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# A bioarchaeological assessment of pubertal timing at Tombos, Sudan (1400–700 BCE)

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**Abstract**: *This study aims to estimate pubertal timing and evaluate the method applicability in a sample from the ancient Egyptian and Nubian site of Tombos (modern-day Sudan), which dates to the New Kingdom through the Napatan periods (c. 1400–700 BCE) In individuals aged 7–21 years, pubertal development was observed by grading eight skeletal elements. Each grade was attributed to a pubertal phase: pre-puberty, initiation/onset, acceleration, Peak Height Velocity (PHV), deceleration, maturation, and post-puberty. Many individuals were found to be in a combined pubertal range such as PHV/deceleration. Precise determination of PHV was challenging due to the small sample size and short timeframe of the pubertal stage. Initiation occurred between 8 to 12 years, acceleration and PHV showed a broader range of 10 to 20 years, and the deceleration phase was predominantly observed in individuals aged 13 to 21 years. Menarche is associated with females at Tombos aged 15 to 20 years. Deceleration occurred earlier in females and revealed broader transitional phases in males. Males and females showed varied fusion between elements, such as the radius and ulna. Individuals with absent features, due to poor preservation, resulted in broader ranges of pubertal stages. These results bring important insights into research on pubertal analysis and methodology of ancient skeletal remains and expand regional coverage of pubertal data. Additionally, morphological variation in the Tombos sample is noted in comparison with published literature and some suggestions for future research are provided.*

**Key words**: New Kingdom; Nubia; adolescence; Egypt

## Introduction

This study assesses the applicability of pubertal analysis and examines a skeletal sample from the site of Tombos to investigate pubertal timing and adolescence in the

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ancient Nile Valley. Tombos, located in Nubia, was established by the Egyptians during the New Kingdom colonial period and was in use through the Napatan period (c. 1400–700 BCE). It represents a mixed community of immigrants, locals, and their descendants coexisting for hundreds of years with few differences in osteological indications of health disparities (Buzon et al. 2024). Using recently refined methods (Falys & Lewis 2020), the pubertal features of individuals aged 7 to 21 years of age are scored and analyzed to determine the pubertal phase and expand our understanding of the biological transition between childhood and adulthood at this site. Much of the published research on puberty and menarche has come from European skeletal populations; this study explores the variability in a group from another region. Continued research into populations from areas outside of Europe from other time periods has the potential to provide a more holistic perspective on the timing variability in which puberty progresses and menarche is attained.

Puberty development is a complex biological process characterized by significant hormonal changes that induce bone growth and maturation (Nilsson et al. 2014). Accelerated bone growth initiates during the pubertal growth spurt, where the ends of long bones extend until the growth plate reaches full formation. During the pubertal growth spurt, an individual's growth velocity, the rate at which height accelerates, experiences a significant increase (Shim 2015). This coincides with a substantial rise in hormones, such as estrogen, growth hormone, and insulin-like growth factor, around the onset of puberty, implicating these hormones in the regulation of longitudinal growth and epiphyseal fusion (Lewis 2022; Nilsson et al. 2005). Researchers have documented varying rates of acceleration in conjunction with other physical maturation markers during puberty (Lewis 2022; Tanner 1963).

The process of epiphyseal fusion occurs at different bone sites and at distinct stages of puberty, allowing researchers to gauge an individual's pubertal timing based on these variations (Shapland & Lewis 2013). These features mature and fuse at specific growth intervals and age ranges in modern/historic populations (e.g., Lewis et al. 2016, Shapland & Lewis 2013, 2014 as cited by Blom et al. 2020). Prepuberty occurs in ages younger than 10 years during adrenarche. Initiation, the onset of puberty, occurs on average between ages 10–12 in females and 11–13 in males. Males generally lag females by 1–2 years and there is a normal variation of 4–5 years in the timing of the onset of puberty in healthy humans (Parent et al. 2003). Acceleration is a time of increased skeletal growth induced by the release of the hormones ranging from 10–13 years seen in Lewis' (2022) study sample of mid-late Upper Paleolithic European individuals. Peak Height Velocity (PHV) is the zenith of the phase between acceleration and deceleration and is considered the pinnacle of growth. It is expressed by traits commonly associated with puberty including other external physical signs of development.

