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Emerging adolescence: current status and potential advances in bioarchaeology

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Title: Emerging Adolescence: current status and potential advances in bioarchaeology.

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Abstract

Adolescence is marked by a wide range of biological, social, and neurological changes. Adolescents are stereotypically viewed as reckless, impulsive, and troubled, but research across the social and biomedical sciences are demonstrating that this is a narrow view of a dynamic period of life. Now, research is showing that adolescents are frequently responsible for the creation and transmission of new ideas and practices and for the creation of new social bonds, which can contribute to personal and community growth. In short, adolescents are key to the development and success of a community.

The bioarchaeological study of adolescence not only speaks to the experiences of adolescents, but captures the life of a community, especially as this period encapsulates early life experiences and lays the foundations for later adult health outcomes. Consequently, the study of adolescence in past populations provides deep-time insights into adolescence as a uniquely human experience.

This special issue of *Bioarchaeology International* focuses on newly developing work within the bioarchaeological study of adolescence, demonstrating how researchers can use bioculturally informed research to advance our understanding of adolescence in the past. In doing so, we demonstrate where the study of adolescence has come from, where it is presently situated, and where we may take it moving forward, as the study of adolescence not only emerges, but flourishes.

Key words: adolescence, bioarchaeology, puberty, social age

Introduction and Background

Adolescence is a key stage in the human life course that encapsulates a period of drastic biological, social, and neurological changes. Biologically, adolescence encompasses the process of puberty, a sequence of hormonal and physical changes resulting in the development of secondary sexual characteristics, the pubertal growth spurt, and sexual fertility (Rogol et al. 2002; Marshall and Tanner 1969; 1970). Socially, adolescence is often a period in which young people take on new roles and responsibilities (e.g., employment, higher education, independence), push boundaries, and form new relationships and communities as they prepare for adulthood (World Health Organization [WHO], 2014), although the ways in which this is accomplished varies globally today, as it would have done in the past. Neurologically, connections within and between brain regions become stronger and more efficient, resulting in risk-taking behaviours and reward-motivated decision-making processes (National Academies of Science, Engineering, and Medicine 2019: 2).

With all these changes, it is perhaps not surprising that adolescents are stereotypically defined as reckless, impulsive, and troubled. These perspectives are not new; in the first century BCE, the Roman statesman Cicero describe adolescent men as arrogant (Isayev 2007), while Aristotle (4th century BCE) described adolescent men in Ancient Greece as naïve and gullible (Laes & Strubbe 2014). In medieval England, reports of unruly groups of male adolescents, fighting and being drawn into petty disputes were common (Spindler 2011), while historical insights into the lives and activities of adolescent females are rare. Yet, a more positive view paints a very different picture. Due to changes in the brain, adolescents are risk-takers, meaning that they are more likely to adopt new technologies or practices than adults (Duell & Steinberg 2019; 2021). By seeking new communities and relationships, adolescents are also highly mobile, spreading new ideas as they travel. As young people's worlds expand, the need to contribute is also particularly significant, coinciding with a time in which they are increasingly capable of making meaningful contributions to those around them (Fuligni 2018). As a result, adolescents can be powerful agents of both personal growth and change, as well as community development and innovation (Sawyer et al. 2012).

Adolescence Today

Biomedical researchers suggest that adolescence is a pivotal life history stage, with a rate of development and change second only to the fetal and infant period (Viner et al. 2015). Beyond the immediate period of adolescence, researchers have also highlighted the ways in which adolescent health is affected by early childhood conditions, shaped by social determinants of health. Rather than an independent feature of somatic growth, clinical research has shown that pubertal timing (i.e., the age at which individuals reach pubertal milestones, or pubertal tempo (i.e., the pace with which they progress through the stages of puberty), is influenced by childhood experiences including environmental, nutritional, and social conditions (Sisk & Gee 2022). Thus, some have proposed that pubertal timing and tempo may be used as a measure of early life stress or increased allostatic load (Joos et al. 2018; Allsworth et al. 2005). 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 immediate 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; Dorn et al. 2019; Hoyt et al. 2020; Mendle et al. 2018). These studies demonstrate that

adolescence and adolescent development are integral components of effective entry into adulthood and later life success and well-being, at the individual and societal level (Hoyt et al. 2020). Understanding adolescence, therefore, is paramount to understanding overall health and well-being in past populations, and the bioarchaeological analysis of adolescents can provide insights into adult health and well-being within a population or highlight potential health consequences within a community.

