Wolf-Rüdiger Teegen

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During the NekroPergEol project[1], 60 human individuals from Hellenistic Pergamon, Elaia and Aigai[2] were studied from an anthropological and, in particular, a palaeopathological point of view. These burials consisted mainly of inhumations (n = 43), to a lesser degree also of cremations (n = 17).

Materials and Methods

The human remains studied belonged to individuals of different social status. They range from those buried in monumental tumuli like Seç Tepe (n = 2) and Kyme (n = 1), or smaller tumuli (Pergamon: n = 3) possibly representing the élite at a level below the Pergamean kings, or the level of the local élite in Aigai (n = 15) and Elaia (n = 1), or the level of the so-called ›middle class‹ (Pergamon: 3; Elaia: 6, Aigai: 18), or, finally, people who cannot really be classified socially (Elaia: 8). Additionally, 3 stray finds of human bones from Pergamon were also examined.

The skeletons and cremated remains were studied with macroscopic and low magnification microscopic techniques. Sex and age determinations followed the recommendations by the European Association of Anthropologists[3]. Metrical data were recorded according to Rudolf Martin[4] and Günter Bräuer[5]. Where possible, body heights were calculated according to Karl Pearson[6]. Epigenetic traits were recorded according to Karin Wiltschke-Schrotta, Gertrud Hauser, Gian Franco De Stefano, and Kurt W. Alt[7]. Pathological alterations were recorded according to Michael Schultz[8], Donald Ortner[9], and Wolf-Rüdiger Teegen[10].

In accordance with the responsible museums and the Turkish Ministry of Culture and Tourism, samples were taken and exported for radiocarbon dating and stable isotope analysis for dietary reconstruction.

1 I am grateful to the DFG (Bonn-Bad Godesberg), the ANR (Paris), the LMU Munich, and the German Archaeological Institute at Istanbul and Berlin for financial and other support. The teams at Pergamon, Elaia, and Aigai gave invaluable help, in particular Ute Kelp.

2 For the archaeological background of these burials see the following contributions in this volume: Pirson – Verger; Pirson; Kelp et al.; Verger – Sezgin – Pace; Kelp – Pace; Van Andringa.

3 Ferembach et al. 1980; Rösing et al. 2007.

4 Martin 1928.

5 Bräuer 1988.

6 Pearson 1899.

7 Wiltschke-Schrotta 1988; Hauser – De Stefano 1989; Alt 1997.

8 Schultz 1988; Schultz 1993.

9 Ortner 2003.

10 Teegen 2004.

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Results

Taphonomy

A major problem during the osteo-archaeological investigations was the state of preservation. Sarcophagus burials were, as the name implies, mostly badly preserved[11]. This was the case not only with the tumuli burials from Pergamon, but also with the stone cist burials from the late Hellenistic circular building at Aigai[12]. The careful study of their remains revealed, however, new data on demography, health and disease. In some cases, the cremations gave more insights into the health status of the deceased than the badly preserved inhumations.

Radiocarbon Dating

For this project, several individuals from Pergamon, Elaia, and Aigai were radiocarbon-dated by the Isotope Laboratory of the University of Groningen (the Netherlands). All dates were re-calibrated[13] using the latest OxCal version 4.4.4, and thus the IntCal20 atmospheric curve[14]. The calibrated radiocarbon dates can be seen in Figure 1. The burials from the circular building at Aigai date between the 4th/3rd century BC and the late 1st century BC/AD[15]. The Roman burial near the stone cists 8 and 9 dates to around 100 AD. There is also an early Byzantine reuse of a tomb which dates to around 500 AD.

The two individuals from the Bouleuterion at Aigai[16] date around 100 and 200 AD. As far as we know, they are not from proper burials; only cranial fragments were found. Of particular importance are the burials from Tumulus 001 at Aigai (see below). Their radiocarbon dates are between 700 and 400 BC, around 400 BC, and between 400 and 200 BC. This means that they belong to the Archaic, Classical and Hellenistic periods.

In this context, stray finds of probable Hellenistic date from the eastern slope in Pergamon were also studied (fig. 1). From a cistern in the so-called workshop one skull fragment of an adult individual (PE09 Zi 01, 07) from a possible late Hellenistic context was dated, as were two fragments from the area of the presumed rock sanctuaries on the eastern slope: They are fragments of a left adult tibia (PE10 So05, 10, 2 ff.) and a fibula fragment (PE10 Ar 05, 62). Both fragments belong to adults. The fibula was not datable due to a lack of collagen, while the tibia fragment dates to the 2nd/1st century BC. The skull fragment dates, surprisingly, to the middle Byzantine period, around 1000 AD. This fragment indicates that there were disturbances in the filling of the cistern. Stratigraphically, the skull fragment was found with late Hellenistic ceramics from the 1st century BC near to the bottom of the cistern. There is another skull fragment from the same layer, belonging to a child; due to conservatory reasons, no samples were taken.

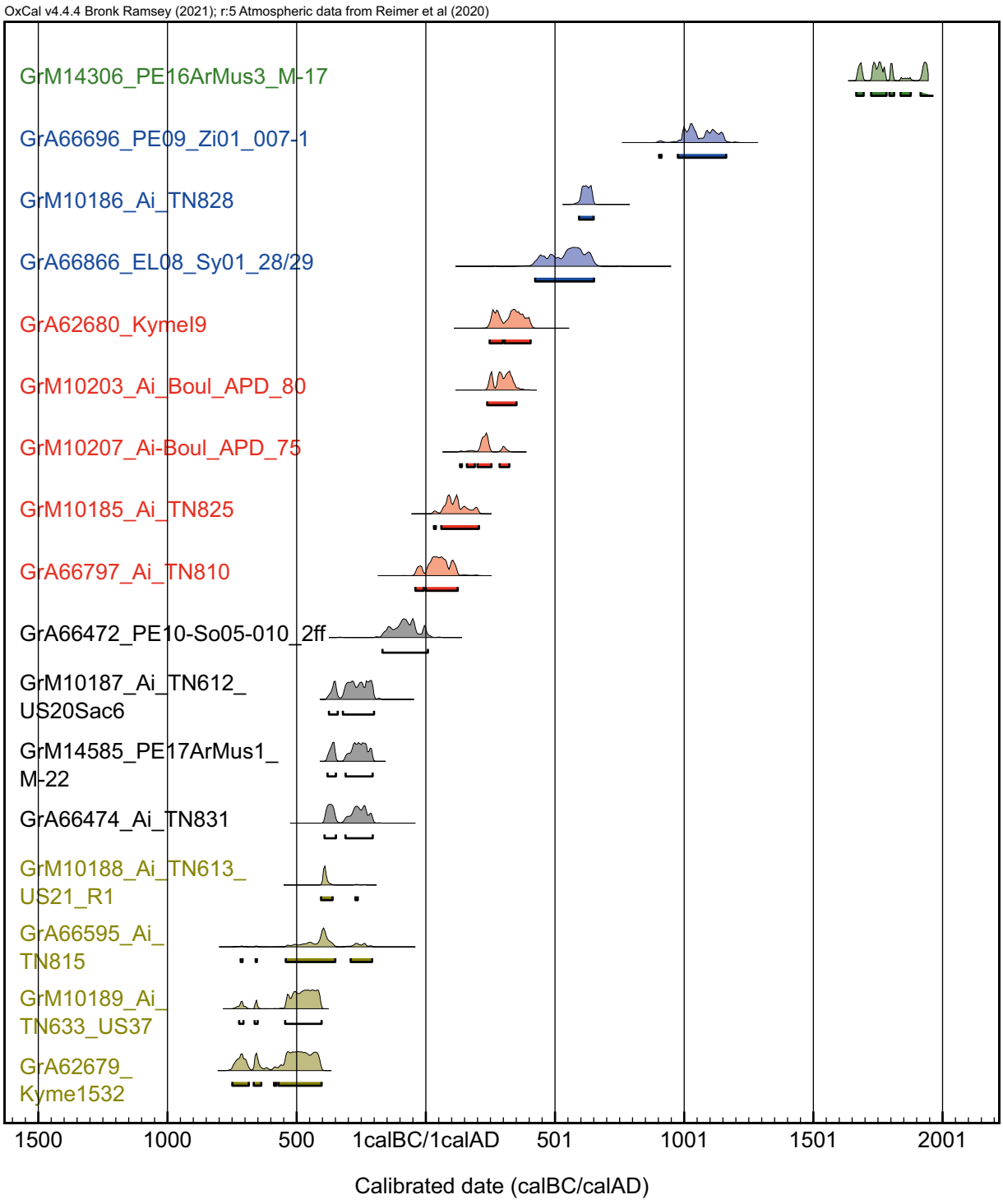
The dates obtained underline the importance of radiocarbon dating for further chronological understanding. Without them, the Byzantine inhumations would not have been identified.

