41.40	14.61	3.30		
			Cr1/2	5.5 ± 0.50	3.3	-19.10	11.59	41.80	14.75	3.30		
			Crc	7.5 ± 0.49	3.9	-19.37	11.43	41.80	14.21	3.43		
			Ri	8.5 ± 0.52	6.2	-19.47	11.72	41.90	13.91	3.51	6.13	
			R1/4	9.5 ± 0.64	4.2	-19.39	12.20	42.40	14.15	3.49		
			R1/2	10.5 ± 0.79	5.9	-21.08	11.66	44.30	12.35	4.18		*
			R3/4, Ac	14.0 ± 2.50	0.5	-	-	-	-	-		+
		ManLM3	Coc	11.5 ± 1.09	2.4	-19.22	12.73	38.40	13.25	3.38		
			Cr1/2	12.5 ± 1.20	6.2	-18.93	12.86	39.40	13.85	3.32		
			Crc	13.5 ±1.17	10.3	-18.97	12.61	42.10	14.75	3.33		
			R1/4	15.5 ± 0.87	7.7	-19.12	12.78	41.00	14.35	3.33	5.36	
			R1/2	16.5 ± 0.78	0.0	-	-	-	-	-		NP
			Ac	23.5 ± 1.12	0.0	-	-	-	-	-		NP

SCR0677	F	MaxLM2	Coc	4.5 ± 0.48	0.0	-	-	-	-	-		NP
			Cr1/2	5.5 ± 0.50	0.0	-	-	-	-	-		NP
			Crc	7.5 ± 0.49	2.2	-19.47	12.21	40.40	14.31	3.29		
			Ri	8.5 ± 0.52	3.1	-20.79	11.57	42.70	12.81	3.89	2.92	*
			R1/4	9.5 ± 0.64	2.4	-20.23	11.81	41.90	13.26	3.68		*
			R1/2	10.5 ± 0.79	0.5	-	-	-	-	-		+
			R3/4	12.5 ± 1.20	0.7	-	-	-	-	-		+
			Ac	16.5 ± 0.78	0.1	-	-	-	-	-		+
		MaxLM3	Coc	10.5 ± 0.79	2.9	-19.94	12.70	41.50	13.77	3.51		
			Cr1/2	11.5 ± 1.09	2.2	-21.02	12.08	40.50	11.94	3.96		*
			Crc	13.5 ±1.17	2.0	-22.26	11.45	42.40	11.07	4.47		*
			R1/4	15.5 ± 0.87	5.0	-20.17	12.09	39.70	12.99	3.56	2.94	
			R1/2	16.5 ± 0.78	0.0	-	-	-	-	-		+
			Ac	23.5 ± 1.12	2.1	-20.15	12.41	40.90	13.25	3.60		
SCR5033	F	ManLM2	Coc	4.5 ± 0.48	0.5	-	-	-	-	-		+
			Cr1/2	5.5 ± 0.50	2.5	-18.62	7.51	39.10	13.36	3.41		
			Crc	7.5 ± 0.49	2.4	-17.89	7.57	39.10	14.13	3.23	3.71	
			Ri	8.5 ± 0.52	2.4	-18.53	7.82	35.10	12.35	3.31		
			R1/4 to Ac	12.5 ± 3.50	1.5	-20.24	7.55	37.10	12.03	3.60		
		ManLM3	Coc	11.5 ± 1.09	0.0	-	-	-	-	-		NP
			Cr1/2	12.5 ± 1.20	0.0	-	-	-	-	-		NP
			Crc	13.5 ±1.17	1.4	-20.16	9.03	40.60	13.20	3.59	3.33	
			R1/4	15.5 ± 0.87	2.4	-19.02	11.48	40.20	13.94	3.36		
			R1/2	16.5 ± 0.78	0.7	-	-	-	-	-		+
			Ac	23.5 ± 1.12	0.0	-	-	-	-	-		NP
SCR5034	F	MaxLM2	All	All	1.9	-22.05	11.23	42.40	11.02	4.49	0.40	*
		MaxLM3	Coc	10.5 ± 0.79	2.1	-20.79	12.11	40.50	12.34	3.83		*
			Cr1/2	11.5 ± 1.09	2.5	-19.66	12.25	40.10	13.38	3.50		
			Crc, R1/4	14.5 ± 2.00	1.8	-21.85	11.20	43.20	11.36	4.43	1.69	*
			R1/2	16.5 ± 0.78	0.2	-	-	-	-	-		+
			Ac	23.5 ± 1.12	0.0	-	-	-	-	-		NP

SCR5079	M	MaxLM2	Coc	4.5 ± 0.48	1.9	-19.12	12.07	41.90	14.71	3.32	3.44	
			Cr1/2	5.5 ± 0.50	4.0	-19.56	11.30	42.90	14.64	3.42		
			Crc	7.5 ± 0.49	3.1	-19.88	11.28	43.10	14.28	3.52		
			Ri	8.5 ± 0.52	4.2	-19.22	11.58	42.30	14.50	3.40		
			R1/4, R1/2	10.0 ± 1.50	3.3	-19.60	11.66	42.80	14.00	3.57		
			R3/4, Ac	14.5 ± 3.00	1.7	-20.45	11.71	43.20	12.89	3.91		*
		MaxLM3	Coc	10.5 ± 0.79	1.5	-18.73	11.75	39.10	14.03	3.25	5.75	
			Cr1/2	11.5 ± 1.09	7.0	-18.79	11.88	42.10	15.10	3.25		
			Crc	13.5 ±1.17	5.8	-18.97	11.65	42.60	15.00	3.31		
			R1/4	15.5 ± 0.87	7.0	-18.99	11.84	41.40	14.59	3.31		
			R1/2	16.5 ± 0.78	2.4	-19.72	12.07	40.30	13.39	3.51		
			Ac	23.5 ± 1.12	0.7	-	-	-	-	-		+

Sex: F = female, M = male. Tooth: Max = maxillary, Man = mandibular, L = left, R = right, M2 = second molar, M3 = third molar. London Atlas development stage derived from AlQahtani *et al.*, (2010, 2014) and Liversidge *et al.* (2020): Coc – cusp outline complete; Cr1/2 – crown half completed; Cr3/4 – crown three quarters completed; Crc – crown completed with defined pulp root; Ri – initial root formation with diverge edges; R1/4 – root length less than crown length with visible bifurcation area; R1/2 – root length equals crown length; R3/4 – three quarters of root length developed with divergent edges; Ac – apex closed with normal PDL width. Exc = excluded samples. Plus sign (+) indicates samples whose collagen was too small to send for mass spectrometry and were not analyzed; asterisk (*) indicates samples that failed measures of sample integrity and were excluded from statistical analysis. NP = not present (worn, damaged); DND = did not demineralize. All blanks in the "Exc" column indicates sections that were included in the current study.

REFERENCES

Acsádi, G., & Nemeskéri, J. (1970). *History of human life span and mortality*. Akademiai Kiado.

AlQahtani, S. J., Hector, M. P., & Liversidge, H. M. (2010). Brief communication: The London Atlas of human tooth development and eruption. *American Journal of Physical Anthropology* 142(3): 481-490. https://doi.org/10.1002/ajpa.21258.

AlQahtani, S.J., Hector, M. P., & Liversidge, H. M. (2014). Accuracy of dental age estimation charts: Schour and Massler, Ubelaker, and the London Atlas. *American Journal of Physical Anthropology* 154(1): 70-78. https://doi.org/10.1002/ajpa.22473.

Ambrose, S. (1993). Isotopic analysis of paleodiet: methodological and interpretive considerations. In: J. B. Edward, & R. A. Benfer (Eds.), *Investigations of ancient human tissue: Chemical analyses in anthropology* (pp.59-130). Gordon and Breach Science Pub.

Amundsen, D. W., & Diers, C. J. (1969). The age of menarche in Classical Greece and Rome. *Human Biology* 41(1): 125-132. https://www.jstor.org/stable/41448952.

Anderson, H. (2020). Developmental nutrition. In Y. N. Evans & A. D. Doctor AD (Eds.) *Adolescent nutrition* (pp. 69-102). Springer Nature. https://doi.org/10.1007/978-3-030-45103-5_4.

Arthur, N. A., Gowland, R., & Redfern, R. (2016). Coming of age in Roman Britain: Osteological evidence for pubertal timing. *American Journal of Physical Anthropology* 159(4): 698-713. https://doi.org/10.1002/ajpa.22929.

Avery, L. C., Brickley, M. B., Findlay, S., Chapelain de Seréville-Niel, C., & Prowse, T. L. (2021). Child and adolescent diet in Late Roman Gaul: An investigation of incremental dietary stable isotopes in tooth dentine. *International Journal of Osteoarchaeology* 31(6): 1226-1236. https://doi.org/10.1002/oa.3033.

Avery, L. C., Prowse, T. L., Findlay, S., Chapelain de Seréville-Niel, C., Bondioli, L., Sperduti, A., & Brickley, M. B. (In preparation). Pubertal timing as a measure of early life stress in Roman Italy and Roman Gaul. Manuscript in preparation for submission to the *American Journal of Physical Anthropology*.

Beaumont, J., Montgomery, J., Buckberry, J., & Jay, M. (2015). Infant mortality and isotopic complexity: New approaches to stress, maternal health, and weaning. *American Journal of Physical Anthropology*, 157(3): 441-457. https://doi.org/10.1002/ajpa.22736.

Beaumont, J., & Montgomery, J. (2016). The great Irish famine: Identifying starvation in the tissues of victims using stable isotope analysis of bone and incremental dentine collagen. *PLOS One* 11:e0160065. https://doi.org/10.1371/journal.pone.0160065.