PHV is the shortest pubertal phase and occurs between the ages 11 to 12 in females and 13 to 14 in males (Lewis 2022), whereas the entire process (acceleration/PHV and PHV/deceleration) can occur between ages 11 to 15 years. Deceleration is when females achieve menarche; and in both males and females, deceleration is a time when growth has returned to normal levels and occurs between 15 to 17 years (Blom et al. 2020). Maturation as a puberty stage is identified when skeletal growth reaches completion between ages 15 to 17 (Lewis et al. 2016). Finally, post-puberty follows the maturation phase and occurs between ages 16 to 22 when the individual reaches adulthood.

This study focuses on understanding the timing of these phases in the ancient Nile Valley. For these communities, information about social age and life phase conceptualization comes from written and pictorial sources primarily in Egypt. Excavation, analysis of mortuary practices, and osteological observations can provide fundamental data regarding the treatment of individuals by age. While some sites have a significant number of pre-adults, many sites in this region have a stark underrepresentation (Kaiser 2020). Adolescents are often found in low numbers due to lower mortality risk, suggesting well-allocated resources throughout the population and care from the community (Avery et al. 2022; Lewis 2009).

Ancient Egyptian texts regarding the training of high priests indicate the beginning of the 'youth' or adolescence phase is around 8 years of age (Harrington 2020). At this time, males may take on additional duties and roles such as apprenticeships in labor and trade as well as formal education. Females would have increased duties in the household (Janssen & Janssen 2007). Some rituals signified age and maturation with specific life stages, such as cutting the lock of hair from a child's ponytail braid to signify the transition from childhood to adolescence/young adulthood. From ancient Egyptian records, it is apparent that adolescent individuals are integral to society as they are fully integrated into work (Marshall 2020). Individuals who have reached puberty are represented in particular ways in art; breasts and pubic hair are indicated on girls, and boys are shown in short kilts. Pubescent females may be marked with tattoos if they are meant for ritual service and males may be circumcised for the priesthood. However, observation of these physical features is limited without preserved soft tissue (Beaumont et al. 2021). Some research suggests that menarche marked marriageable age (Graves-Brown 2010). As such, estimating the age of pubertal changes in the Tombos skeletal sample provides the opportunity to link chronological age with our understanding of an important social age transition regarding adult work and marriageability within the context of the ancient Nile Valley.

# Materials and methods

## Sample

A sample from the ancient Egyptian and Nubian site of Tombos was assessed to estimate pubertal timing and evaluate the method applicability to a population outside of Europe predating past pubertal studies. The total sample from the site consists of 175 discrete individuals. Individuals aged 7–21 years with at least 3 skeletal pubertal features were included in this sample, resulting in 25 observed individuals. The age range begins at 7 years of age due to four individuals with age range estimates of 7 to 11 or 8 to 12 years. Temporal changes in social conditions and resources may have varied throughout the sample; however, there is no archeological or osteological