Routine radiocarbon dating is, therefore, a prerequisite for modern funerary archaeology in general and for multiple burials and stray finds in particular. It gives insights into burial sequences, and is also a prerequisite for the identification of the reuse of graves in later times.

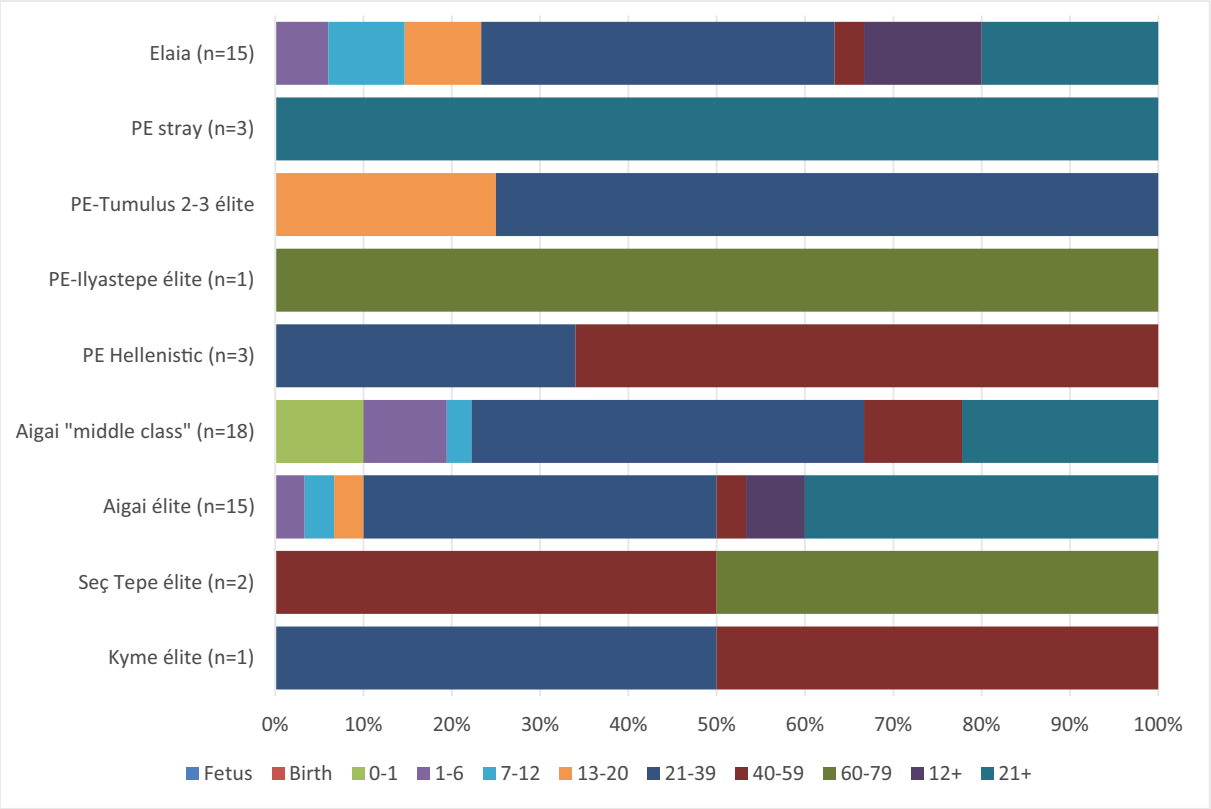
Mortality

The overall mortality rates are given in Figure 2. Due to poor preservation, only several individuals could be determined as adult (21+ years). However, all age classes from the infant up to the elderly (60+ years old) individual are present (fig. 2). The age of the İlyastepe male was determined by histomorphology by Michael Schultz and Jan Nováček as 65–75 years[17]. The macroscopic age determination revealed only a late mature individual (55–65 years)[18]. This underlines the importance of the histomorphological age determination. It is, however, a destructive method which needs sampling and thin section preparation. It is, therefore, not a field method.

11 Cf. Teegen et al. 2018.
12 See Appendix 1.
13 Originally, the radiocarbon dates were calibrated in 2018 with OxCal version 4.3.2, using the IntCal13 atmospheric curve (Reimer et al. 2013). This was redone in July 2022.
14 Reimer et al. 2020.
15 See Appendix 1 with fig. 14.
16 See Appendix 1.
17 Schultz – Nováček 2011, 171.
18 Teegen 2011b, 160.



1 NekroPergEol Project. Radiocarbon dating of (presumably) Hellenistic individuals from Pergamon, Aigai, Kyme, and Elaia. Radiocarbon dating revealed also Classical (brown), Roman (red), Byzantine (blue) and Ottoman individuals (green)



2 NekroPergEol Project. Overall mortality of 60 (presumably) Hellenistic individuals from Pergamon, Aigai, Kyme, and Elaia

Only 16 of the 60 individuals studied could be sexed in the field (fig. 3). This was due to poor bone preservation. Hopefully, more individuals will be sexed during the analysis of the recorded dental and bone measurements.

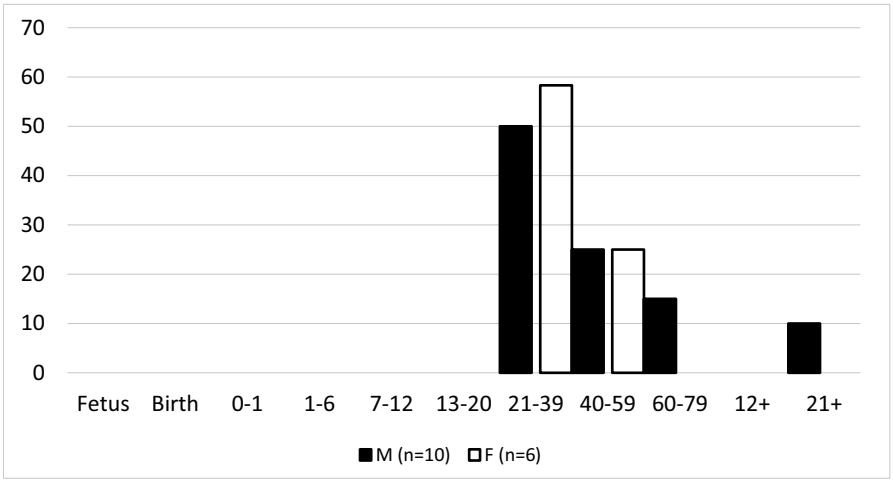
There is a sex difference in mortality, which is to be expected. Females tended to die earlier, at less than 40 years of age, while the males sometimes reached a high age (approx. 65–75 years) (fig. 3).