Bondioli, L., Nava, A., Rossi, P. F., & Sperduti, A. (2018). Lo studio antropologico delle sepolture di Larcius Felix ed Onesime. In M. Cébeillac-Gervasoni, N Laubry, F Zevi (Eds.). *Ricerche su Ostia e il suo territorito. Atti del Terzo Seminario Ostiense* (pp. 363-373). Collection de l'école française de Rome.

Bradley, K. R. (1991). *Discovering the Roman family*. Oxford University Press.

Brickley, M.B., Kahlon, B., & D'Ortenzio, L. (2019). Using teeth as tools: Investigating the mother-infant dyad and developmental origins of health and disease hypothesis using vitamin D deficiency. *American Journal of Physical Anthropology* 171(2): 342-353. https://doi.org/10.1002/ajpa.23947.

Brooks, S., & Suchey, J. (1990). Skeletal age determination based on the os pubis: A comparison of the Acsadi-Nemeskeri and Suchey-Brooks Methods. *Human Evolution* 5: 227-238. https://doi.org/10.1007/BF02437238.

Bruun, C. (2016). Tracing familial mobility: Female and child migrants in the Roman West. In: De Ligt L, Tacoma LE (Eds.), *Migration and mobility in the early Roman Empire*. Brill. Pp. 176-204.

Caldwell, L. (2015). *Roman girlhood and the fashioning of femininity*. Cambridge University Press.

Calza, G., & Becatti, G. (2008). *Ostia: Itineraries of the museums, galleries and monuments in Italy*. Instituto Poligrafico e Zecca Dello Stato S.P.A.

Cardoso, H. (2008a). Epiphyseal union at the innominate and lower limb in a modern Portuguese skeletal sample, and age estimation in adolescent and young adult male and female skeletons. *American Journal of Physical Anthropology* 135(2):161-170. https://doi.org/10.1002/ajpa.20717.

Cardoso, H. (2008b). Age estimation of adolescent and young adult male and female skeletons II, Epiphyseal union at the upper limb and scapular girdle in a modern Portuguese skeletal sample. *American Journal of Physical Anthropology* 137(1):97-105. https://doi.org/10.1002/ajpa.20850.

Cho, H., & Stout, S. D. (2003). Bone remodeling and age-associated bone loss in the past: A histomorphometric analysis of the Imperial Roman skeletal population of Isola Sacra. In Agarwal SC, Stout SD (Eds.). *Bone Loss and Osteoporosis: An Anthropological Perspective* (pp. 207-228). Kluwer Academic.

Craig, O. E., Biazzo, M., O'Connell, T. C., Garnsey, P., Martinez-Labarga, C., Lelli, R., Salvadei, L., Tartaglia, G., Nava, A., Reno, L., Fiammenghi, A., Rickards, O., & Bondioli, L. (2009). Stable isotope evidence for diet at the Imperial Roman coastal site of Velia (1st and 2nd centuries AD) in southern Italy. *American Journal of Physical Anthropology* 139(4): 572-583. https://doi.org/10.1002/ajpa.21021.

Crowe, F., Sperduti, A., O'Connell, T. C., Craig, O. E., Kirsanow, K., Germoni, P., Macchiarelli, R., Garnsey, P., & Bondioli, L. (2010). Water-related occupations and diet in two Roman coastal communities (Italy, first to third century AD): Correlation between stable carbon and nitrogen isotope values and auricular exostosis prevalence. *American Journal of Physical Anthropology* 142(3): 355-366. https://doi.org/10.1002/ajpa.21229.

DeNiro, M. J. (1985). Post-mortem preservation and alteration of in vivo bone collagen isotope ratios in relation to palaeodietary reconstruction. *Nature* 317:806–809. https://doi.org/10.1038/317806a0.

Dixon, S. (1992). *The Roman family*. The John Hopkins University Press.

Eerkens, K. W., Berget, A. G., & Bartelink, E. J. (2011). Estimating weaning and early childhood diet from serial micro-samples of dentin collagen. *Journal of Archaeological Science* 38(11): 3101-3111. https://doi.org/10.1016/j.jas.2011.07.010.

Erdkamp, P. (2015). Supplying cities. In J Wilkins, R Nadeau (Eds.). *A Companion to Food in the Ancient World.* Wiley Blackwell. P183-192.

Eyben, E. (1972). Antiquity's view of puberty. *Latomus* 31(3): 677-697. https://www.jstor.org/stable/41529266.

Eyben, E. (1993). *Restless youth in ancient Rome*. Routledge.

France, C., Giaccai, J., & Cano, N. (2011). The effect of PVAc treatment and organic solvent removal of $\delta^{13}C$, $\delta^{15}N$, and $\delta^{18}O$ values of collagen and hydroxyapatite in a modern bone. *Journal of Archaeological Science* 38(12): 3387-3393. https://doi.org/10.1016/j.jas.2011.07.024.

Fraschetti, A. (1997). Roman youth. In G. Levi, & J. C. Schmitt (Eds.). *A history of young people in the West* (pp. 51-82). The Belknap Press of Harvard University Press.

Garnsey, P. D. A. (1999). *Food and society in classical antiquity.* Cambridge University Press.

Germoni, P., Millett, M., Keay, S., Reynolds, J., & Strutt, K. (2011). The Isola Sacra: Reconstructing the Roman landscape. In S. Keay & L. Paroli (Eds.), *Portus and its Hinterlands: Recent Archaeological Research* (pp. 231-260). The British School at Rome.

Grubbs, J. E. (2002). *Women and the law in the Roman Empire*. Routledge.

Gustafson, G., & Koch, G. (1974). Age estimation up to 16 years of age based on dental development. *Odontologisk Revy* 25(3): 297-306.

Harlow, M., & Laurence, R. (2002). *Growing up and growing old in ancient Rome.* Routledge.

Hermansen, G. (1981). *Ostia: Aspects of Roman city life*. The University of Alberta Press.

Holleran, C. (2016). Labour mobility in the Roman world: A case study of mines in Iberia. In: L De Ligt, LE Tacoma (Eds.). *Migration and mobility in the early Roman Empire.* Brill. P95-137.

Hoover, K. C., Corruccini, R. S., Bondioli, L., & Macchiarelli, R. (2005). Exploring the relationship between hypoplasia and odontometric asymmetry in Isola Sacra, an Imperial Roman necropolis. *American Journal of Human Biology* 17(6): 752-764. https://doi.org/10.1002/ajhb.20436.

Joyce, R. A. (2017). Sex, gender and anthropology: Moving bioarchaeology outside the subdiscipline. In S. C. Agarwal, & J. K. Wesp (Eds.), *Exploring sex and gender in bioarchaeology* (pp. 1-14). University of New Mexico Press

Katz, D., & Suchey, J. (1986). Age determination of the male os pubis. *American Journal of Physical Anthropology* 69(4): 427-435. https://doi.org/10.1002/ajpa.1330690402.

Kaur, A., & Kumar, R. (2015). Comparative analysis of parametric and non-parametric tests. *Journal of Computer and Mathematical Sciences* 6(6): 336-342.

Keay, S., Millett, M., & Patterson, H. (2005). Introduction. In: S. Keay, M. Millett, L. Paroli, & K. Strutt. (Eds.), *Portus: An archaeological survey of the port of Imperial Rome* (pp. 1-9). The British School at Rome.

Keay, S., & Millett, M. (2005). Portus in context. In S. Keay, M. Millett, L. Paroli, & K Strutt (Eds.), *Portus: An archaeological survey of the port of Imperial Rome* (pp. 297-314). The British School at Rome.

Laes, C. (2019). Women, children and food. In P. Erdkamp, & C. Holeran (Eds.), *The Routledge handbook of diet and nutrition in the Roman world* (pp177-187). Routledge Press.

Laes, C., & Strubbe, J. (2014). *Youth in the Roman Empire: The young and the restless years?* Cambridge University Press.

Laurence, R. (2000). Metaphors, monuments, and texts: The life course in Roman culture. *World Archaeology* 31(3): 442-455. https://doi.org/10.1080/00438240009696931.

Lewis, M. E. (2018). Children in Bioarchaeology: methods and interpretations. In A. Katzenberg, & A. Grauer (Eds.), *Biological anthropology of the human skeleton* (pp. 119-143). Academic Press.

Liversidge, H. M., AlQahtani, S. J., & Hector, M. P. (2020). *Playback.* The London Atlas: Version 2. http://www.ibossolutions.com/qmul/v3/.

Manzi, G., Sperduti, A., & Passarello, P. (1991). Behavior-induced auditory exostoses in Imperial Roman society: Evidence from coeval urban and rural communities near Rome. *American Journal of Physical Anthropology* 85: 253-260.

Manzi, G., Salvadei, L., Vienna, A., & Passarello, P. (1999). Discontinuity of life conditions at the transition from Roman Imperial age to the early Middle Ages: Example from central Italy evaluated by pathological dento-alveolar lesions. *American Journal of Human Biology* 11(3): 327-341. https://doi.org/10.1002/(SICI)1520-6300(1999)11:3<327::AID-AJHB5>3.0CO;2-M.

Meiggs, R. (1973). *Roman Ostia*. Clarendon Press.

Milella, M., Gerling, C., Doppler, T., Kuhn, T., Cooper, M., Mariotti, V., Belcastro, M. G., Ponce de Leon, M. S., & Zollikofer, C. P. E. (2019). Different in diet: Different in life? Diet and mobility correlates of irregular burials in a Roman necropolis from Bologna (Northern Italy, 1st-4th century CE). *Journal of Archaeological Science: Reports* 27: 101926. https://doi.org/10.1016/j.jasrep.2019-101926.