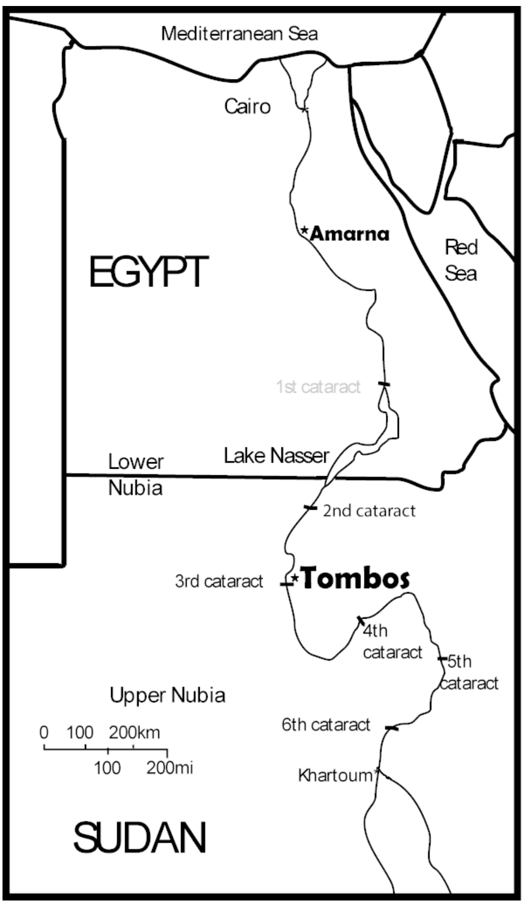


**Figure 1.** Location of Tombos and Tell el-Amarna.

evidence of significant effect of these changes. Therefore, the sample was analyzed without consideration for those variables.

The sample used in this study originated from the site of Tombos, located in modern-day Sudan at the Third Cataract of the Nile River (**Figure 1**). This cemetery dates from the mid-18$^{th}$ Dynasty of the Egyptian New Kingdom Period through the Nubian Napatan Period (c. 1400–700 BCE). The burials were excavated from three main areas of the cemetery (north, east, and west) and contained within various tomb types including underground chamber tombs, pyramids, chapel tombs, pits, and tumuli (Buzon et al. 2024). The remains, currently at Purdue University, were excavated by the University of California, Santa Barbara-Purdue University Tombos Archaeological Project from 2000–2020 and were exported with permission from the National Corporation of Antiquities and Museums in Sudan.

The site of Tombos was established during the Egyptian colonial occupation of Nubia. Documented walls and large buildings indicate that it was likely the Egyptian fortress of Taroy (Smith & Buzon 2018). Analysis of burial practices and strontium isotopes ($^{87}Sr/^{86}Sr$) provide evidence consistent with a community of immigrant Egyptians, local Nubians, and their descendants (Buzon et al. 2024). Tomb structures and burial practices indicate that various socioeconomic status levels exist at the site; however, given the lack of grave goods in most of the burials from this study, it is not possible to discern definite social class differences between individuals. Indications of good health, lack of famine and disease, and sufficient access to resources were generally evident in the skeletal sample. For a population that continued for approximately 700 years under colonial rule and beyond, the limited presence of antemortem/perimortem trauma and low levels of stress indicators suggest an overall good living standard (Buzon et al. 2016; Buzon & Smith 2023; Buzon et al. 2024).

## Age at death estimation

Age at death was estimated using tooth formation and eruption of the third molar (Schaefer et al. 2009; AlQahtani et al. 2010). For individuals of 15+ years, further analysis of epiphyseal fusion was completed to narrow the age estimate. The level of fusion was evaluated on nine features unassociated with pubertal analysis: distal and proximal femur, tibia, fibula, humeral head, acromion process, and proximal radius. Mandibular canines were not considered in general age analysis, as their mineralization is strongly correlated with pubertal hormonal changes and were used as a pubertal indicator (Bareggi 2022; Shapland & Lewis 2013, 2014). Taking into account the estimated biological sex (see below), an age range was documented for each feature according to Scheuer and Black (2009). The individuals with indeterminate sex were allocated to a broader age range, due to a larger standard deviation that combined the earliest and latest fusion times regardless of sex.

## Sex estimation

Individuals 15+ years old were evaluated for biological sex using Buikstra and Ubelaker (1994). Features of the pelvis, mandible, and humerus were evaluated in individuals below the age of 15 according to Rogers (2009), Blake (2019), Wilson (2008), and Schutkowski (1993). Biological sex was only estimated for individuals below 15 years if the evaluation of each skeletal trait resulted in the same score indicating that estimated sex (Lewis et al. 2016).