Pathologies

At all the sites mentioned there are not only Hellenistic burials but also those from the Roman and Byzantine periods present. They were mostly studied in other projects, such as the South-East Necropolis excavation in Pergamon[19], or the ongoing TransPergMikro project[20]. The Byzantine burials from the ›Stadtgrabung‹ were studied by Michael Schultz and Tyede Schmidt-Schultz[21]. Other Byzantine burials from Pergamon were recently studied by the author[22]. This will allow us to compare the pathological findings from the NekroPergEol project across a much broader chronological frame. This is of particular interest for the badly preserved burials at Aigai[23].

The Hellenistic people from Pergamon, Elaia, and Aigai studied so far suffered from a wide range of diseases – Skull: trauma and inflammatory processes of the external lamina of the skull, inflammatory processes of the internal lamina of the skull, e. g. meningitis or haemorrhages (fig. 20), inflammatory processes of the intracranial sinuses (Sinus sagittalis superi-

19 Teegen 2017.
20 Pirson et al. 2020, 156–159; Teegen 2020; Teegen 2022c; Teegen – Doğan 2021; Teegen – Doğan 2022; Teegen – Doğan 2024.
21 Schultz – Schmidt-Schultz 2017 (with references).
22 E. g. Teegen 2014, 155; Teegen 2016a, 194 f.
23 See below, in particular Appendix 1.



3 NekroPergEol Project. Sex and Age distribution of 16 out of 60 individuals studied

or, Sinus transversi, Sinus sigmoidei), inflammatory processes of the paranasal sinuses (Sinus frontalis [fig. 4], Cellulae ethmoidales, Sinus maxillaris, Sinus sphenoidalis [fig. 16], the middle ear and the mastoid process). – Teeth and jaws: Dental caries (fig. 5), abscesses (fig. 5), dental calculus (fig. 5), parodontitis (fig. 5), intra vitam tooth loss (fig. 6). – Unspecific stress markers: Linear (fig. 7) and point-like enamel hypoplasias, root hypoplasias or periradicular bands (figs. 7. 9. 21), Harris' lines, Cribra orbitalia. – Postcranial skeleton: Diseases of the lower respiratory tract (fig. 10), degenerative diseases of the spine (fig. 11), and the large and small body joints (fig. 17), enthesopathies (fig. 18)[24], and fractures of the ribs, and lumbar vertebra transverse processes (fig. 12). Some of these diseases or symptoms are discussed in the following.

Unspecific Stress Markers

Of particular importance for a social interpretation are developmental disturbances of the teeth in the form of enamel and dentine defects and of the long bones (Harris' lines) during childhood. Enamel defects of the teeth, such as linear enamel hypoplasias[25], are often still visible in adulthood (fig. 7). Both enamel as well as dentine defects could be found in all social strata from Hellenistic times at Pergamon, Elaia and Aigai. Unfortunately, these defects are not pathognomic for certain diseases. Therefore, they can only be interpreted as unspecific stress markers. They are often connected with diseases of the intestinal tract[26], e. g. during the weaning process. Their presence and the time frame in which they developed were recorded for every tooth (cf. fig. 8).

The tooth roots, which develop later than the enamel of the tooth crown, can also show development disturbances in the form of root hypoplasias or periradicular bands (fig. 7. 9. 21)[27]. Recording and analysing these dentine defects can expand the time frame for developmental defects: while crown development ends at approximately 12 years (completion of the M3 crown), root development ends at approximately 15 years (completion of the M3 roots)[28].

As a working hypothesis, one can postulate that the children of the élite suffered from several diseases in childhood. However, they survived – in contrast to many poorer children[29]. This was probably possible due to better access to resources for the élite: special diet, better living conditions, medical care and attention. For the Hellenistic burials from the Aeolis this is, however, only a hypothesis. Similar observations can be made also in other élite burials in the Old World, e. g. from Late Antiquity or from the Middle Ages[30]. The presence and sometimes also a high inci-

24 See Appendix 1.

25 For pathogenesis see e. g. Berten 1895; Schultz et al. 1998, and Hillson 2014 (each with further references).

26 Cutress – Suckling 1982; Suckling 1989; Jälevik – Norén 2000; Seow 2017.

27 Teegen 2004; Teegen 2022b, 108.

28 Ubelaker 1989; Scheuer – Black 2000; Schaefer et al. 2009.

29 This can be seen as the so-called osteological paradox (Wood et al. 1992); see also DeWitte – Stojanowski 2015.

30 In detail: Teegen – Schultz 2017.

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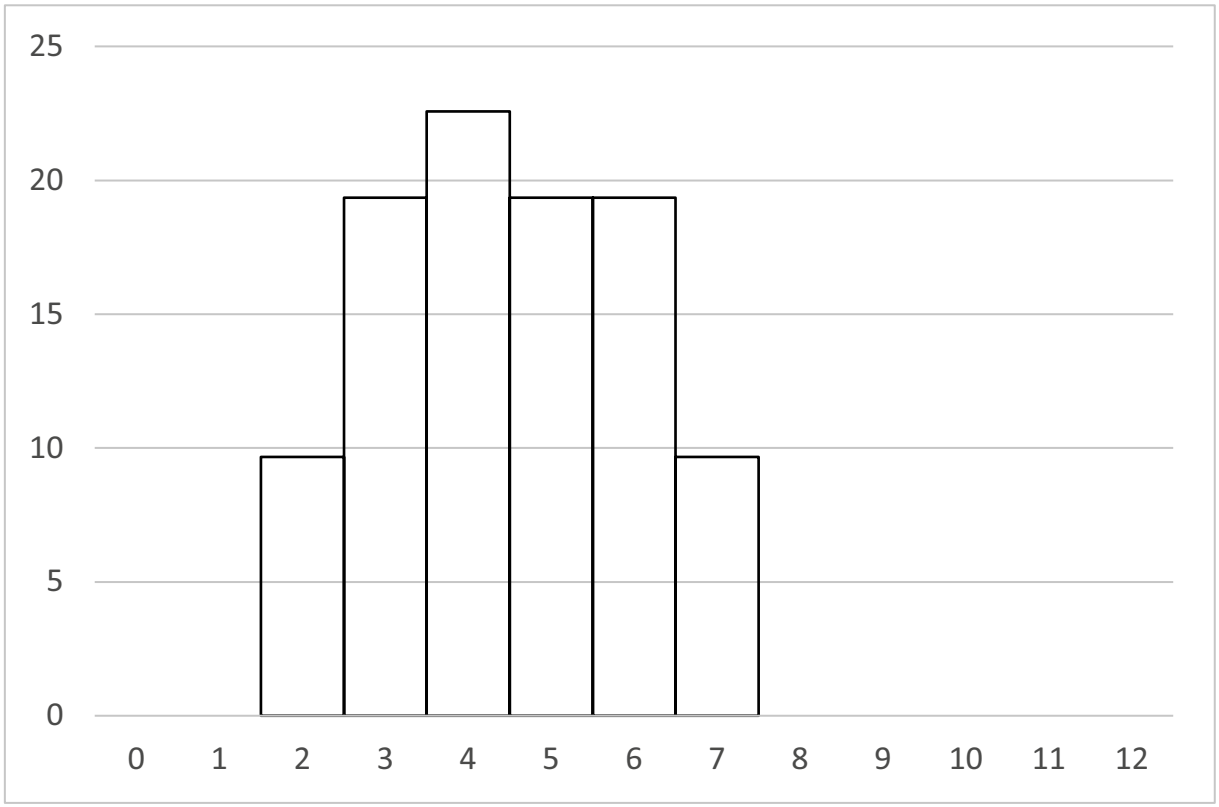
4 Pergamon, İlyastepe, Main burial. Male, 65–75 years. Left frontal sinus, seen from the inside. Slight new bone formation is indicating a well healed frontal sinusitis. Scale 1 cm