Where are the adolescents of the past?

Despite the importance of studying adolescents to better understand childhood and adult health outcomes, and communities more broadly, the topic had not, until recently, been widely embraced in biological anthropology. Part of this lack of engagement is due to the history of the discipline. The study of children as an essential window into health in the past only emerged 30 years ago and has taken time to mature (Baxter 2008; Lewis 2007; Kamp 2001). Avery et al. (2021) and Lewis (2022) suggest that the lack of engagement with the bioarchaeology of adolescence stems from three main challenges.

First, biological anthropologists studying adolescents are routinely confronted with small sample sizes (Lewis 2022). While infants and young children have high mortality risk 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).

The second challenge is unreliable sex estimation methods for those still undergoing growth and development. Standard approaches 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 the complete analysis and interpretation of results.

The third challenge is an issue of conceptualization. Due to the development of our discipline, bioarchaeologists must contend with the long-standing non-adult/adult division, in how skeletal remains are recorded, or how methods are applied. This contributes to what Avery and colleagues call the "intangibility of adolescence", that is, biological anthropologists acknowledge that adolescents are important and worthy of study, but are uncertain how to conceptualize, investigate, and rationalize adolescents within the confines of the discipline as it currently stands (Avery et al. 2022a: 9). Much of this intangibility comes down to definitions of "adolescence" and identifying when this period of life occurred. Such definitions are culturally dependent, but at its broadest, adolescence is understood to occur between 10 and 25 years, a topic that will be discussed in the section, *Defining "Adolescence"*, below.

Bioarchaeologists who engage with this period of the life course are demonstrating that the study of adolescence is instrumental, not only to our understanding of adolescents, but also to our understanding of children, adults, and societies. Initial strides made within the study of adolescence in bioarchaeology have shown great promise for understanding life in the past as well as the present.

Over the past 150 years, the average age of menarche has fallen from approximately 16 years in the 1870s to 12 years in modern populations (Bellis et al. 2006). The perceived secular change has raised concerns about the impacts of air pollution and endocrine disrupting chemicals (EDCs) contributing to

lower age of pubertal onset (Huang et al. 2017; Lucaccioni et al. 2020; Walvoord 2010). However, these studies compared modern healthy teenagers to individuals dying during the industrial revolution, a period of poor nutritional health and significant environmental and occupational hazards. Thus, air pollution is not entirely unique to the modern environment, and EDCs are not the only contributor. The publication of pubertal timing methods by Shapland and Lewis (2013, 2014), has allowed bioarchaeologists to contribute to these discussions by exploring patterns of pubertal timing and tempo in diverse contexts. The long-term perspectives provided by bioarchaeologists demonstrate that pubertal development 150 years ago was anomalous due to poor health conditions including inadequate nutrition, disease exposure, and hard physical labour (Blom et al. 2021; Henderson & Padez 2017). Meanwhile, the ages of pubertal attainment and menarche in the pre-Roman, Roman and Medieval periods roughly correspond to what we see today (Lewis et al. 2016; Papadimitriou, 2016; Doe et al., 2019; Arthur et al. 2016; Avery et al. 2022b; Bareggi et al. 2022). These findings provide new insights into how puberty operates, and what 'normal' pubertal timing might look like by incorporating greater timescales into our analyses.

In addition to the development of new methods to trace the adolescent growth spurt as a proxy for pubertal development (Shapland and Lewis 2013; 2014), advances in biochemical analyses have also facilitated the study of adolescence. For example, advancements in incremental analysis allows us to track dietary and mobility changes across infancy, childhood, and into adolescence, giving us a unique perspective to study change and continuity during this period of the life course (e.g., Avery et al., 2021; Coffin et al., 2022). The application of peptide analysis for the estimation of biological sex means that we can investigate lived experiences for males and females of all ages with greater reliability (Stewart et al. 2017) and has recently been applied in tandem with the pubertal timing methods (Avery et al. 2022b). Other methods are continually being adapted for application for adolescents. For example, Lockau et al. (2019) found what may be adolescent-specific manifestations of Vitamin D deficiency, a topic Lamer et al. (2023) has investigated more directly, demonstrating that when the current methods are not sufficient, new approaches can, and must be, considered.