Moore, A. J. (2009). *Young and old and Roman Britain: Aspects of age identity and life-course transitions in regional burial practice*. Doctoral Dissertation. University of Southampton. https://eprints.soton.ac.uk/360559/1/Young%2520and%2520Old%2520in%2520Roman%2520Britain.pdf

Nathan, G. (2021). Looking for children in Late Antiquity. In L. A. Beaumont, M. Dillon, & N. Harrington (Eds.), *Children in antiquity: Perspectives and experiences of childhood in the ancient Mediterranean* (pp. 134-149). Routledge Press.

O'Sullivan, A. J. (2009). Does oestrogen allow women to store fat more efficinetly? A biological advantage for fertility and gestation. *Obesity reviews* 10(2): 168-177. https://doi.org10.1111/j.1467-789X.2008.00539.x

Olivanti, P., & Spanu, M. (2018). Necropoli dell'Isola Sacra, scavo 1988-1989: Alcune riflessioni su occupazione degli spazi, cronologia delle sepolture, corredi. In Cébeillac-Gervasoni, N. Laubry, F. Zevi (Eds.), *Ricerche su Ostia e il suo territorio. Atti del Terzo Seminario Ostiense* (pp. 1-20). Collection de l'École française de Rome.

Phenice, T. W. (1969). A newly developed visual method of sexing the os pubis. *American Journal of Physical Anthropology* 30(2): 297-301. https://doi.org/10.1002/ajpa.1330300214.

Pilkington, N. (2013). Growing up Roman: Infant mortality and reproductive development. *Journal of Interdisciplinary History* 44(1): 1-35. https://doi.org/10.1162/JINH_a_00499.

Prowse, T. L., Schwarcz, H. P., Saunders, S., Macchiarelli, R., & Bondioli, L. (2004). Isotopic paleodiet studies of skeletons from the Imperial Roman-age cemetery of Isola Sacra, Rome, Italy. *Journal of Archaeological Science* 31(3): 259-272. https://doi.org/10.1016/j.jas.2003.08.008.

Prowse, T. L., Saunders, S. R., Schwarcz, H. P., Garnsey, P., Macchiarelli, R., & Bondioli, L. (2008). Isotopic and dental evidence for infant and young child feeding practices in an Imperial Roman skeletal sample. *American Journal of Physical Anthropology* 137(3): 294-308. https://doi.org/10.1002/ajpa.20870.

Prowse, T. L., Schwarcz, H. P., Garnsey, P., Knyf, M., Macchiarelli, R., & Bondioli, L. (2007). Isotopic evidence for age-related immigration to Imperial Rome. *American Journal of Physical Anthropology* 132(4): 510-519. https://doi.org/10.1002/ajpa.20541.

Prowse, T. L., Schwarcz, H. P., Saunders, S. R., Macchiarelli, R., & Bondioli, L. (2005). Isotopic evidence for age-related variation in diet from Isola Sacra, Italy. *American Journal of Physical Anthropology* 128(1): 2-13. https://doi.org.10.1002/ajpa.20094.

Rawson, B. (1966). Family life among the lower classes at Rome in the first two centuries of the Empire. *Classical Philology* 61(2): 71-83.

Rawson, B. (2003). *Children and childhood in Roman Italy*. Oxford University Press.

Reitsema, L. J. (2013). Beyond dietary reconstruction: Stable isotope applications to human physiology, health, and nutrition. *American Journal of Human Biology* 25(4): 445-456. https://doi.org/10.1002/ajhb.22398.

Reitsema, L. J., & Holder, S. (2018). Stable isotope analysis and the study of human stress, disease, and nutrition. *Bioarchaeology International* 2(2): 63-74. https://doi.org/10.5744/bi.2018.1018.

Revel, L. (2005). The Roman life course: A view from the inscriptions. *European Journal of Archaeology* 8(1): 43-63. https://doi.org/10.1177/1461957105058209.

Rissech, C., Pujol, A., Christie, N., Lloveras, L., Richards, M. P., & Fuller, B. T. (2016). Isotopic reconstruction of the human diet at the Roman site (1st-4th c. AD) of Carrer Ample 1, Barcelona, Spain. *Journal of Archaeological Science: Reports* 9: 366-374. https://doi.org/10.1016/j.jasrep.2016.08.020.

Sadler, K. (2017). Pubertal development. In M. A. Goldstein (Ed.), *The MassGeneral Hospital for Children adolescent medicine handbook* (pp. 19-26) Springer International Publishing. https://doi.org/10.1007/978-3-319-45778-9_3.

Saller, R. P. (1987). Men's age at marriage and its consequences in the Roman family. *Classical Philology* 82(1): 21-34.

Schwarcz, H. P., & Schoeninger, M. H. (1991). Stable isotope analyses in human nutritional ecology. *Yearbook of Physical Anthropology* 34(S13): 283-321. https://doi.org/10.1002/ajpa.1330340613.

Shapland, F., & Lewis M. E. (2013). Brief communication: A proposed osteological method for the estimation of pubertal stage in human skeletal remains. *American Journal of Physical Anthropology* 151(2): 302-310. https://doi.org/10.1002/ajpa/22268.

Shapland F., & Lewis, M. E. (2014). Brief communication: A proposed method for the assessment of pubertal stage in human skeletal remains using cervical vertebrae maturation. *American Journal of Physical Anthropology* 153(1): 144-153. https://doi.org/10.1002/ajpa.22416.

Shaw, B. D. (1987). The age of Roman girls at marriage: some reconsiderations. *The Journal of Roman Studies* 77: 30-46. https://doi.org/10.1017/S0075435800008492.

Soncin, S., Talbot, H. M., Fernandes, R., Harris, A., Von Tersch, M., Robson, H. K., Bakker, J. K., Richter, K. K., Alexander, M., & Craig, O. R. (2021). High-resolution dietary reconstruction of victims of the 79 CE Vesuvius eruption at Herculaneum by compound-specific isotope analysis. *Science Advances* 7(35): eabg5791. https://doi.org/10.1126/sciadv.abg5791.

Sperduti, A., Bondioli, L., & Garnsey, P. (2012). Skeletal evidence for occupational structure at the coastal towns of Portus and Velia (1st – 3rd c. AD). In I. Schrufer-Kolb (Ed.), *More than just numbers? The role of science in Roman archaeology* (pp. 53-70). Journal of Roman Archaeology Supplementary Series Number 91.

Stark, R. (2016). *Ancient lives in motion: A bioarchaeological examination of stable isotopes, nonmentric traits and human mobility in the Imperial Roman context (1st-3rd c. CE).* Unpublished Doctoral Dissertation. McMaster University, Hamilton, Canada. http://hdl.handle.net/11375/20937.

Stewart, N. A., Gerlach, R. F., Gowland, R., Gron, K., & Montgomery, J. (2017). Sex determination of human remains from peptides in tooth enamel. *Proceedings of the National Academy of Sciences of the United States of America* 114(52): 13649-13654. https://doi.org/10.1073/pnas.1714926115.

van Klinken, G. J. (1999). Bone collagen quality indicators for palaeodietary and radiocarbon measurements. *Journal of Archaeological Science* 26(6): 687–695. https://doi.org/10.1006/jasc.1998.0385.

Vuolanto, V. (2015). Children and work: Family strategies and socialization in Roman and Late Antique Egypt. In K. Mustakallio, & J. Hanska (Eds.), *Agents and objects: Children in Pre-Modern Europe* (pp. 97-112). Institutum Romanum Finlandiae.

Walter, B. S., DeWitte, S. N., Dupras, T., & Beaumont, J. (2020). Assessment of nutritional stress in famine burials using stable isotope analysis. *American Journal of Physical Anthropology* 172: 214-226. https://doi.org/10.1002/ajpa.24054.

Waters-Rist, A. L., & Katzenberg, M. A. (2010). The effect of growth on stable nitrogen isotope ratios in subadult bone collage. *International Journal of Osteoarchaeology* 20(2): 172-191. https://doi.org/10.1002/oa.1017.

White, K. (1976). Food requirement and food supplies in classical times. *Progress in Food & Nutrition* 2: 143-191.

CHAPTER 5: DISCUSSION AND CONCLUSION

UNCOVERING ROMAN *ADULESCENTIA*

Roman writers called the period between childhood and adulthood '*adulescentia*' and describe it as a period of exploration and learning, when young men were encouraged to drink heavily, visit brothels, and begin small business ventures (Eyben, 1993). However, these literary sources tend to focus on the experiences of wealthy, literate, men, and may not represent the experiences of middle- or lower-class individuals or women within the Roman Empire (Alberici & Harlow, 2007). Additionally, non-wealthy individuals tend to leave less visible traces in the archaeological record, as they are not routinely captured in great works of art, architecture, and other material objects (Dasen, 2021). Bioarchaeology is well suited to addressing this gap, by directly analyzing human remains, to learn more about embodied experiences of life in the past for individuals of all social strata. For the study of *adulescentia*, however, this has not yet been done, as the bioarchaeology of adolescence is a newly developing field of study. Bioarchaeologists would greatly benefit from a more conscious inclusion of adolescents into their studies, to learn about early childhood experiences, the transition between childhood and adulthood, and possible outcomes into adulthood.

The primary purpose of this thesis was to explore the period of *adulescentia* for two middle-class populations in the Roman Empire, using a biocultural approach, to better understand how this transitional period of the life course was experienced for both men and women. To accomplish this, my doctoral research had two objectives:

1. To correlate historical evidence for social age changes between childhood, adolescence, and adulthood for middle-class populations, with dietary evidence derived from stable isotopes of incremental tooth dentine sections.
2. To understand when the physical changes associated with puberty occurred in the Roman Imperial period for two middle-class populations from France and Italy, as determined through observed changes in the human skeleton.