5 Aigai, Bouleuterion. Male, 25–35 years (AI05-Bouleuterion-APD), with dental abcesses, dental caries, dental calculus, parodontopathies, and linear enamel hypoplasias (arrow heads). Scale 1 cm

6 Aigai, Urban necropolis, Tumulus 001 Cremation of an adult individual. Intra vitam tooth loss. Scale 1 cm

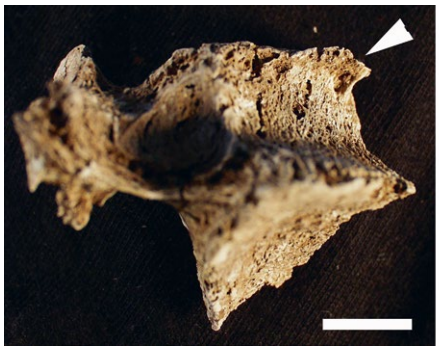
7 Pergamon, Lower City, South necropolis. Female, 25–35 years (PE17-Ar-Mus2_M-6), with linear enamel hypoplasias (arrows) and root hypoplasia or periradicular band (arrow head)

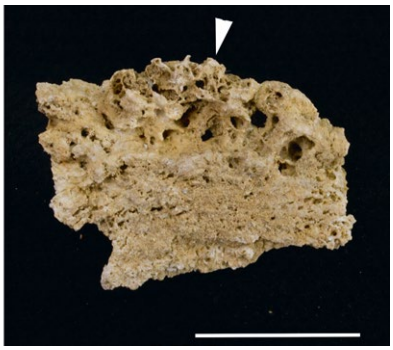


8 Pergamon, Lower City. Female, 25–35 years (PE17-Ar-Mus2_M-6). Developmental age of linear enamel hypoplasia (X-axis) and number of teeth with enamel defects of a specific age

9 Aigai, Urban necropolis, Tumulus 001. Dental root with root hypoplasia or periradicular band (arrow heads) and hypercementosis (arrow). Scale 1 cm

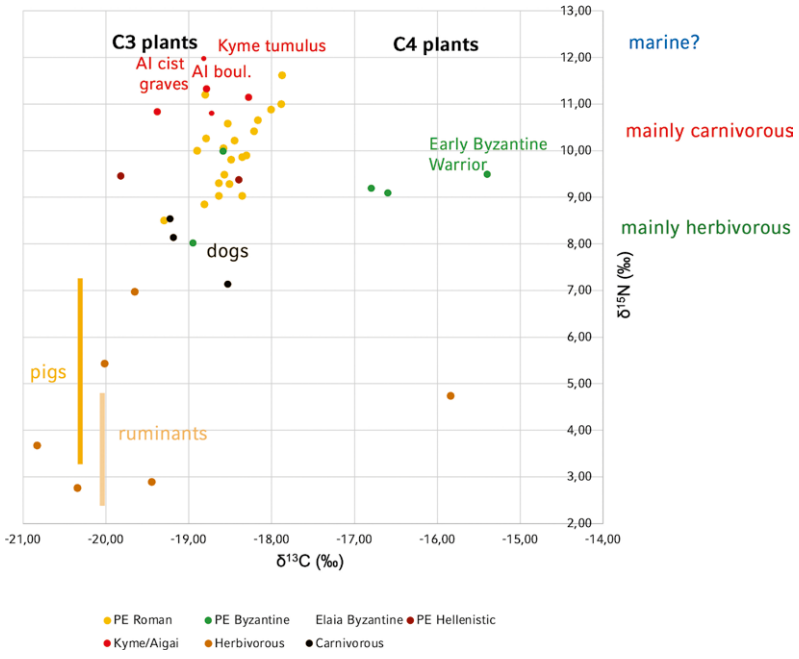
10 Pergamon, Lower City. Male, 55–65 years (PE17-Ar-Mus3_M-17), with new bone formation on the visceral side of a left rib





11 Left: Aigai, Tumulus 001, Cremation of an adult individual. Thoracic vertebra in caudo-lateral view with liping due to degenerative joint disease. Right: Elaia. Female, 30–49 years (EL08-Ar01-008). Lumbar vertebral fragment in cranial view with severe liping due to degenerative joint disease. Scale 1 cm

12 Elaia. Probable male (M > F), 30–35 years (EL08-Ar01-013), with healed fracture of a left transverse process of a lumbar vertebra



13 NekroPergEol Project. Carbon ($\delta^{13}C$) and nitrogen ($\delta^{15}N$) stable isotope data for diet reconstruction. The signature for herbivores includes also omnivorous pigs. Vertical lines for pigs and ruminants are indicating the span of their $\delta^{15}N$ values. Data from Roman and Byzantine Pergamon are including also analyses from Müldner et al. 2011 and Propstmeier et al. 2017

dence of dental defects could possibly correspond to the presence of wet nurses in antiquity. As we know from different sources, both from the Greek and the Roman world, the mothers of the élite would not breastfeed their offspring. Wet nurses (nutrices) are well known in ancient societies[31]. We further know from ancient literature that the emotional bond between the wet nurse and the children was sometimes closer than with their own mother[32]. Isotopic data from Sagalassos indicates that breastfeeding could continue until 2–4 years[33]. This can probably be correlated with a peak in enamel hypoplasia formation in this age. The elderly male from the tumulus on the İlyastepe showed enamel hypoplasia, formed in the fifth and sixth years of age[34]. In this individual, all other possible hypoplasias were not preserved due to severe dental attrition.

Diseases of the skull, such as inflammatory processes of the paranasal sinuses, were quite common in the Hellenistic people studied (figs. 4. 16). They were found, as mentioned before, not only at the top of the society, but also in all other social strata. They were also observed in some cremations.

The presence of infections of paranasal sinuses indicates poor heating during winter in all habitations, not only in huts and small houses, but also the palaces and noble houses. Furthermore, these diseases also indicate indoor air pollution caused by heating, but also by cooking. It can be expected that females and children suffered more under these conditions. Unfortunately, this hypothesis cannot be tested due to the limited number of cases and rare sex determinations (see above).

In contrast to the upper respiratory tract, which is regularly affected by inflammatory processes, the lower tract is more rarely affected. There are small new bone formations on the visceral surface of the ribs (fig. 10)[35]. They are caused either by a well healed pleurisy and/or are the result of the intercostal muscle attachments. Regarding the latter, the intercostal muscle attachments show slight micro traumata, possibly due to body movements and/or a severe cough.