The study of adolescence would not be possible without the application of biocultural theoretical approaches, understanding the ways in which society and culture are embodied in those who live within them (Halcrow & Tayles 2008). Bioarchaeologists are working to investigate social age transitions in the past, through the incorporation of a biocultural approach, whether through changing dietary patterns (Avery et al. 2021; Wang et al., 2022), development of pathological conditions (Clark et al., 2019), greater incidence of trauma (Lewis 2016), or a combination therein (Castro et al. 2017). Meanwhile, using an evolutionary framework, Nowell and French (2020) have developed a model of what adolescence may have looked like during the European Upper Palaeolithic. In doing so, they define ways in which the period of adolescence may be explored in bioarchaeology (French & Nowell 2022).

Emerging Adolescence: A Special Issue

With these methodological, theoretical, and conceptual developments, this special issue of *Bioarchaeology International*, places developments related to adolescence in bioarchaeology at the centre of wider developments initiated by anthropologists working across the social sciences and allied areas. Some contributors to this special issue have studied the bioarchaeology of adolescence since its inception, while others were invited to consider adolescence within their work in new and innovative ways. The results are astounding. Papers in this special issue cover from the ancient Roman Empire to

early colonial Canadian history, and from medieval England to modern identified collections. Methods range from biochemical, to morphological, to metric, incorporating an even wider range of datasets to interpret and understand the lives of adolescents in the past.

Mary Lewis and Janet Montgomery use a multiproxy approach that combines puberty stage assessment, historical records, paleopathology, lead concentrations and isotopic evidence for migration on a group of adolescents, before and after the Black Death (AD 1348-50). This approach provides direct evidence for the fate of young migrants around the time of their relocation, rather than the normal retrospective approach gained by examining the teeth of adult individuals who moved years before their death. A picture emerges of young people moving from great distances before the pandemic, while post-pandemic, movement appears to have been curtailed, perhaps by labour laws brought in after the plague. Intriguingly, the high levels of lead exposure at York are suggested as a potential cause for the anti-social behaviour commonly levelled at medieval adolescents at the time.

Creighton Avery and colleagues also used stable isotope analysis to detail the lives of adolescents in the Roman Empire. Using incremental analysis of tooth dentine and a novel oblique cutting protocol, they investigate the transition from a child to adult diet in the Roman Empire, incorporating longitudinal patterns of dietary change for males and females. They find that, contrary to results in Late Roman Gaul, sex-specific patterns of dietary intake are present throughout childhood and adolescence. This research emphasizes that the biological and social changes associated with adolescence need to be considered in tandem, as evidence of protein insufficiency for two males may, in fact, be the result of increased nutritional requirements during puberty rather than a purely socially-driven dietary change.

One of the first attempts to explore adolescence in a non-European group is provided by Amy Scott and colleagues who draw together evidence for their burial treatment, puberty stage, health, and age drawing on isotopic evidence for diet and migration of 13 male adolescents discovered in an 18th century military fortress in Nova Scotia, Canada. Four of these adolescents would have appeared particularly young, having just completed their growth spurt. As soldiers, their biological development took second place to their social roles with no differences found in diet, health or manner of burial. Scott et al. argue that in contrast to other adolescents buried in the area, the lack of special treatment reflects their distance from home and absence of their family, strengthening their identity as full adults.

Jose Sanchez and Robert Hoppa tackle methodological issues through the analysis of adolescent remains, exploring when pelvic sexual dimorphism becomes a reliable feature by which biological sex may be assessed, in comparison to pubertal growth. Their research demonstrates a nuanced relationship, with some pelvic traits showing high accuracy in relation to biological sex estimations during peak height velocity, while other features lack high accuracy until the deceleration or maturation stages of pubertal development. While biochemical approaches to estimate biological sex are becoming more widely available, such approaches are still destructive and costly. In their paper, Sanchez and Hoppa demonstrate that incorporating pubertal stage analysis in tandem with sex estimations can allow bioarchaeologists to explored nuanced sex-specific patterns of the adolescent experience in past populations with a higher confidence than employing morphological analyses in isolation.