## Puberty features

Osteological features associated with puberty were observed and assessed collectively by all the authors using methods described by Shapland and Lewis (2013, 2014) and summarized by Falys and Lewis (2020), including mandibular canine root, hamate, distal humerus, proximal ulna, distal radius, iliac crest, proximal-distal manual phalanges and cervical vertebral body morphology (CVM, vertebrae C3 to C6). Stages of development were used for the mandibular canine root (stages F, G, H), the hamate (stages G, H, H.5, I), and CVM (stages 1–6) while the distal humerus, proximal ulna, distal radius, iliac crest, and proximal-distal manual phalanges were graded on a 1–3 fusion scale (1: unfused, 2: fusing, 3: fused). Radiographs were taken of the mandible for the individuals with dentition *in situ* to avoid damaging the remains. This provided a more comprehensive observation of the crown-to-root and root-to-bone ratio to evaluate the canine root. The same grading scale (Demirjian et al. 1973) was used to identify the root development present in the radiographs. Consistency in scoring was verified after initial data collection.

The Risser scale (1958) was utilized on the iliac crests that were categorized as fusing (stage 2) for supplemental evaluation pertinent to pubertal stage analysis. This scale established the stages of ossification between grades 1 to 5 and scored the crest from lateral to medial in quarters. This evaluation using the Risser scale is key for indicating menarche as it is an important characteristic of PHV. Fragmentation resulted in potential ambiguity when discerning between unfused and fusion stages. Ultimately, the absence of the crest was not entirely indicative of a lack of ossification, considering possible taphonomic events.

## Phase determination

Analysis of the data was completed using Shapland and Lewis (2013, 2014) and Falys and Lewis (2020). An overall pubertal score was assigned to an individual based on an evaluation of the feature scores. The stages included prepuberty (0), initiation/onset (1), acceleration(2), Peak Height Velocity (PHV; 3), deceleration (4), maturation (5), and post-puberty (6).

## Results

Of the 25 individuals aged 7–21, ten are female, eight are male, and seven are of indeterminate sex (**Supplementary Table 1**). Three individuals from this age range were excluded from this study due to the presence of fewer than three puberty features. For ten individuals, all eight pubertal features were present; the remaining included between three to six observable features (**Table 1**). Taphonomic changes and post-mortem fragmentation were present throughout the sample, affecting the number of features present upon analysis.

**Table 1**. Presence of pubertal markers in sample.

| Pubertal marker | All individuals (n=25) | Males (n=8) | Females (n=10) | Indeterminate sex (n=7) |
|---|---|---|---|---|
| canine | 13 (52.0%) | 3 (37.5%) | 6 (60.0%) | 4 (57.1%) |
| hamate hook | 19 (76.0%) | 6 (75.0%) | 8 (80.0%) | 5 (71.4%) |
| distal humerus | 23 (92.0%) | 7 (87.5%) | 10 (100.0%) | 6 (85.7%) |
| proximal ulna | 24 (96.0%) | 7 (87.5%) | 10 (100.0%) | 7 (100.0%) |
| distal radius | 21 (84.0%) | 4 (50.0%) | 10 (100.0%) | 7 (100.0%) |
| manual phalanges | 22 (88.0%) | 7 (87.5%) | 8 (80.0%) | 7 (100.0%) |
| iliac crest | 24 (96.0%) | 7 (87.5%) | 10 (100.0%) | 7 (100.0%) |
| CVM | 22 (88.0%) | 6 (75.0%) | 9 (90.0%) | 6 (85.7%) |

### Fusion rate by element

Individuals with unfused features ranged from ages 7 to 20 years and fusing and fused features were observed in individuals aged 8 to 21 years. The fusing stage often occurred in a broader age range, for example, ages 12 to 21 years (radius) or 10 to 21 years (humerus & iliac crest). The hamate presented with a more extended developmental stage ranging from 8–20 years, verifying the hamate is the first element to fuse during puberty (Lewis et al. 2016). The total age range for each fusion category in the present study is represented in **Table 2**.

### Developmental timing

Pre-PHV—Some individuals were assigned to two pubertal stages based on the marker scores. Pre-puberty to initiation of puberty occurred in individuals aged 7 to 12. Estimated age for individuals solely in the initiation stage of puberty from this sample is as low as 8 years and as high as 15 years. Individuals in the acceleration/PHV category occurred between the ages of 10 to 20 years. The only feature graded as developing or developed during these stages was the hamate, as a fully complete hamate hook indicates the individual has reached PHV (Falys & Lewis 2020).