Indications for infectious diseases – with the exception of dental caries and inflammations of the paranasal sinuses – are very rare at ancient, Byzantine, and Ottoman Pergamon. One of the rare examples is a 37–54 year old male from the plot 191 Ada 8 Parsel burial M-321 (PE16-Ar-Mus-03) in the South Necropolis[36].Thick layers of new bone formation were found on the visceral surfaces of his left ribs, indicating pleurisy. Radiocarbon dating revealed, however, an Ottoman individual[37]. DNA testing for Mycobacterium tuberculosis remained unsuccessful[38].

Archaeological findings and radiocarbon dating revealed Archaic[39] and Hellenistic as well as Roman and Ottoman burials within the plots 191 Ada, 7 Parsel (PE17-Ar-Mus-01) and 191 Ada, 8 Parsel (PE16-Ar-Mus-03) in the north-eastern part of the former South Necropolis of ancient Pergamon.

The postcranial skeleton shows degenerative joint diseases of the body joints and the spine. Due to the poor preservation, no quantitative analyses are possible. The clearest alterations can be observed in the vertebrae, as shown by two cremated fragments from Elaia and Aigai (fig. 12).

Present are also alterations of the ligaments, so-called enthesopathies, which indicate repetitive use of certain muscles, such as the so-called ›tennis‹ (fig. 18) or ›golfer's elbow‹[40].

Trauma is rare in our sample: The cremation of an adult male from Elaia (EL08-Ar01-013) showed a healed fracture of the left transversal process of a lumbar vertebra (fig. 12). Such fractures are rare in the prehistoric and ancient osteoarchaeological record. Furthermore, they can be easily overlooked. They can be caused by an accident or by maltreatment. In the living person, the transversal processes are well shielded by muscles, in particular the M. ilio-psoas[41]. In recent traumatology, they are not so rare. C. D. Miller and co-workers observed a frequency of 22% in 191 lumbar fractures[42]. They also found that lumbar transverse process fractures are often combined with serious internal injuries.

Another adult from Elaia (EL08-Ar01-004) showed a well-healed rib fracture. Rib fractures are quite common and are often caused by accidents, interpersonal violence, but also by diseases of the lower respiratory tract, possibly by severe coughing. So-called ›cough fractures‹ can also be observed today[43].

31 Sparreboom 2014 (with references).
32 Carroll 2014, 166 with further references in n. 56.
33 Fuller et al. 2012. Breastfeeding and the weaning process could be studied in detail by incremental analyses of the dentine, e. g. of the first permanent molar (cf. Cocozza et al. 2021).
34 Teegen 2011b, 152.
35 Radiocarbon dating (see fig. 1) revealed an Ottoman date of this individual PE17-Ar-Mus3_M-17. For similar alterations see Nováček et al. 2017, 331 fig. 20, 16.
36 Teegen 2022c, 374 fig. 82.
37 Teegen – Doğan 2022, 375–376 fig. 84–85.
38 Pers. comm. by N. Ezgi Altınışık and Mehmet Somel, ancient DNA lab, Middle East Technical University Ankara (May 2024).
39 Pirson – Ustura 2022.
40 For a discussion see below in Appendix 1.
41 Nicoll 1949, 378.
42 Miller et al. 2000.
43 Hanak et al. 2005.

The Burials from the Tumuli

The best data was obtained from the main burial from the İlyastepe. Macroscopic age determination showed a late mature individual, while histological analysis of long bone thin sections revealed a much older individual of 65–75 years of age. This is not uncommon, due to the fact that age determination from cranial sutures generally underestimates older people.

The palaeopathological investigations revealed severe dental attrition, enamel hypoplasia, inflammatory processes of the paranasal sinuses (fig. 4). The latter one is particularly interesting. It points to a poorly heated palace in the upper town. Heating is poorly documented. Braziers[44] were probably the only form of heating. They represent open fires with smoke development and, as a result, indoor air pollution. This would further enhance the inflammatory processes of the paranasal sinuses. The socially distinguished man from the İlyastepe also suffered from mastoiditis, which often follows an inflammatory process of the middle ear region.

Diet and Related Diseases

Diet leaves very different traces in the osteoarchaeological record, either macroscopically (e. g. through dental attrition, dental diseases, and so on) or microscopically (e. g. micro traces of attrition, micro traces in enamel composition, and so forth).

Dental caries (fig. 5) is present in individuals from all social classes. This reflects not only their carbohydrate intake but also a low level of dental hygiene. Furthermore, all adults with preserved teeth showed dental calculus layers. This is also linked to poor dental hygiene. Dental plaques, which are not archaeologically preserved, and their bacterial load as well as the resulting dental calculus are responsible for gingivitis and, later, for the reduction of the bony alveolar rims (parodontitis).

Dental caries leads to the destruction of enamel and dentine – and therefore often to the destruction of the entire crown, as seen in a Roman burial from the Bouleuterion at Aigai (fig. 5). Due to the cariogenic opening of the pulpa cavity, microorganisms could penetrate the root canal and cause an abscess at the root tip. Sooner or later, this leads to intra vitam tooth loss. This is also clearly visible in cremations (fig. 6). The abscess cavities can also be found in cremated jaws[45].

Stable Isotopes

Furthermore, the composition of the stable carbon, nitrogen and sulphur isotopes ($\delta^{13}C$, $\delta^{15}N$, $\delta^{34}S$) in bones give important information about the diet in ancient times. Due to different turnover rates, bones give an overall picture of the diet over the last ~ 5 years (ribs)[46] or > 20 years (long bones)[47]. The consumption of animal protein either in the form of meat or fish is reflected by an elevated $\delta^{15}N$ content (meat) or an elevated $\delta^{13}C$ and $\delta^{34}S$ content (marine resources). Furthermore, meat and fish consumption is strongly wealth dependent, as evidenced by Diocletian's edict on maximum prices from 301 AD[48]. Here, we see different prices for different species[49]. The age of the animals is also important (young vs. old)[50]. This can be directly determined by archaeozoology from the waste of houses of different social categories[51]. Written sources from ancient literature (e. g. Petronius' Cena trimalchionis)[52], medicine (in particular Galenos' De alimentorum facultatibus)[53] or law provide further information.

At the Isotope Laboratory of the University of Groningen (the Netherlands), the stable carbon ($\delta^{13}C$) and nitrogen values ($\delta^{15}N$) were also determined. The results clearly show that the people investigated consumed mainly C_3-based alimentary resources.

C_3 wild and domesticated plants incorporate the CO_2 from the air in the so-called Calvin cycle. They are the predominant plant type in the Old World and therefore also in the Mediterranean. In addition, domestic and wild animals feed on them. They therefore show the C_3 signal in their stable isotope composition (fig. 13). So-called C_4 plants are rare in the an-

44 An example from the Lampon house in Priene: Rumscheid 2008.

45 E. g. Propstmeier et al. 2017, 240 fig. 15, 2.

46 Fahy et al. 2017. New investigations by Quinn 2024 have shown a much higher average turnover rate of 13–23 years.

47 Hedges et al. 2007.

48 Edictum Diocletiani de pretiis rerum venalium: CIL 3, 1926–1953.

49 Blümner 1893; some examples in Gerlach 2001, 108, e. g. peacock: 300 denarii (Diocl. Edict. IV 39 f.), pheasant, hare: 200 denarii (Diocl. Edict. IV 17 ff. 32).

50 A pound of pork costs 12 denarii (Diocl. Edict. IV 1a), while a pound of the piglet costs 16 denarii (Diocl. Edict. IV 46).