Lastly, Alison Ham and Sharon DeWitte discuss the relevance of pubertal timing in skeletal remains as part of our toolkit for measuring health and well-being in the past. By drawing on clinical literature, as well as information from economists and human biologists, they outline the complexity of factors that dictate the timing of this important biological and social transition in human life history. They argue that

we have the opportunity to study puberty timing not only as an embodiment of social inequality, but also as a way of feeding into discourses on the role of biological sex and gender (be it binary or non-binary) on cultural identity, at a point when social roles are often defined.

All of the papers presented in this special issue have worked to overcome the longstanding challenges of sample size, biological sex estimation and how we define adolescence in various ways. For example, Lewis and Montgomery address issues of small sample sizes by incorporating individuals from multiple sites in the north of England, while Avery and colleagues explore indicators of adolescent life as captured in adult remains, where sex estimations can be performed more reliably. Other papers tackle these issues more directly, including Sanchez and Hoppa, who test the limits of morphological sex estimation in peri-pubertal remains. All papers, however, seek to make adolescence tangible, and demonstrate how adolescents can be explored using a wide range of methods and incorporation of osteological, paleopathological, biochemical, historical, and archaeological datasets.

The picture this special issue paints is one of diversity. Not only of the approaches used, but of the lived experiences of adolescents in the past. Some suggest that adolescence was a period of new found freedom and travel that was drastically impacted by wide socio-cultural events such as the Black Death (Lewis & Montgomery). Others find that adolescence was a sex-based experience, that was potentially stressful on young developing bodies (Avery et al.). In different contexts, researchers find that adolescents could not be distinguished from adults within the populations (Scott et al.), suggesting that a period of 'adolescence' is not universal, but a culturally defined and varied experience. In all cases, however, the stories of adolescents are integral for understanding periods of transition and change, and tell us about the lives of previously overlooked individuals sitting at the crux of change within their own bodies, families, and communities.

Defining "Adolescence"

In the following papers, adolescence has been defined as individuals aged 10 to 25 years (Lewis & Montgomery), or 12 to 19 years (Sanchez & Hoppa) or intentionally undefined (Avery et al.). This ambiguity or inconsistency is not unique to biological anthropology. The WHO defines adolescents as those aged between 10 and 19 years (UNICEF 2011), while some clinicians suggest a period between 14 and 24 years of age, based on long-lasting neurological changes associated with adolescence (Sawyer et al. 2012). Others simply define adolescence as the period between the onset of puberty and attainment of adulthood (National Academies of Science, Engineering, and Medicine 2019). However, these limits can be hard to identify. The age of puberty onset is influenced by a complex alchemy of genetic, nutritional, social, and environmental factors contributing to a wide variation in the ages at which different the different stages of sexual maturation are attained, both at an individual and population level.

Ultimately, adolescence is a socially constructed age category, and needs to be defined within its own social and temporal contexts. It is not considered problematic that the definitions of adolescents may vary within bioarchaeological research, in fact, it is inevitable as we navigate new ways of identifying, studying, and learning about adolescence in the past. Having said this, it is important that researchers clearly define which approach to defining adolescence they have adopted, and whether they are exploring this life stage based on physical development, neurological changes, or expected social changes within the specific time and place under investigation.

The Future Study of Adolescence

So where do we go from here? There are many challenges still to be addressed, with implications both for the osteological methods we use to track puberty in the skeletons of past adolescents, and in the conversations we have about what it was like to be an adolescent in any given time or place. Currently, much of what we know is based on those living in Europe, and while this special issue provides some of the first studies exploring adolescents in North America (Scott et al.), these individuals are of European descent. As Ham and Dewitte (this issue) argue, we have the opportunity to explore puberty timing as a measure of social inequality and well-being in communities often neglected by clinical studies that is, non-WEIRD groups (i.e., Western, educated, industrialized, rich and democratic). Exploring how individuals from different groups experienced adolescence, perhaps through the lens of structural violence or institutional racism, will enrich our understanding of social and health inequalities, and has resonance for modern populations where we seek to learn lessons from the past.