**Table 2.** Score by element and associated age ranges.

| | **Age range (years) observed in this sample (number of individuals in each stage)** | | |
|---|---|---|---|
| Element | Undeveloped | Developing | Developed |
| canine[1] | 7-12 (3) | 8-12 (1) | 12-20 (9) |
| hamate[2] | 10-12 (1) | 8-20 (4) | 8-21 (14) |
| humerus[3] | 8-15 (8) | 10-21 (10) | 13-20 (5) |
| ulna[3] | 7-15 (8) | 10-20 (9) | 10-21 (7) |
| radius[3] | 7-15 (9) | 12-21 (5) | 14-20 (7) |
| phalanges[3] | 7-20 (9) | 10-20 (5) | 12-20 (8) |
| iliac crest[3] | 7-20 (10) | 10-21 (11) | 12-20 (3) |
| CVM[4] | 7-15 (8) | 10-20 (10) | 12-18 (2) |

[1] F = undeveloped; G = developing; H = developed
[2] G = undeveloped; H/H.5 = developing; I = developed
[3] unfused = undeveloped; fusing = developing; complete = developed
[4] scores 1 and 2 = undeveloped; 3 and 4 = developing; 5 and 6 = developed

PHV—There were no individuals determined to be at the exact point of PHV. According to Lewis (2022), the PHV stage occurs in the shortest time frame, as it is a rapid phase of biological growth acceleration. Therefore, with a small sample and broad age range estimates, there is a low chance of finding an individual at this specific point in the pubertal process.

Post PHV—Individuals graded beyond PHV were all aged 12–21 years. Most of these individuals were graded to be at or in the deceleration phase, with few exceptions for individuals scored in two phases, such as PHV/deceleration and deceleration/maturation. The timing of PHV and deceleration in the sample is consistent with the theory that PHV is a set point of peak growth acceleration (Falys & Lewis 2020). Therefore, the transition from PHV to the deceleration phase occurs quickly. Conversely, the deceleration phase occurs over a longer period and thus is found in a larger age range of individuals for both males and females (see **Table 3**).

There were 29 missing/excluded features in this sample. All features were present in 22.2% of males, 55.6% of females, and 22.2% of indeterminate individuals (**Supplementary Table 1**).

## Variation in results between males and females

The total pre-PHV age range for estimated females is 10 to 15 years; the lower boundary is defined by the start of the prepuberty stage (10 years) and the upper boundary of pre-PHV is defined by the start of post-PHV stages (PHV/Deceleration; 15 years). The pre-PHV age range (10 to 20 years) in estimated males is broader than that of females. In this sample, male ulnae fused before their radii, whereas female ulnae fused after their radii. This indicates the females' radii fused at an older age range within

**Table 3.** Number of individuals in each pubertal stage by sex and age range.

| Stage | N | Age range |
|---|---|---|
| **Females** | | |
| Prepuberty | 1 | 10-12 |
| PHV/Deceleration | 2 | 15-20 |
| Deceleration | 3 | 14-20 |
| Deceleration/ Maturation | 4 | 15-20 |
| **Males** | | |
| Initiation | 1 | 12-15 |
| Acceleration | 1 | 12-20 |
| Acceleration/PHV | 1 | 10-14 |
| Deceleration | 1 | 14-21 |
| Deceleration/Maturation | 4 | 12-17 |
| **Indeterminate sex** | | |
| Prepuberty/Initiation | 2 | 7-12 |
| Initiation | 3 | 8-14.5 |
| Initiation/Acceleration | 1 | 12-14 |
| Acceleration/PHV | 1 | 10-15 |

the same pubertal stage as the males. Also, male phalanges fused earlier; however, there were no male individuals with phalanges scored in the fusing stage. As such, small sample sizes may affect these observations. All other features, including canine, hamate, humerus, ulna, and ilium, appear consistent with pubertal developmental timing between sexes.

## Discussion

### Differences between the estimated sexes

Biological and bioarchaeological literature indicate pre-adult (prior to reaching adult fusion—less than or equal to 20 years of age) females tend to experience more rapid, earlier development, while pre-adult males have a longer growth period, which leads to males achieving a greater height and increased muscle mass (Bareggi et al. 2022; Doe et al. 2022; Bogin et al. 2018; Tanner 1989). This is consistent with this sample and corresponds with the males having a comparatively prolonged growth period while reaching peak height velocity.