THE SOCIAL CHANGES

To explore social age transitions in the Roman Empire and identify individuals who may have been socially considered to be in *pueritia* (childhood), *adulescentia* (adolescence) and *juventus* (young adulthood), I examined patterns of dietary intake and change. This approach was selected based on medical texts from the Greco-Roman period that recommend diets based, in part, on one's gender and age, with children, adults and the elderly consuming different diets (Garnsey, 1999). Previous isotopic studies of diet in Roman Italy (1-4th centuries CE) also indicate that children and adults consumed different foods, demonstrating the potential of using dietary change along with contextual evidence to interpret social age changes (Prowse *et al.,* 2005; Milella *et al.,* 2019). This approach also means I can circumvent many of the issues previously identified when

using the mortuary profile to investigate social age changes (see Chapter one), including unreliable sex estimations of pre-pubertal individuals, preservation and completeness of burial environments, and issues related to the Osteological Paradox. By incorporating incremental analysis of dentine sections from second and third molars, I investigate dietary changes as individuals age, allowing me to disentangle biological, chronological, and social ages. In doing so, I investigate how and when diet changed, and work to relate this to changes in social age across a spectrum of age, rather than using biological divisions commonly employed in biological anthropology that have little to no meaning to ancient Romans (see Halcrow & Tayles, 2008).

The results of my research on samples from Roman Gaul (Lisieux-Michelet) and Roman Italy (*Isola Sacra*) demonstrate that dietary change and, I argue, social age changes associated with *adulescentia,* were not experiences common to all, but rather took on different forms depending on one's social status, gender, location and/or time-period within the Roman Empire. Stable isotope analysis of incremental dentine sections from *Isola Sacra* (1^{st}-4^{th} centuries CE, Italy) suggests that males and females consumed slightly different diets as young as 4.5 years of age, during *infantia* (infancy, ~0-7) and *pueritia* (childhood, ~7-14). Between 14.5 and 16.5 years of age, some males may have consumed a protein-deficient diet, indicated by lower $\delta^{15}N$ values, likely due to their involvement in apprenticeships or other occupational activities outside the home as part of *adulescentia* among middle-class males (Chapter four). Females buried at *Isola Sacra*, however, did not exhibit these changes, and instead, stable isotope results suggest they experienced a gradual increase in $\delta^{13}C$ and $\delta^{15}N$ during the period of *adulescentia,* with no clear dividing point that could be interpreted as the start of *adulescentia* or a sudden transition to adulthood. However, rather than concluding that women did not experience a sudden shift in social age, we must consider that dietary change may not be an appropriate proxy for social age in this circumstance. According to Laes (2019), women in the Roman Empire were largely responsible for preparing foods and would have had greater control over their diets. Thus, even if they experienced a sudden social age transition, we may not be able to detect it using dietary stable isotopes. Other methods may be needed to further explore social age changes for women in the Roman Empire.

At the site of Lisieux-Michelet (4-5^{th} centuries CE, France), stable isotope results indicate that males and females consumed similar terrestrial-based diets between 4.5 and 15.5 years of age, (Chapter two). At 16.5 years of age, however, gendered diets emerged, with males exhibiting significantly lower $\delta^{15}N$ values than females, suggesting these young men were consuming less protein and/or lower trophic level proteins than women at this point. This dietary change closely corresponds to the beginning of *adulescentia*, where middle-class boys, like those buried at Lisieux-Michelet, would begin to take on adult roles by joining the military or beginning formal apprenticeships, likely at the military garrison or craft production centre at *Noviomagus Lexoviorum* (Paillard *et al.,* 2006). Young women, however, did not join the military nor begin apprenticeships. Instead, they likely stayed close to their natal homes, and continued preparing foods that were familiar to them. The isotopic results of this study support this interpretation, as the linear correlation for females demonstrates a subtle increase in both $\delta^{13}C$ and $\delta^{15}N$ with age, reflecting consistent and gradual incorporation of higher trophic level proteins as they aged.

These two studies show that diets, as inferred through dietary stable isotopes, changed as individuals aged, although the specific timing and patterns of change differed between the two archaeological sites. By using a biocultural approach and incorporating other lines of evidence, these changes are interpreted as the result of changing social roles for men and women within their respective communities. These different patterns may be related to geographical or temporal

contexts, as social age definitions and manifestations depend on the historical and cultural context of the sample (Kamp, 2001; Gowland, 2016; Halcrow & Tayles, 2008). The *Isola Sacra* necropolis is associated with *Portus Romae*, the main port servicing Rome during the Roman Imperial period. Due to their proximity to Rome, and continual access with the city, individuals living at *Portus* may have been aware of medical recommendations regarding age- and gender-specific diets or have been influenced by dietary practices in Rome (Alberici & Harlow, 2007). Use of the necropolis also largely predates Christian practices, as Christianity was officially recognized in 313 CE, with churches in nearby *Ostia* constructed in the later 4th century CE (Karivieri, 2020). Meanwhile, those buried at Lisieux-Michelet, associated with *Noviomagus Lexoviorum*, lived in Roman Gaul, during the Late Roman period (4-5th centuries CE), a period dominated by drastic social changes including the rise of Christianity and changes in the seat of power (Halsall, 2012; Wickham, 2005). Accordingly, those living at *Noviomagus* may have been more influenced by Christian doctrines and local foodways than earlier medical writers role in Rome. When analyzing age at marriage for women in the Roman world, Shaw (1987) found that, generally, women from Christian contexts married later than women from earlier 'pagan' contexts (i.e., prior to the 4th century CE). The stable isotope results in this thesis suggest that diets for males and females buried at Lisieux-Michelet changed up to two years later than individuals buried at *Isola Sacra*, possibly reflecting different patterns or timings of *adulescentia*. In tandem with the later age of marriage, this may suggest that those in Late Roman Gaul experienced a longer or delayed period of *adulescentia* compared to those in Roman Italy.

THE PHYSICAL CHANGES

My research works to address previously identified methodological limitations when using the pubertal timing methods summarized by Shapland and Lewis (2013, 2014), including issues of small sample sizes, unreliable non-adult sex estimation methods, and complications arising from comparisons between longitudinal and cross-sectional datasets (Arthur *et al.*, 2016).

1. Lower mortality in adolescence and resulting small sample sizes.

   While infants and young children have high risk of mortality due to immature immune systems and stressful periods of change (i.e., weaning), adolescents are often the healthiest within a community, with strong and resilient immune systems (Golub, 2000; McDade, 2003). As a result, adolescents have lower mortality risk, and are subsequently underrepresented in cemetery sites and osteological collections (Lewis, 2007). To mitigate this limitation, my research used individuals from two large osteological collections. To circumvent issues of preservation and maximize the number of people in included in this study, multiple age estimation methods were used.

2. Difficulties assessing biological sex in non-adult skeletons.

   Standard methodologies used to assess biological sex in human remains often rely on sexually dimorphic features that develop during, or following, pubertal development, limiting their applicability to pre- and peri-pubertal individuals (Cardoso, 2008). However, as puberty occurs at different times for males and females, determining biological sex is paramount for complete analysis and interpretation of results. In this thesis, multiple methods were used to estimate biological sex, including juvenile, adolescent, and adult specific morphological methods, as well as dental metrics. Biochemical methods, involving novel peptide analysis to detect

amelogenin X and amelogenin Y peptides in dental enamel, were also used for the youngest individuals (Stewart *et al.*, 2017). This multi-pronged approach, particularly with the inclusion of peptides, allowed me to more confidently estimate biological sex, leading to a more rigorous and sex-specific assessment of pubertal timing.

3. Limitations comparing modern and osteological data.

Modern puberty data is often gathered in a longitudinal fashion, following the development of boys and girls over an extended period (e.g., Deardorff *et al.*, 2021). As a result, these studies produce *average age-at-entry* for each stage of pubertal development. Meanwhile, osteological studies incorporate cross-sectional data from deceased adolescents, and results in *average in-stage age*. Comparisons of the two may result in inflated age-at-pubertal-stage estimates for past populations, leading to the potentially misguided interpretations between the two samples (Arthur *et al.*, 2016). To mitigate this issue, my research intentionally avoids direct comparisons to modern data, and instead focuses on osteological data gathered using the same methodology to assess pubertal stage at death (i.e., Shapland and Lewis, 2013; 2014). While this approach ultimately limits what we can say about puberty in the past in relation to puberty today, it is the most suitable approach based on the ways data are collected for living and deceased samples.

By mitigating these issues, this research demonstrates that males and females buried at *Isola Sacra* and Lisieux-Michelet experienced puberty between 9 and 20 years of age, suggesting an extended period of puberty compared to the duration described in ancient literary sources (Chapter three).

In their initial publication outlining the methodology, Shapland and Lewis (2013: 307) posed the possibility that pubertal timing patterns may, one day, "provide an insight into the environmental and social factors that affected the maturation process in the past". In this research, I incorporate models of early life stress (ELS) and allostatic load, outlining how pubertal timing may reflect early life conditions and physiological stress during childhood. In doing so, my research found that middle-class individuals in these two Roman Imperial samples had similar exposure to ELS, as evident in the similar patterns of pubertal timing. Meanwhile, based on the early onset and longer period of puberty, females in the current study had greater exposure to ELS than those represented in ancient literary sources (i.e., wealthy, literate populations), while no differences were noted for males between the osteological and literary evidence. Consequently, this research demonstrates how a study of puberty can inform anthropological understandings of childhood and population 'health' more broadly, providing another way for bioarchaeologists to investigate 'stress', 'health' and 'wellbeing' in past populations.