51 For general aspects see deFrance 2009.

52 Schmeling 1970, tab. 1 (menu and wine list).

53 Grant 2000.

cient Mediterranean. The most important C_4 plant is millet (Panicum miliacaeum). In Pergamon, a C_4 signal was only detected in the early Byzantine warrior[54] (fig. 13). There is one bovine from Pergamon which shows a high $\delta^{13}C$ value. Here, it is possible that the animal's fodder consisted of C_4 plants.

For the poorer strata of society, we would expect a diet based mainly on plant resources. Meat was probably only available at religious or communal feasts. The well-known Mediterranean Triad consists of (barley) pulses or bread as a carbohydrate source, olive oil as a fat source and beans as the most important plant-based protein source. The famous 2nd century physician Galenos, who influenced Old World medicine until the middle of the 19th century AD, described the above-mentioned barley-bean soup as a fortifying diet for (Pergamean) gladiators[55]. The main sources of liquids are water, diluted vinegar or wine, beer and milk. Water and beer pose particular health hazards due to contamination by micro-organisms, especially in summer. As Walter Scheidel and others have shown from funerary inscriptions, mortality in the Mediterranean is highest in summer – very likely due to gastrointestinal diseases caught, for example, from contaminated water or food[56].

The $\delta^{15}N$ values for people living mainly on plant resources will be between 7.8 and 9.8. This is clearly visible on the graph.

Individuals with a mainly carnivorous diet, i. e. a regular consumption of meat, will show a $\delta^{15}N$ value between 9.8 and 10.8 or higher.

The individuals from the monumental tumulus at Kyme and the cist graves at Aigai showed $\delta^{15}N$ values of around 11 or more (fig. 13). This indicates a diet based on animal proteins in the form of meat and/or dairy products. So far, we have no further stable isotope data. Samples from four Byzantine burials at Aigai have not yet been analysed.

In summary, the limited data available so far for late Classical and Hellenistic times indicates a high protein intake for the élite and an overwhelmingly plant-based diet for the middle and lower social strata. Our data is clearly comparable with the results from Classical to Hellenistic Sagalassos[57], where the rich burials are still missing.

Body Height

Due to poor bone preservation, body height could only be reconstructed for two individuals, one male and one female: The reconstructed heights using the formulas of Pearson are approximately 160 cm for the male and 147 cm for the female. This is quite similar to the calculations for individuals from the Roman South-East and South necropoleis in Pergamon[58].

In his literature survey on stature in ancient Anatolia, Aytek gives an average height for Hellenistic to Roman males of 165.8 cm, and 157.3 cm for females[59], using the formulae of Trotter and Gleser. Their results are approximately 3–4 cm higher than Pearson's estimations[60]. According to the Turkish government, the modern average body height in 2016 was 173.2 cm for males and 161.4 cm for females[61].

Body height, as determined on the basis of the length of the long bones, is an important proxy for protein intake in past and present populations[62]. The body height of prehistoric and historic skeletons can, however, only be approximated using long bone lengths[63]. As we can see in the various crises of the 19th and 20th centuries, it directly reflects the nutritional situation during long bone development (0–14/18 y); this was demonstrated by Geoffrey Kron in his keynote at the AIAC 2018 conference in Bonn in May 2018[64].

Outlook – Palaeogenetics

As mentioned above, bone preservation at Pergamon and Aigai is often quite poor. Collagen preservation was only given in approximately two thirds of the samples submitted for radiocarbon dating. Collagen preservation can be proved by palaeohistological investigations[65]. Fortunately, the main burial from the sarcophagus in

54 Müldner et al. 2011, 400 tab. 23.
55 Grant 2000.
56 Scheidel 1996; Scheidel 2009, 9.
57 Fuller et al. 2012.
58 Teegen 2020, § 217; Teegen 2022c, § 169.
59 Aytek 2020a, 5 f.; no standard deviations are given. Trotter – Gleser 1952, 478 tab. 5.
60 Siegmund 2010, 37–40 tab. 10–13.
61 Aytek 2020a, 8 tab. 3; no standard deviations are given.
62 Cf. Koepke 2008; Koepke – Baten 2008; Rosenstock 2014; Scheibner 2016; Jongman et al. 2019 (each publication with further references).
63 Here, direct comparisons between the different long bones would be more accurate. Body height is, however, more easily understood by most people than bone metrics. K. Harper (Harper 2017, 299–303 Appendix A) provides average femur lengths for several late antique populations.
64 Kron 2018.
65 Schultz – Schmidt-Schultz 1994.

the İlyastepe tumulus also showed collagen preservation[66]. During the 2021 campaign at Pergamon, samples for an ancient DNA pilot study were collected. They were analysed by Mehmet Somel and his team at the Middle East Technical University at Ankara. DNA preservation is present, however, in different qualities[67].

Conclusions

Burials from all social strata were analysed. The number of burials studied (N = 60) is quite sufficient, but poor bone preservation made the project difficult. Complete skeletons are rare in the sample, both in inhumations and cremations.

Routine radiocarbon dating gave important results, sometimes indicating Byzantine reuse of tombs; bad bone preservation without collagen yielded no results for a third of the radiocarbon samples, however.

The Hellenistic people from Pergamon, Elaia, and Aigai studied so far suffered from a wide range of diseases. The diseases observed are also present in Roman (Pergamon) and Byzantine (Pergamon, Aigai, Kyme) burials.

The high incidence of unspecific stress markers such as enamel hypoplasias in élite burials indicates diseases known in infancy and childhood, and possibly also the use of wet nurses.

The presence of infections of the paranasal sinuses indicates poor heating during winter, even in the palaces and noble houses, not only in the dwellings of the poor. It is also likely that indoor air pollution was common in both noble and poor houses.

Due to poor preservation, cremations were sometimes a better source for palaeopathology than badly preserved inhumations. At most sites, we have to deal with case studies from a palaeopathological point of view.

Stable isotope analyses are an important tool for social differentiation through diet. People buried in monumental tumuli, sarcophagi and stone cists had higher protein intakes than people from ordinary burials.

Appendix 1: Aigai – The Human Remains

All human remains from inhumations and some cremations from the circular building and Funeral enclosure 04 were studied using well established anthropological and palaeopathological (field) methods, described above.

The Circular Building

Of particular interest are the burials from the late Hellenistic or early Roman circular building. As described above, stone cists 1–6 are located inside the circular building (fig. 14) and stone cists 7–9 were found outside, at a different angle to the aforementioned burials. Eight out of nine of these stone cist burials were inhumations. Only stone cist 3 contained the cremated remains of an adult individual. The paraboloid heat cracks and the white colour of the cremains indicate a high temperature of the pyre (> 650/800 °C)[68]. The cremains are representatively preserved, as are those from cremation burial TN 839. This is quite indicative of a primary burial.