### Inter-site comparison

When compared to the Amarna population, a New Kingdom period sample from Egypt (Dabbs 2024), Tombos individuals appear to have reached the earlier stages of puberty at younger ages (ages 10 to 12 in Tombos compared to age 15 in Amarna). The delayed fusion rate at Amarna is suggested by Dabbs (2024) to be due to significant stress experienced by the community, shifting the established baseline of their growth and development. Many compounding variables such as disease and available resources could have significantly altered developmental timing (Lewis et al. 2016; Dabbs 2024). High levels of stress were evident in the bioarchaeological record at Amarna including physical trauma, nutritional deficiencies, and possible endemic infectious diseases. Indicators of growth and development disruptions were also present throughout the pre-adult sample, resulting in low adult stature and linear enamel hypoplasia (Dabbs 2024). Such health trends were generally absent in the Tombos sample, suggesting the divergence between these samples could be due to access to resources and community differences (Buzon & Smith 2023).

According to prior clinical and bioarchaeological research, PHV precedes menarche, the first occurrence of menstruation in females, by 1 to 2 years (Evelath & Tanner 1990; Lewis 2022; Shapland & Lewis 2013). Considering the number of Tombos females present in the deceleration and deceleration/maturation phases, it is possible to associate menarche occurring at ages 15–20. In the Amarna sample, menarche reportedly occurred between ages 14 to 19 years (Dabbs 2024). While maturation occurred within a similar age range, the time from PHV to menarche varied between populations. The Amarna sample, for instance, displayed a shortened deceleration phase, potentially due to catch-up growth (Dabbs 2024; Bareggi et al. 2022). This phenomenon represents a pattern of extended adolescence (Lewis 2022; Nilsson et al. 2005; Tanner 1963). A complete understanding of the growth and fusion discrepancies between Amarna and Tombos cannot be fully evaluated, as published data from Amarna sample was only provided the PHV phase and beyond; additionally, the timing of the onset of puberty, associated with the complete development of the hamate hook, was not presented. The elements analyzed at Amarna displayed a significant delay in fusion, resulting in PHV, deceleration, and maturation phases occurring at overlapping ages (14 to 19 years, Dabbs 2024) compared to the Tombos sample, which exhibited evenly distributed age ranges for initiation and acceleration to deceleration and maturation. The composition of the Tombos community with immigrant and local individuals may also have affected puberty; additional studies of groups from the larger ancient Nile Valley region may provide additional insight into regional variation.

Due to the limited time frame of use for the Amarna site (two decades versus hundreds of years at Tombos), it is difficult to provide a holistic comparison between these two populations. Based on information from Egyptian textual sources, it is assumed that menarche was associated with a transition to adulthood in Amarna and Tombos. This transition would have been significant as the gendered jobs and social expectations likely would have greatly increased for the individual experiencing puberty. Because particular biological ages with the correlating social transition are not specifically documented in ancient Egyptian texts, using puberty analysis to estimate the time range of puberty can provide historical and anthropological context to the Tombos population in the New Kingdom and early Napatan periods. Studies from other regions and time periods reveal the variation across populations. For example, age of menarche is similar in Upper Paleolithic Europe (16 to 17 years, Lewis et al. in press) and pre-Roman Italy (14 to 17 years, Bareggi et al. 2022) while Blom and colleagues (2020) find a much later menarche (19 to 20 years) attributed to a delay in puberty completion due to hard physical work and pathological conditions in the Dutch post-medieval community.