MAKING ADOLESCENCE TANGIBLE

The first aim of this thesis was to explore the physical and social changes in Roman *adulescentia*, but the second aim of this thesis was to demonstrate how bioarchaeologists can explore the period of adolescence. In many ways, the development of the bioarchaeological study of adolescence mirrors that of the bioarchaeological study of childhood. In 2001, Kathryn Kamp (2001: 2) stated that, "archaeologists neglect childhood not because it is perceived as unimportant, but because it is too intangible". By working to make childhood tangible, the study of childhood in the past has flourished into a vibrant field of study (Baxter, 2008). The bioarchaeology of adolescence, however, has continued to receive limited focus, despite it being an important

transitional period between childhood and adulthood (Shapland & Lewis, 2013). This general paucity of research is likely because the study of adolescence is also viewed as intangible. That is, we acknowledge that adolescence is an important period of the life course, but engagement in the study of adolescence is lacking as we are not sure how to investigate, or even conceptualize, adolescence. I argue this intangibility is due to artificial divisions within the field of biological anthropology, rather than real limitations, that nevertheless need to be addressed to facilitate the growth of this subfield of study. These divisions are discussed further in the next section.

NON-ADULT/ADULT METHODS

The first division contributing to the intangibility of adolescence is the methods used within biological anthropology and bioarchaeology, which artificially divide the life course into adults and non-adults. For example, body mass equations and calculations are different for unfused femora (applicable to individuals 1-17 years of age) and fused femora (applicable to individuals age 17+) (Ruff, 2007; Auerbach & Ruff, 2004). While this division is based on the biological development of the human body (e.g., epiphyseal fusion), it establishes an assumption that individuals fall into one of those two categories, leaving those that bridge this period without clear methodological or conceptual approaches (Halcrow & Tayles, 2008). For those who wish to evaluate body mass over the period of adolescence, the two methodological approaches may not produce comparable results, limiting analysis within this age group. By refining bioarchaeological methods across the life course, we may be able to remove this methodological barrier which creates artificial divisions between adults, non-adults, and those viewed as in-between (Sofaer, 2006). This work is already underway in some areas. For example, Vitamin D deficiencies are often described in terms of non-adult or adult manifestations, but more recently bioarchaeologists are working to examine how vitamin D deficiencies manifest in adolescence, by focusing on skeletal elements that fuse during this period, including in the sternum and sacral segments (e.g., Lockau *et al.*, 2019; Lamar, 2020). Other researchers are developing methods to better consider biological experiences on a spectrum of age rather than in discrete age categories. For example, examining interglobular dentine (IGD) in dental structures, D'Ortenzio and colleagues (2016; 2018) identify the age at which Vitamin D deficiencies occurred, removing methodological divides between non-adults and adults, and those in between. Further reassessment and refinement of common methodological approaches may be needed to reduce or remove the divide between non-adult and adult skeletal remains and facilitate the ongoing study of adolescence in bioarchaeology.

In the current research, the use of incremental sections of dentine overcomes this non-adult/adult division, by analysing dietary difference in short and discrete time frames across the development of the second and third molars. In doing so, we are not restricted to traditional categories of non-adult/adult but can look at age-based changes on a more fluid spectrum.

THE BIOLOGICAL/SOCIAL BODY

The second division hindering the study of adolescence in bioarchaeology is the separation of the biological and social aspects of human remains. Although biological anthropologists acknowledge that the body is both a biological and social entity, little research works to incorporate both into their perspectives, leaving studies to consider the biological or the social experiences in isolation of each other (Halcrow & Tayles, 2008). As adolescence is both a biological and social

experience, these separate approaches limit engagement with this subject matter. Considering the biological and social aspects in tandem will allow biological anthropologists to engage with this period of life more appropriately and thoroughly, and may also provide unique insights into the aging process (i.e., how aging was perceived by past peoples). For example, if aging in the Roman Empire was driven by biological age, pubertal onset (e.g., breast budding in girls) would have likely been an outward sign that the individual had reached *adulescentia*. In response to this change, the *adulescens* may start consuming a different diet. Therefore, bioarchaeologically, we may expect pubertal onset to occur prior to changes in diet. If, however, dietary changes occur before pubertal changes, it may be that the individual reached the social age of *adulescentia*, independent of their biological age or pubertal stage, and thus, we may conclude that aging was not driven by biological changes. With a more finely tuned methodology related to incremental dentine sectioning protocols, we may be better able to investigate how the physical and social changes influence and affect one another for individuals in the past.

My dissertation research begins to bridge the social and biological, by considering how early social conditions may contribute to patterns of pubertal timing, or how biological changes associated with puberty may affect stable isotope values. Further development of theoretical models has the potential to strengthen the connection between these two in the future.

FUTURE RESEARCH DIRECTIONS

The research in this thesis focused on the experiences of middle-class individuals at two sites in Roman Italy and Roman Gaul. Future research may wish to learn more about the relationship between diet and social age changes for other groups, including higher status populations, those in different geographical regions, or those in different periods of the Roman Empire. The results of this thesis show that lived experiences of *adulescentia* were more nuanced or complicated than literary representations, and I hypothesize that the same is true for other populations in the Roman Empire. Bioarchaeologists are well suited to investigating these experiences using a biocultural approach, identifying how social age transitions were experienced in other populations of the Roman Empire (Harlow & Laurence, 2002).

Dietary change may not always capture social age changes. Thus, researchers need to consider the types of activities individuals participate in as they age, and how these activities may be reflected in the human remains. For example, Nowell & French (2020) suggest that adolescence in the Upper Paleolithic (circa 40,000 to 12,000 years ago) was characterized by long distance trade and exploration. Thus, by using strontium and stable oxygen isotopes analysis of tooth enamel of second and third molars, we may expose patterns of migration and mobility during adolescence (e.g., Evans *et al.*, 2006). Depending on the temporal or social context, adolescence may have also been the period in which young people transitioned to different jobs or joined the workforce. Analysing the development of entheseal changes and occupational markers across this period of the life course may, therefore, help us identify when this transition occurred, and when young people were expected to contribute to their families and communities (e.g., Henderson & Cardoso, 2013). However, until we address the artificial divide between non-adult and adult categories within biological anthropology, the approaches we can take to study adolescents will be limited. Thus, methodological and theoretical developments are also needed, to provide new ways of studying the lived experiences of adolescents and better understand the *process* of aging during adolescence, rather than considering changes in discrete bioarchaeological age categories.

CONCLUSIONS

In this thesis, I set out to uncover the biological (i.e., pubertal timing, diet) and social experiences of Roman Imperial *adulescentia* in middle-class individuals, who are traditionally overlooked using other lines of evidence. These investigations reveal that the physical changes associated with puberty occurred over an extended period of time, between 9 and 20 years of age, and menarche (for females) occurred around 15 years of age (Chapter three). When comparing pubertal timing patterns between the two archaeological sites considered in this thesis, osteological analysis reveals similar patterns of pubertal timing, suggesting similar exposure to ELS. Compared to literary evidence, which may represent higher status or idealized versions of pubertal timing patterns, females in the current research experienced an early onset, as well as a longer period of puberty, indicating greater exposure to ELS. Males, however, showed no differences between osteological and literary sources, indicating more comparable exposure to ELS. These results suggest that gendered exposure to ELS were influenced by social status in the Roman Empire.

The social changes, investigated through contextualized analysis of dietary stable isotopes, suggests that diets changed during *adulescentia*, reflecting changing social roles. However, different patterns were noted at the two sites. For those buried at *Isola Sacra*, sex-specific diets are present as young as 4.5 years of age, contrary to literary evidence regarding gendered experiences in childhood. However, longitudinal profiles suggest that during the period of *adulescentia*, diets were further influenced by gender, likely in response to changing social roles for men and women within their communities. For those buried at Lisieux-Michelet, sex-specific diets emerge during *adulescentia*, and when contextualized using archaeological and literary evidence, points to changing social roles as women remained close to their natal home, learning domestic skills, while men took on new roles in their communities, as apprentices or in the military.

Ultimately, the results of this research demonstrate that *adulescentia* was an extended period of biological and social changes for men and women, and that the specific patterns of change depended on one's gender, social status, location and/or time period within the Roman Empire.

By considering how pubertal timing is influenced by early life conditions, my research outlines a new way for bioarchaeologists to explore experiences in childhood, using the skeletal remains of individuals that survived this period of the life course. In doing so, this research connects adolescence to the life course more broadly, rather than treating it as a distinct and independent stage of life. Furthermore, by interpreting stable isotope values using culturally constructed age categories, this research investigates the relationship between diet and social age changes using a more culturally informed model, rather than imposing modern constructions of biological or chronological age. Consequently, my research demonstrates how bioarchaeologists can investigate the process of maturation and aging, rather than considering age in discrete categorical variables.

The research within this thesis also serves to make the bioarchaeological study of adolescence tangible, by demonstrating how we can investigate the biological and social changes associated with this period of life, and the types of stories we can uncover by examining deceased adolescents (through the analysis and interpretation of puberty) and those who survived this period of the life course (using stable isotopes of incremental dentine sections). By incorporating newer methodologies, including oblique sectioning of dentine sections, assessment of pubertal timing,

and enamel peptides to assess biological sex for the younger individuals, this research demonstrates that the study of adolescence in the past is, indeed, tangible.

The bioarchaeological study of adolescence is a relatively new field, with researchers taking disparate approaches to the study of the physical or social changes encapsulated in this period of the life course. This research, for the first time, demonstrates how both may be investigated and brought together to gain a more holistic interpretation of this transitional period of the life course.

REFERENCES

Alberici, L. A., & Harlow, M. (2007). Age and innocence: Female transitions to adulthood in late antiquity. *Hesperia Supplements* 41: 193-203. https://www.jstor.org/stable/20066790.

Alduc-Le Bagousse, A., & Blondiaux, J. (2001). Hyperostoses corticales fœtale et infantile à Lisieux (Ive s.) : Retour à Costebelle. *Centre Archéologique de Var.* 2001 : 60-64.