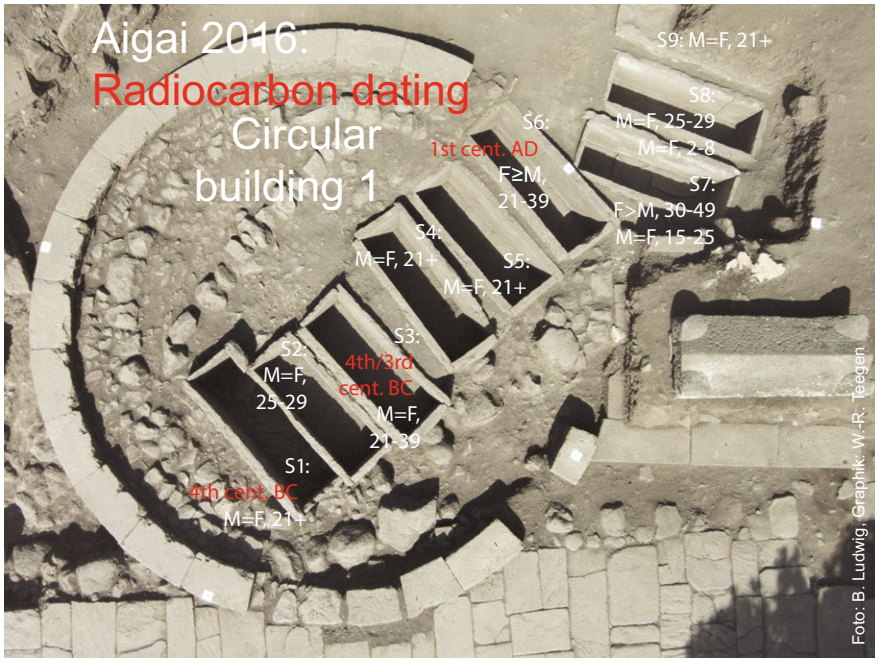
All inhumation burials are quite badly preserved, and almost all of the bones are very fragmented. Pathological alterations are, therefore, only randomly preserved. This means that they are mostly only of casuistic significance.

Among the animal bones from the circular building and its surroundings, human remains were also found and studied.

66 Schultz – Nováček 2011.

67 First results from palaeogenomics for population genetics and molecular palaeopathology were presented by N. Ezgi Altınışık and Mehmet Somel in an internal meeting in May 2024.

68 Großkopf 2004.



14 Aigai. Circular building with stone cists (S) 1–6 and 7–9

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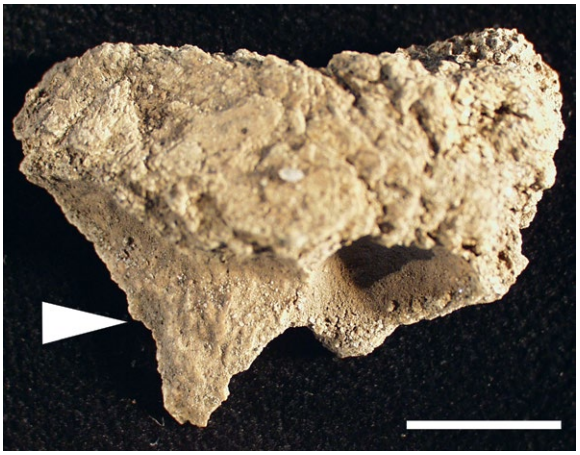

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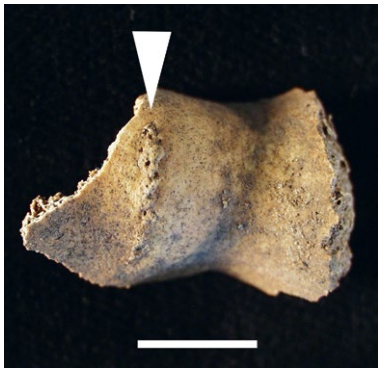

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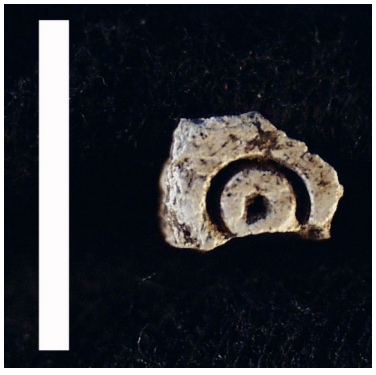

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15–19
Abb. 15 Aigai, Circular building, Stone cist 6 (TN831). Female (F ≥ M), 21–39 (45) years. Internal lamina of the skull, with well organised new bone formation. Scale 1 cm. Abb. 16 Aigai, Circular building, Stone cist 6 (TN831). Female (F ≥ M), 21–39 (45) years. Sinusitis sphenoidalis. Scale 1 cm. Abb. 17 Aigai, Circular building, Stone cist 4 (TN824). Not dermined (M = F), 21+ years. Trochlea of the right distal humerus with degenerative joint disease. Scale 1 cm. Abb. 18 Aigai, Circular building, Stone cist 4 (TN824). Not dermined (M = F), 21+ years. Left distal humerus with lateral epicondylitis (›tennis elbow‹). Abb. 19 Aigai, Cremation burial TN839. Not dermined (M = F), 21+ years. Cremated animal bone fragment with decoration, probably belonging to a comb

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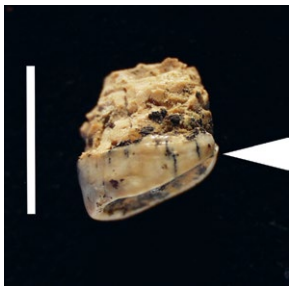

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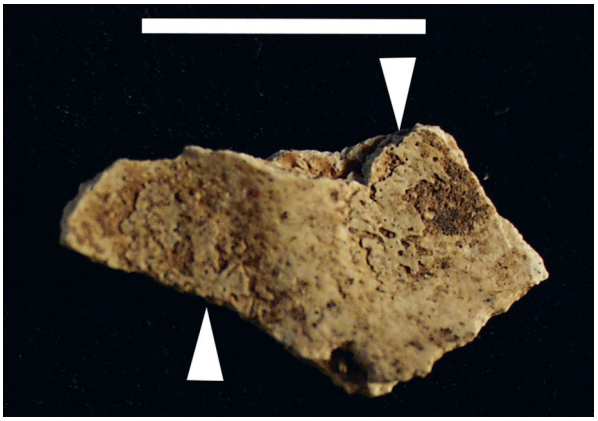

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20–24
Abb. 20 Aigai, Cremation burial TN839. Inlay of a *fulcrum* (?) Abb. 21 Aigai, Funerary enclosure 04, Burial L.102. Not determined (M = F), 30–49 years. Premolar with basal linear enamel hypoplasia (Arrow). Scale 1 cm Abb. 22 Aigai, Funerary enclosure 04, Burial L.103. Individual 2 (M = F, 3–9 months of age). Skull fragment, internal lamina with plaque-like new bone formations in the digitial impressions due to an haemorrhagic-inflammatory meningeal process. Scale 1 cm Abb. 23 Aigai, Funerary enclosure 04, Stone cist (A.18 Sy4, 336). Male (M > F), 25–35 years. Orthophotograph by Structure from Motion of the in situ-situation Abb. 24 Aigai, Funerary enclosure 04, Burial A.18 Sy4, 336 (M > F, 25–35 years). Thickened parietal bone (thickness 10 mm) with a slight bulky defect (Diam. ca. 3 mm). Scale 1 cm

Pathological Alterations

The adult individual from stone cist 6 showed spindle-like new bone formations on the internal lamina of the skull: these alterations are present laterally of the *Sulcus sinus sagittalis superioris* above the *Crista galli*, and on a non-localised skull fragment (fig. 15). They are the remnants of an organised inflammatory process of the meninges. The same individual showed in its frontal sinus a healed frontal sinusitis (fig. 16).

Degenerative joint diseases could only be observed in some cases. A clear example of this is the trochlea of the right distal humerus from stone cist 4 (fig. 17). The alterations indicate severe degenerative changes in the elbow joint.