Attallah and colleagues (1983) report on the average age of menarche in Khartoum, Sudan schoolgirls from three different groups (high, middle and low income). Menarche began as early as 10.5 years, with average age of menarche at 13.35, 13.85 and 14.06 years for the three groups, respectively. Higher average age of menarche in the lowest income group is associated with larger family size suggestive of a direct environmental effect regarding nutrition and standards of care. In comparison, Attallah and colleagues (1983) also report average age of menarche at 12.6 for higher income girls and 13.9 for lower income girls in Egypt. More recently, Hemmeda and colleagues (2025) report menarche between ages of 9 and 15 years, with a mean age of 12.23 years for girls from Omdurman, Sudan, confirming the secular trend of younger puberty internationally over the last few decades. Pubertal timing is associated with adiposity in epidemiological and genetic studies, especially in girls. Higher body mass index is correlated with earlier onset of puberty (Brito et al. 2015). Thus, changing environmental conditions affecting nutrition likely account for the earlier age ranges of menarche in modern populations in comparison with the archaeological samples.

## Methodological considerations, limitations, and future considerations

The canine and hamate were the most commonly absent elements and the iliac crest in this sample was most often found fragmented. If fragmentation affected reliable observation, that feature was excluded; if fewer than three features were present, the individual was excluded from the sample. The missing data have the potential to affect the variability of the male and indeterminate sex samples, considering different elements often indicate different stages of puberty. If elements that indicate earlier stages of puberty are absent in an individual, the pubertal stage may be scored as reaching later stages of puberty. Therefore, relying on only one of the elements to assess pubertal timing could potentially skew the estimated stage of puberty to an earlier or later stage. Fortunately, within this sample, all other features present were consistent with the estimated pubertal stage. Bilateral skeletal fusion asymmetry was taken into consideration, as it has been documented in other pubertal assessment studies (Lewis et al. 2016). In this study, there were two ulnae, one humerus, and multiple manual phalanges, that were assigned the grade of later stage of development between the asymmetrical elements.

Much of the research on pubertal timing methodology is based on modern, medieval, and post-medieval populations (Lewis 2022) from similar geographical areas; ancient populations may not correspond to these standards. Additionally, the Tombos sample size is limited, and pubertal timing would be more evident in a larger sample with a more equal estimated sex distribution. Considering the discrepancy between modern and historical samples, it may be beneficial to expand the age range attributed for analysis. Maturation timing has shifted over time and can vary between populations (Blom et al. 2020; DeWitte 2020; Lewis et al. 2016). The pubertal stages used for analysis were originally established in modern populations, combining chronological and possible social factors assigned to an individual based on visible external changes (Lewis 2022). Since analysis of soft tissue and hormone changes cannot be done on skeletal remains, the elements assessed in pubertal studies may provide more clarity to the age discrepancies seen between studies. The age range selected for assessment should be broadened to elaborate on this sample's social age and account for the possible adjustment in physical maturation during ancient periods. Due to the high significance puberty/menarche holds in social life, tracking its timing in skeletal remains is important; grasping the timing in different populations can provide further data when there are fewer elements present for analysis.

## Conclusion

The examination of pubertal growth in bioarchaeology research holds significance due to its capacity to offer insight into important social transitions in a pre-adult's lifetime, such as age at marriage, that may be linked to biological maturity. Measuring several pubertal elements enhances reliability by providing a holistic view of growth and development. For the Tombos sample, deceleration is achieved as early as 12 and as late as 21 and females reached menarche between 15 to 20 years; the broad ranges are likely due to preservation of markers and precision of aging techniques. Because most pubertal timing results are compared to modern biological trends in puberty, the expectations of pubertal benchmarks in this sample may be altered due to the time period and geographical area. Understanding the established benchmarks can provide further insight into the social timings of important life phases. While females reached the later stages of puberty earlier, they stayed in these stages for a longer period of time. This provided females with an extended period for growth and development and could have led to female social expectations beginning at a younger age. Males approached later stages of puberty approximately two years later; however, maturation was reached around the same age. It is not clear if this is due to the broad age range of males in the maturation stage or a chronological discrepancy.

Ancient archeological samples introduce limitations that may impact the validity and generalizability of these findings, including smaller sample sizes, taphonomic damage or missing elements, and lack of medical/archival records for sex, age, and developmental context. More multidisciplinary research in broader archeological contexts would assist in improving the standardization in methodology and analysis. The information gained from this population spanning around 700 years is significant in providing insight into how puberty and social age manifested in an ancient Nile Valley community.

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