Alduc-Le Bagousse, A., & Blondiaux, J. (2002). Maternal death and perinatal pathology at Lisieux (Calvados, France) during the first millennium. *Bulletins et Mémoires de la Société d'Anthropologie de Paris* 14(2-3) : 295-309.

Arthur, N. A., Gowland, R., & Redfern, R. (2016). Coming of age in Roman Britain: Osteological evidence for pubertal timing. *American Journal of Physical Anthropology* 159(4): 698-713. https://doi.org/10.1002/ajpa.22929.

Auerbach, B., & Ruff, C. B. (2004). Human body mass estimation: A comparison of "morphometric" and "mechanical" methods. *American Journal of Physical Anthropology* 125(4): 331-342. https://doi.org/10.1002/ajpa.20032.

Avery, L.C., Prowse, T.L., & Brickley, M.B. (2019). Dental health and dietary difference at Late Roman Winchester. *Bioarchaeology International* 3(3): 157-173. https://doi.org/10.5744/bi.2019.1011.

Baldassarre, I. (1978). La necropolis dell'Isola Sacra. *Quaderni de 'La Ricerca Scientifica'* 100: 3-20.

Baldassarre, I. (1990). Nuove ricerche nella necropolis dell'Isola Sacra. *Quaderni di Archeologia Etrusco-Italica* 19: 164-172.

Baldwin, R. (1985). Intrusive burial groups in the Late Roman cemetery at Lankhills, Winchester – A reassessment of the evidence. *Oxford Journal of Archaeology* 4(1): 93-104. https://doi.org/10.1111/j.1468-0092.1985.tb00233.x.

Baxter, J. E. (2008). The archaeology of childhood. *Annual Review of Anthropology* 37: 159-175. https://doi.org/10.1146/annurev.anthro.37.081407.058129.

Binford, L. R. (1971). Mortuary practices: Their study and their potential. *Memoirs of the Society for American Archaeology* 25: 6-29. https://doi.org/10.1017/S0081130000002525.

Blom, A. A., Schats, R., Hoogland, M. L. P., & Waters-Rist, A. (2020). Coming of age in the Netherlands: An osteological assessment of puberty in a rural Dutch post-medieval community. *American Journal of Physical Anthropology* 174(3): 463-478. https://doi.org/10.1002/ajpa.24161.

Blondiaux, G., Blondiaux, J., Secousee, R., Cotton, A., Danze, P. M., & Flipo, R. M. (2002). Rickets and child abuse: The case of a two-year-old girl from the 4th century in Lisieux (Normandy). *International Journal of Osteoarchaeology* 12(3): 209-215. https://doi.org/10.102/oa.616.

Blondiaux, J., Fontaine, C., Demondion, X., Flipo, R. M., Colard, T., Mitchell, P. D., Buzon, M., & Walker, P. (2012). Bilateral fractures of the scapula: Possible archaeological examples of

beatings from Europe, Africa and America. *International Journal of Paleopathology* 2(4): 223-230. https://doi.org/10.1016/j.jipp.2012.10.002.

Bradley, K. R. (1991). *Discovering the Roman family*. Oxford University Press.

Brickley, M. B., Mays, S., George, M., & Prowse, T. L. (2018). Analysis of patterning in the occurrence of skeletal lesions used as indicators of vitamin D deficiency in subadult and adult skeletal remains. *International Journal of Paleopathology* 23: 43-53. https://doi.org/10.1016/j.ijpp.2018.01.001.

Caldwell, L. (2015). *Roman girlhood and the fashioning of femininity*. Cambridge University Press.

Calza, G., & Becatti, G. (2008). *Ostia: Itineraries of the museums, galleries and monuments in Italy*. Instituto Poligrafico e Zecca Dello Stato S.P.A.

Cameron, N. (2003). Assessment of maturation: Bone age and pubertal assessment. In F. H. Glorieux, J. M. Pettifor, & H. Juppner (Eds.). *Pediatric Bone: Biology and Diseases* (pp. 325-338). Academic Press.

Cardoso, H. (2008). Sample specific (universal) metric approaches for determining the sex of immature human skeletal remains using permanent tooth dimensions. *Journal of Archaeological Science* 35(1): 158-168. https://doi.org/10.1016/j.jas2007.02.013.

Carswell, J. M., & Stafford, D. E. (2016). Normal physical growth and development. In L. S. Neinstein, & D. K. Katzman (Eds.), *Adolescent and young adult health care: A practical guide. Sixth Edition* (pp. 22-37). Wolters Kluwer.

Cho, H., & Stout, S. D. (2003). Bone remodeling and age-associated bone loss in the past: A histomorphometric analysis of the Imperial Roman skeletal population of Isola Sacra. In Agarwal SC, Stout SD (Eds.). *Bone Loss and Osteoporosis: An Anthropological Perspective* (pp. 207-228). Kluwer Academic.

Crockett, L. J. (1997). Cultural, historical, and subcultural contexts of adolescence: Implications for health and development. In J. Schulenberg, J. L. Maggs, & K. Hurrelmann (Eds.), *Health risks and developmental transitions during adolescence* (pp. 23-53). Cambridge University Press.

Crowe, F., Sperduti, A., O'Connell, T. C., Craig, O. E., Kirsanow, K., Germoni, P., Macchiarelli, R., Garnsey, P., & Bondioli, L. (2010). Water-related occupations and diet in two Roman coastal communities (Italy, first to third century AD): Correlation between stable carbon and nitrogen isotope values and auricular exostosis prevalence. *American Journal of Physical Anthropology* 142(3): 355-366. https://doi.org/10.1002/ajpa.21229.

D'Ortenzio, L., Kahlon, B., Peacock, T., Salahuddin, H., & Brickley, M. (2018). The rachitic tooth: Refining the use of interglobular dentine in diagnosing vitamin D deficiency. *International Journal of Paleopathology* 22: 101-108. https://doi.org/10.1016/j.ijpp.2017.10.001.

D'Ortenzio, L., Ribot, I., Raguin, E., Schattmann, A., Bertrand, B., Kahlon, B., & Brickley, M. (2016). The rachitic tooth: A histological examination. *Journal of Archaeological Science* 74: 152-163. https://doi.org/10.1016/j.jas.2016.06.006.

Dasen, V. (2021). Roman childhood revisited. In L. A. Beaumont, M. Dillon, & N. Harrington (Eds.), *Children in antiquity: Perspectives and experiences of childhood in the ancient Mediterranean* (pp. 105-120). Routledge Press.

Deardorff, J., Marceau, K., Johnson, M., Reeves, J. W., Biro, F. M., Kubo, A., Greenspan, L. C., Laurent, C. A., Windham, G. C., Pinney, S. M., Kushi, L. H., & Hiatt, R. A. (2021). Girls' pubertal timing and tempo and mental health: A longitudinal examination in an ethnically diverse sample. *Journal of Adolescent Health* 68(6): 1197-1203. https://doi.org/10.1016/j.jadohealth.2021.01.020.

Demirjian, A., Buschang, P. H., Tanguay, R., & Kingnorth Patterson, D. (1985). Interrelationships among measures of somatic, skeletal, dental and sexual maturity. *American Journal of Orthodontics* 88(5): 433-438. https://doi.org/10.1016/0002-9416(85)90070-3.

DeWitte, S. N., & Lewis, M. (2021). Medieval menarche: changes in pubertal timing before and after the Black Death. *American Journal of Human Biology* 33(2): e23439. https://doi.org/10.1002/ajhb.23439.

Dimeglio, A. (2006). Growth in Pediatric Orthopaedics. In R. T. Morrisy, & S. L. Weinstein (Eds.), *Lovell and Winter's pediatric orthopaedics* (pp. 35-66). Lippincott Williams and Wilkins.

Dixon, S. (1992). *The Roman family*. The John Hopkins University Press.

Doe, D. M., Moreno, M. M., Perez, J. R., Gonzalez, N. C., Cambra-Moo, O., Martin, M. C., & Martin, A. G. (2019). Puberty in the Bronze Age: First application of a puberty estimation method to a prehistoric population. *International Journal of Osteoarchaeology* 29(6): 1091-1099. https://doi.org/10.1002/oa.2822.

Dorn, L. D., Hostinar, C. E., Susman, E. J, & Pervanidou, P. (2019). Conceptualizing puberty as a window of opportunity for impacting health and well-being across the life span. *Journal of Research on Adolescence* 29(1): 155-176. https://doi.org/10.1111/jora.12431.

Ebling, F. J. P. (2005). The neuroendocrine timing of puberty. *Reproduction* 129(6): 675-683. https://doi.org/10.1530/rep.1.00367.

Evans, J. A., Chenery, C. A., & Fitzpatrick, A. P. (2006). Bronze Age childhood migration of individuals near Stonehenge, revealed by strontium and oxygen isotope tooth enamel analysis. *Archaeometry* 48(2): 309-321. https://doi.org/10.1111/j.1475-4754.2006.00258.x.

Eyben, E. (1972). Antiquity's view of puberty. *Latomus* 31(3): 677-697. https://www.jstor.org/stable/41529266.

Eyben, E. (1993). *Restless youth in ancient Rome*. Routledge.

FitzGerald, C., Saunders, S., Bondioli, L., & Macchiarelli, R. (2006). Health of infants in an Imperial Roman skeletal sample: Perspective from dental microstructure. *American Journal of Physical Anthropology* 130(2): 179-189. https://doi.org/10.1002/ajpa.20275.

Francis, J. C. (2014). History and trends of pubertal development in females. In J. E. Dietrich (Ed.), *Female Puberty: A Comprehensive Guide for Clinicians* (pp. 1-6). Springer.