While the timing and tempo of sexual maturation is gaining attention, there is still a lot to be learned about the synchronicity of the skeletal features that we use to trace their progress through puberty. For example, cervical vertebra morphology (CVM) is a popular indicator of skeletal maturity in the clinical literature (Duque et al. 2022). However, several studies have noted a discrepancy in the puberty stage obtained from CVM when compared to other features in the arm or pelvis (Arthur et al. 2016; Henderson & Padez 2017; Bareggi et al. 2022). This variability in past puberty studies may be the result of the method, that has six stages in the scoring scheme as opposed to just 3 or 4, making determinations between one stage to another more open to interpretation, or maybe it is due to issues of translating radiographical features to dry bone. Perhaps this discrepancy is a reflection of true asynchronicity, specific to the European adolescents studied so far, or a phenomenon of adolescents in the past. For now, approaches that allow flexibility in its use to predict puberty stage (e.g., one stage above or below the other predictors) is a workable solution (Avery et al. 2021). There is more work to be done collaborating with clinicians to develop our understanding of skeletal changes during pivotal events during puberty, such as menarche and peak height velocity, perhaps using data from known age males and females recorded at specific stages of their pubertal development.

Exploring the average age of the onset of menarche in past populations from different environments is a particularly exciting aspect of adolescent bioarchaeology. While we must be cautious when directly comparing ages of onset with modern groups, for reasons outlined in detail elsewhere (Lewis 2022), this highly complex process can provide information on conditions in utero, exposure to physiological and psychological stress during childhood, and fertility (Lerner and Foch 2021). We are hindered by the fragile nature of the iliac crest, which ossifies as a series of thin plates of bone that can be difficult to recover archaeologically. There may be other features we can use to explore this crucial part of female adolescence. Until we develop them, defining females as pre- and post-menarche (e.g., before and after deceleration) allows us to make general inferences about menarcheal onset in different environmental circumstances (DeWitte & Lewis 2021). This focus on the lives of young females is a refreshing development in bioarchaeology, allowing us to consider aspects of their lives in more detail especially with regard to their health as young mothers and their influence across generations.

Traditional measures of psychosocial stress are often considered out of the reach of bioarchaeologists (Edes & Crews 2016), but psychological stress has a direct impact on the age at which puberty is reached and on the onset of menarche. The skeletal remains of children and adolescents exposed to conflict and

famines are available to us and offer an opportunity to examine the effect of these environments on their bodies, potentially allowing us to make inferences about the sexual maturation of their offspring, and the impact of the psychological trauma across multiple generations. With industrialisation in Europe, more young people would have travelled to large urban centres, causing not only health issues, but also potential exposure to violence and environmental pollutants, both of which slow the pace of puberty. At an individual level, the extent of adolescent development provides a unique and detailed contextual osteobiography (Hosek & Robb 2019), which has implications for forensic anthropology and biological identification.

The health of adolescents not only reflects their own experience, that of their parents (Soubry 2018; Ellis 2004), and potentially their grandparents (Cirillo et al. 2021; Sari et al. 2021), but also that of their own offspring (Torvie et al. 2015; Kuzawa 2020), making it an important cross-road in human health . Adolescence provides an exciting avenue for paleopathology, as their risky behaviours and transitions in the immune system signal the development of new and reactivated diseases, differences between males and females, and the impact of diseases such as tuberculosis on sexual maturation (Lewis et al. 2016). What we are learning about the lifestyle of these young people has an impact for older age groups too, as a focus on the bodies of these young people begins to reveal pathological changes such as osteoarthritis and Schmorl's nodes that we once considered the preserve of older individuals.

We hope this Special Issue of *Bioarchaeology International* will inspire more research into this exciting new avenue for bioarchaeologists as the incredible potential of adolescence emerges and develops into a discipline as fruitful as research into their younger counterparts.

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