Fuller, B. T., Richards, M. P., & Mays, S. A. (2003). Stable carbon and nitrogen isotope variations in tooth dentine serial sections from Wharram Percy. *Journal of Archaeological Science* 30(12): 1673-1684. https://doi.org/10.1016/S0305-4403(03)00073-6.

Garnsey, P. D. A. (1999). *Food and society in classical antiquity.* Cambridge University Press.

Germoni, P., Millett, M., Keay, S., Reynolds, J., & Strutt, K. (2011). The Isola Sacra: Reconstructing the Roman landscape. In S. Keay & L. Paroli (Eds.), *Portus and its Hinterlands: Recent Archaeological Research* (pp. 231-260). The British School at Rome.

Golub, M. S. (2000). Adolescent health and the environment. *Children's Health Review* 108: 355-362. http://ehpnetl.niehs.ni.gov/docs/2000/I08p355-362golublabstnract.ht7nl.

Goodman, A. H., & Leatherman, T. L. (1998). *Building a new biocultural synthesis: Political-economic perspectives on human biology*. The University of Michigan Press.

Gowland, R. (2001). Playing Dead: Implications of mortuary evidence for the social construction of childhood in Roman Britain. In G. Davies, A. Gardner, K. Lockyear (Eds.), *TRAC 2000: Proceedings of the Tenth Annual Theoretical Roman Archaeology Conference* (pp. 152-168). Oxbow Books.

Gowland, R. (2016). Ideas of childhood in Roman Britain: The bioarchaeology and material evidence. In M. Millett, L. Revell, & A. Moore (Eds.), *The Oxford Handbook of Roman Britain* (pp. 303-320). Oxford University Press. https://doi.org/oxfordhdb/9780199697731.013.019.

Hagg, U., & Taranger, J. (1982). Maturation indicators and the pubertal growth spurt. *American Journal of Orthodontics* 82: 299-309. https://doi.org/10.1016/0002-9416(82)90464-X.

Halcrow, S. E., & Tayles, N. (2008). The bioarchaeological investigation of childhood and social age: Problems and prospects. *Journal of Archaeological Method and Theory* 15: 190-215. https://doi.org/10.1007/s10816-008-9052-x.

Halsall, G. (2012). *Barbarian migrations and the Roman west, 376-568.* Cambridge University Press.

Harlow, M., & Laurence, R. (2002). *Growing up and growing old in ancient Rome.* Routledge.

Henderson, C. Y., & Cardoso, F. A. (2013). Entheseal changes and occupation: Technical and theoretical advances and their applications. *International Journal of Osteoarchaeology* 23: 127-134. https://doi.org/10.1002/oa.2298.

Henderson, C. Y., & Padez, C. (2017). Testing times: Identify puberty in an identified skeletal sample. *Annals of Human Biology* 44(4): 332-337. https://doi.org/10.1080/03014460.2016.1250949.

Hoover, K. C., Corruccini, R. S., Bondioli, L., Macchiarelli, R. (2005). Exploring the relationship between hypoplasia and odontometric asymmetry in Isola Sacra, an Imperial Roman necropolis. *American Journal of Human Biology* 17(6): 752-764. https://doi.org/10.1002/ajhb.20436.

Isayev, E. (2007). Unruly youth? The myth of generation conflict in late Republican Rome. *Historia: Zeitschrift fur Alte Geschichte* 56(1): 1-13. https://www.jstor.org/stable/25598371.

Joos, C. M., Wodzinski, A. M., Wadsworth, M. E., & Dorn, L. D. (2018). Neither antecedent nor consequence: Developmental integration of chronic stress, pubertal timing, and conditionally adapted stress response. *Developmental Review* 48: 1-23. https://doi.org/10.1016/j.dr.2018.05.001.

Kamp, K. (2001). Where have all the children gone? The archaeology of childhood. *Journal of Archaeological Method and Theory* 8(1): 1-34. https://doi.org/10.1023.a:1009562531188.

Karivieri, A. (2020). New trends in Late Antique religions, beliefs, and ideas: Christianity, Judaism, Philosophy and magic at Ostia. In A. Karivieri (Ed.). *Life and death in a multicultural harbour city: Ostia Antica from the Republic through late Antiquity* (pp. 371-386). Instituti Romani Finalndiae.

Keay, S., & Millett, M. (2005). Portus in context. In S. Keay, M. Millett, L. Paroli, & K Strutt (Eds.), *Portus: An archaeological survey of the port of Imperial Rome* (pp. 297-314). The British School at Rome.

Laes, C., & Strubbe, J. (2014). *Youth in the Roman Empire: The young and the restless years?* Cambridge University Press.

Laes, C. (2019). Women, children and food. In P. Erdkamp, & C. Holeran (Eds.), *The Routledge handbook of diet and nutrition in the Roman world* (pp177-187). Routledge Press.

Lam, T., Williams, P. L., Lee, M. M., Korrick, S. A., Birnhaum, L. S., Burns, J. S., Sergeyev, O., Revich, B., Altshul, L. M., Patterson, D. G., & Hauser, R. (2015). Prepubertal serum concentrations of organochlorine pesticides and age at sexual maturity in Russian boys. *Environmental Health Perspectives* 123(11): 1216-1221. https://doi.org/10.1289/ehp.1409022.

Lamer, M. (2020). *Decoding adolescent rickets: The effects of the environmental and social contexts on the development of rickets in adolescents in the Netherlands from the 17th to 19th centuries.* Unpublished MA Thesis, McMaster University. https://macsphere.mcmaster.ca/handle/11375/25918

Laurence, R. (2000). Metaphors, monuments, and texts: The life course in Roman culture. *World Archaeology* 31(3): 442-455. https://doi.org/10.1080/00438240009696931.

Lelis, A. A., Percy, W. A., & Verstraete, B. C. (2003). *The Age of marriage in ancient Rome*. The Edwin Mellen Press.

Lewis, M. E. (2019). Children in Bioarchaeology: methods and interpretations. In A. Katzenberg, & A. Grauer (Eds.), *Biological anthropology of the human skeleton* (pp. 119-144). Academic Press. https://doi.org/10.1002/9781119151647.ch4.

Lewis, M., Shapland, F., & Watts, R. (2016). On the threshold of adulthood: A new approach for the use of maturation indicators to assess puberty in adolescents from Medieval England. *American Journal of Human Biology* 28(1): 48-56. https://doi.org/10.1002/ajhb.22761.

Lewis, M. E. (2007). *The bioarchaeology of children: Perspectives from biological and forensic anthropology*. Cambridge University Press.

Lockau, L., Atkinson, S., Mays, S., Prowse, T., George, M., Sperduti, A., Bondioli, L., Wood, C., Ledger, M., & Brickley, M. B. (2019). Vitamin D deficiency and the ancient city: Skeletal evidence

across the life course from the Roman period site of Isola Sacra, Italy. *Journal of Anthropological Archaeology* 55: 101069. https://doi.org/10.1016/j.jaa.2019.101069.

Manzi, G., Sperduti, A., & Passarello, P. (1991). Behavior-induced auditory exostoses in Imperial Roman society: Evidence from coeval urban and rural communities near Rome. *American Journal of Physical Anthropology* 85(3): 253-260. https://doi.org/10.1002/ajpa.1330850303.

Marciniak, S., Herring, D. A., Sperduti, A., Poinar, H. N., & Prowse, T. L. (2018). A multi-faceted anthropological and genomic approach to framing *Plasmodium falciparum* malaria in Imperial period central-southern Italy (1st-4th c. CE). *Journal of Anthropological Archaeology* 49: 210-224. https://doi.org/10.1016/jj.jaa.2018.01.004.

Marshall, W. A., & Tanner, J. M. (1969). Variations in pattern of pubertal changes in girls. *Archives of Disease in Childhood* 44(235): 291-303. https://doi.org/10.1136/adc.44.235.291.

Marshall, W. A., & Tanner, J. M. (1970). Variations in the pattern of pubertal changes in boys. *Archives of Disease in Childhood* 45(239): 13-23. https://doi.org/10.1136/adc.45.239.13.

Mays, S., Prowse, T., George, M., & Brickley, M. B. (2018). Latitude, urbanization, age, and sex as risk factors for vitamin D deficiency disease in the Roman Empire. *American Journal of Physical Anthropology* 167(3): 484-496. https://doi.org/10.1002/ajpa.23646.

McDade, T. W. (2003). Life history theory and the immune system: Steps toward a human ecological immunology. *Yearbook of Physical Anthropology* 122(S37): 100-125. https://doi.org/10.1002/ajpa.10398.

Milella, M., Gerling, C., Doppler, T., Kuhn, T., Cooper, M., Mariotti, V., Belcastro, M. G., Ponce de Leon, M. S., & Zollikofer, C. P. E. (2019). Different in diet: Different in life? Diet and mobility correlates of irregular burials in a Roman necropolis from Bologna (Northern Italy, 1st-4th century CE). *Journal of Archaeological Science: Reports* 27: 101926. https://doi.org/10.1016/j.jasrep.2019-101926.

Moore, A. J. (2009). *Young and old and Roman Britain: Aspects of age identity and life-course transitions in regional burial practice*. Doctoral Dissertation. University of Southampton. https://eprints.soton.ac.uk/360559/1/Young%2520and%2520Old%2520in%2520Roman%2520Britain.pdf

Nadler, G. L. (1998). Earlier dental maturation: Fact or fiction? *The Angle Orthodontists* 68(6): 535-538. https://doi.org/10.1043/0003-3219(1998)068<0535:EDMFOF>2.3.CO;2.

Nava, A., Frayer, D. W., & Bondioli, L. (2019). Longitudinal analysis of the microscopic dental enamel defects of children in the Imperial Roman community of *Portus Romae* (necropolis of Isola Sacra, 2nd-4th century CE, Italy). *Journal of Archaeological Science: Reports* 23: 406-415. https://doi.org/10.1016/j.jasrep.2018.11.007.

Nowell, A., & French, J. C. (2020). Adolescence and innovation in the European Upper Palaeolithic. *Evolutionary Human Sciences* 2(e36). https://doi.org/10.1017/ehs.2020.37.

Paillard, D., Alduc-Le Bagousse, A., Allen, M. I., Blondiaux, J., Buchet, L., Chapelain de Seréville-Niel, C., Guihard, P. M., Maneuvrier, C., Pacory, J., Pilet, C., Pilet-Lemière, J., & Vipard, P. (Forthcoming). *La nécropole Michelet. Bilan et perspectives des recherches sur la cité*

de Lisieux (Calvados) de ses origines au IX^e siècle, Publications du Craham, Presses Universitaires de Caen.

Paillard, D., Alduc-Le Bagousse, A., Buchet, L., Blondiaux, L., & Niel, C. (2009). Identité sociale ou miroir d'une société en évolution? Les tombes remarquables de la seconde moitié de IV^e siècle dans la nécropole Michelet à Lisieux (Calvados). *Inhumations de prestige ou prestige de l'inhumation?* Université de Caen – CRAHM; 1-22. https://hal/archives-ouvertes.fr/hal-00469526.

Paillard, D., Buchet, L., & Alduc-Le Bagousse, A. (2006). Nombre d'inhumés, nombre d'habitants: Estimations archéologiques et anthropologiques. Lisieux (Calvados), IV^e siècle de notre ère. In L. Buchet, C. Dauphin, I. Séguy (Eds.), *La paléodémogrphie. Mémoire d'os, mémoire* (pp. 209-223). Proceedings from the 8th Anthropology Day of Valbonne.

Paillard, D. (1994). Le quartier artisanal de Michelet. In J. Bergeret (Ed.), *Lisieux avant l'an mil: Essai de reconstitution* (pp. 36-45). Musées de la ville de Lisieux.

Pozo, J., & Argente, J. (2002). Delayed puberty in chronic illness. *Best Practice and Research Clinical Endocrinology and Metabolism.* 16(1): 73-90. https://doi.org/10.1053/beem.2002.0182.

Prowse, T. L., Schwarcz, H. P., Saunders, S., Macchiarelli, R., & Bondioli, L. (2004). Isotopic paleodiet studies of skeletons from the Imperial Roman-age cemetery of Isola Sacra, Rome, Italy. *Journal of Archaeological Science* 31(3): 259-272. https://doi.org/10.1016/j.jas.2003.08.008.

Prowse, T. L., Saunders, S. R., Schwarcz, H. P., Garnsey, P., Macchiarelli, R., & Bondioli, L. (2008). Isotopic and dental evidence for infant and young child feeding practices in an Imperial Roman skeletal sample. *American Journal of Physical Anthropology* 137(3): 294-308. https://doi.org/10.1002/ajpa.20870.

Prowse, T. L., Schwarcz, H. P., Garnsey, P., Knyf, M., Macchiarelli, R., & Bondioli, L. (2007). Isotopic evidence for age-related immigration to Imperial Rome. *American Journal of Physical Anthropology* 132(4): 510-519. https://doi.org/10.1002/ajpa.20541.

Prowse, T. L., Schwarcz, H. P., Saunders, S. R., Macchiarelli, R., & Bondioli, L. (2005). Isotopic evidence for age-related variation in diet from Isola Sacra, Italy. *American Journal of Physical Anthropology* 128(1): 2-13. https://doi.org.10.1002/ajpa.20094.

Revel, L. (2005). The Roman life course: A view from the inscriptions. *European Journal of Archaeology* 8(1): 43-63. https://doi.org/10.1177/1461957105058209.

Roches, E., Blondiaux, J., Cotton, A., Chastanet, P., & Flipo, R. M. (2002). Microscopic evidence for Paget's disease in two osteoarchaeological samples from Early Northern France. *International Journal of Osteoarchaeology* 12(4): 229-234. https://doi.org/10.1002/oa.617.

Rogol, A., Roemmich, K. N., & Clark, P. A. (2002). Growth at puberty. *Journal of Adolescent Health* 31(6): 192-200. https://doi.org/10.1016/S1054-139X(02)00485-8.

Rosen, D. S., & Foster, C. (2001). Delayed puberty. *Pediatrics in Review* 22(9): 309-315. https://doi.org/10.1542/pir.22.9.309.

Ruff, C. (2007). Body size prediction from juvenile skeletal remains. *American Journal of Physical Anthropology* 133(1): 698-716. https://doi.org/10.1002/ajpa.20568.

Saller, R. P. (1987). Men's age at marriage and its consequences in the Roman family. *Classical Philology* 82(1): 21-34.

Sawyer, S. M., & Patton, G. C. (2018). Health and well-being in adolescence: A dynamic profile. In J. E. Lansford, & P. Banati (Eds.). *Handbook of adolescent development research and its impact on global policy* (pp. 27-48). Oxford University Press.

Shapland, F., & Lewis M. E. (2013). Brief communication: A proposed osteological method for the estimation of pubertal stage in human skeletal remains. *American Journal of Physical Anthropology* 151(2): 302-310. https://doi.org/10.1002/ajpa/22268.

Shapland F., & Lewis, M. E. (2014). Brief communication: A proposed method for the assessment of pubertal stage in human skeletal remains using cervical vertebrae maturation. *American Journal of Physical Anthropology* 153(1): 144-153. https://doi.org/10.1002/ajpa.22416.

Shaw, B. D. (1987). The age of Roman girls at marriage: some reconsiderations. *The Journal of Roman Studies* 77: 30-46. https://doi.org/10.1017/S0075435800008492.

Sofaer, J. (2006). *The body as material culture: A theoretical osteoarchaeology*. Cambridge University Press.

Soliman, A., De Sanctis, V., & Elalaily, R. (2014). Nutrition and pubertal development. *Indian Journal of Endocrinology and Metabolism* 18(S1): S39-S47. https://doi.org/10.4103/2230-8210.145073.

Sperduti, A., Bondioli, L., & Garnsey, P. (2012). Skeletal evidence for occupational structure at the coastal towns of Portus and Velia (1st – 3rd c. AD). In I. Schrufer-Kolb (Ed.), *More than just numbers? The role of science in Roman archaeology* (pp. 53-70). Journal of Roman Archaeology Supplementary Series Number 91.

Stark, R. (2016). *Ancient lives in motion: A bioarchaeological examination of stable isotopes, nonmentric traits and human mobility in the Imperial Roman context (1st-3rd c. CE).* Unpublished Doctoral Dissertation. McMaster University, Hamilton, Canada. http://hdl.handle.net/11375/20937.

Stewart, N. A., Gerlach, R. F., Gowland, R., Gron, K., & Montgomery, J. (2017). Sex determination of human remains from peptides in tooth enamel. *Proceedings of the National Academy of Sciences of the United States of America* 114(52): 13649-13654. https://doi.org/10.1073/pnas.1714926115.

Sun, Y., Mensah, F. K., Azzopardi, P., Patton, G. C., & Wake, M. (2017). Childhood social disadvantage and pubertal timing: A national birth cohort from Australia. *Pediatrics* 139(6): 1-10. https://doi.org/10.1542/peds.2016-4099.

Tanner, J. M. (1986). Normal growth and techniques of growth assessment. *Clinics in Endocrinology and Metabolism* 15: 411-451. https://doi.org/10.1016/S0300-595X(86)80005-6.

Timmins, S., Sereville-Niel, C., & Brickley, M. B. (2017). Childhood cranial trauma from a Late Roman and Merovingian context from Michelet, Lisieux, France. *International Journal of Osteoarchaeology* 27(4): 715-722. https://doi.org/10.1002/oa.2581.

Van den Berg, S. M. (2006). Individual differences in puberty onset in girls: Bayesian estimation of heritabilities and genetic correlations. *Behavior Genetics* 36: 261-270. https://doi.org/10.1007/s10519-005-9022-y.

Viner, R. M., Ross, D., Hardy, R., Kuh, D., Power, C., Johnson, A., Wellings, K., McCambridge, J., Cole, T. J., Kelly, Y., & Batty, G. D. (2015). Life course epidemiology: Recognizing the importance of adolescence. *Journal of Epidemiology & Community Health* 69(8): 719-720. https://doi.org/10.1136/jech-2.14-205300.

Walvoord, E. D. (2010). The timing of puberty: Is it changing? Does it matter? *Journal of Adolescent Health* 47(5): 433-439. https://doi.org/10.1016/j.jadohealth.2010.05.018.

Wickham, C. (2005). *Framing the Early Middle Ages: Europe and the Mediterranean, 400-800.* Oxford University Press.

Wohlfahrt-Veje, C., Mouritsen, A., Hagen, C. P., Tinggaard, J., Mieritz, M. G., Boas, M., Petersen, J. H., Skakkabaek, N. E., & Main, K. M. (2016). Pubertal onset in boys and girls is influenced by pubertal timing of both parents. *The Journal of Clinical Endocrinology & Metabolism* 101(7): 2667-74. https://doi.org/10.1210/jc.2016-1073.

Wood, J.W., Milner, G. R., Harpending, H. C., & Weiss, K. M. (1992). The osteological paradox: Problems of inferring prehistoric health from skeletal samples [and comments and reply]. *Current Anthropology* 33(4): 343-370. https://doi.org/10.1086/204084.

World Health Organization. (2014). *Health for the world's adolescents: A second chance in the second decade.* World Health Organization. www.who.int/adolescent/second-decade.

Yang, D. (1997). *DNA Diagnosis of thalassemia from ancient Italian skeletons.* Unpublished Doctoral Dissertation. McMaster University, Hamilton, Canada. http://hdl.handle.net/11375/12939.