The left lateral epicondyle of the same individual shows 2–3 mm long bony exostoses (fig. 18). They are pathognomic for a lateral epicondylitis, the so-called ›tennis elbow‹. In the orthopaedic literature of the 19th century, this phenomenon was first described in professional secretaries, and also in washers. Therefore, it was sometimes called ›washer women's elbow‹, and then later ›tennis elbow‹[69].

A premolar from stone cist 8 shows a basal linear enamel hypoplasia, indicating stress during the development of the tooth crown, probably at 5 or 6 years of age.

The Roman Cremation Burial TN839

Above the stone cists 7–9, the Roman cremation burial TN839 was localised, which contained cremains of an adult. The caudal joint of thoracic vertebra 11 shows clear degenerative changes. Among the cremated remains a pear-shaped glass balsamarium was found, as well as a calcinated animal bone fragment with a circular ornament (fig. 19). It probably belonged to a comb. Present is also a triangular animal bone fragment, probably an inlay of a *fulcrum* (fig. 20). Among the stray finds (TN 841), a premolar and a molar fragment show linear transversal enamel hypoplasia.

Radiocarbon Dating

From the 2015 campaign, human remains from five out of nine stone cists were subjected to radiocarbon dating at the University of Groningen isotope laboratory (fig. 1)[70]. Three out of five samples taken yielded enough collagen for radiocarbon dating[71]. The results were quite surprising: The bones from the stone cists 1 and 6 gave a date of around 400 BC and the 4th/3rd century respectively. Stone cist 3 dates from the 1st century AD. The latter belongs to a cremation.

Furthermore, samples of two human remains identified amongst the animal bones from around the circular building were dated[72]. They revealed a late Hellenistic (TN825) and an early Byzantine date (TN828). The first one, a cremation, indicates the presence of at least one Hellenistic cremation burial. The second documents the reuse of the area as a cemetery in Byzantine times, as we can observe in Pergamon and Elaia as well[73].

Recent research[74] into the radiocarbon dating of cremations indicate that the carbon in the samples could, under certain circumstances, have come from the wood used for the pyre[75].

Funerary Enclosure 04

The burials of the Funerary enclosure 04, not far away from the circular building, were excavated in the 2005 and 2018 campaigns. Skeletal remains were present in six out of eleven burials. These six burials contained the remains of eight individuals, ranging in age from 3–9 months (L.103) up to a late mature to early senile male of about 57–63 years (L.118). Samples taken for radiocarbon and stable isotope analyses revealed no collagen preservation and, therefore, no results.

Linear enamel hypoplasia was present in only two adult individuals (burials L.102 and 336). The defect in individual L.102 (fig. 21) developed at around five or six years of age.

69 Renström 1995, 155.

70 This lab developed radiocarbon dating of cremations about 20 years ago (see Lanting et al. 2001).

71 Palstra 2016: GrA 66595 (TN815), 66797 (TN810), 66474 (TN831).

72 Palstra 2017: GrM 10185 (TN825), 10186 (TN828).

73 See Teegen 2018, 178 f. fig. 82.

74 Olson et al. 2013; Snoeck et al. 2014; Snoeck et al. 2017; Snoeck 2023.

75 In most cases, fresh, i. e. contemporaneous wood was used for the pyre. In some cases, as shown by Olsen et al. 2013, old wood was used. This should be taken into consideration.

A skull fragment of an infant aged 3–9 months (burial L.103, individual 2) showed fine plaque-like new bone formations on the internal lamina (fig. 22). These are mostly located in the digital impressions and were very likely caused by an inflammatory-hemorrhagic meningeal process (meningitis).

The elderly individual L.118 shows inflammatory processes of the paranasal sinuses.

It further presents several traces of degenerative joint diseases in the large and small joints of the body, as well as in the spine.

The male (M > F), 25–35 years old individual 336 (fig. 23) shows a thickened parietal bone (thickness 10 mm) with a slight bulky defect (diam. ca. 3 mm) (fig. 24). There is probably a demarcation line, dividing the old skull bone from the newly built bone.

Bouleuterion

Fragmented human remains are often difficult to identify during excavation among the animal bones. Therefore, all animal bones found during the 2005 excavation of the Bouleuterion and its surroundings were checked for human remains. Two plastic bags contained the facial skeleton of a young male, as well as gracile parietal bones. Both individuals were sampled for radiocarbon dating. Surprisingly, Roman dates resulted, around 300 AD and 200 AD respectively[76].

The young male shows intravitam tooth loss, severe dental caries with root abscesses (fig. 5) and a maxillary sinusitis on both sides.

Stable Isotope Analysis

For all radiocarbon-dated inhumations, a first isotope analysis of the stable ^{13}C and ^{15}N isotopes was carried out at the University of Groningen[77]. The individuals from stone cists 1 and 6 showed an elevated $\delta^{15}N$ value. This is similar to the data for the individual from the monumental tumulus at Kyme (see fig. 13). The higher nitrogen content indicates a remarkable proportion of animal protein in their diet. The same is true for the Roman individuals from the Bouleuterion. This could be an indication of the higher social status of these individuals. These five individuals are quite different from most of the individuals from Roman and Byzantine Pergamon studied so far[78].

Stress Markers

Some teeth with enamel hypoplasias were discovered in all the samples studied from Aigai (funeral enclosure 04, Bouleuterion, circular building and Tumulus 001). According to the classification of Berten[79] and Hillson[80], they are mostly linear transversal defects; one plane defect is also present. Furthermore, root hypoplasias or periradicular bands were found. They can also be determined in cremations. Both alterations indicate several periods of stress during infancy.

Conclusions

For Aigai, the burials below the circular building, and Tumulus 001 could probably belong to an upper segment of the society. The same could be hypothesised for the Funerary enclosure 04; at least it could belong to an (upper) segment of the ›middle class‹. This interpretation derives from the localisation of the burials and their containers (sarcophagi, stone cists), as well as the grave goods in Tumulus 001. It correlates well with the first isotope analyses for the reconstruction of a diet with a high proportion of animal protein (meat). Nevertheless, several individuals showed repetitive stress, indicated by linear enamel hypoplasia and/or root hypoplasia in infancy and childhood (developed mostly between 4 and 6 years of age), probably caused by diseases. However, these individuals survived these stress episodes. The undoubtedly harsh climatic conditions of the winter could have caused a high incidence of diseases of the airways. The presence of several kinds of sinusitis (see above) supports this hypothesis.

76 Palstra 2017: GrM 10203, 10207 (both Ai2005, Bouleuterion, APD).
77 Palstra 2016; Palstra 2017.
78 Cf. Propstmeier et al. 2017.
79 Berten 1895.
80 Hillson 2014.

Appendix 2: Palaeodemographic Conclusions from Sarcophagus and Grave Lengths

During the Aigai necropolis survey[81], the outer and inner dimensions of sarcophagi and graves were recorded[82]. As will be shown below, these measurements supply important information about the people buried in these burial containers.

Stature and Age

The stature of infants, children and adolescents are clearly age dependent. This is not only an everyday life experience, but also a biological fact. In fact, long bone lengths are regularly used to determine the age of fetuses, infants, children and adolescents[83]. From the length of the long bones, it is also possible to estimate the height of the individual[84]. The body height itself correlates with length of the coffin or sarcophagus: it makes little sense to use a coffin that is shorter than the deceased. If no bones are preserved, the measurements of the coffin or the sarcophagus can tell us something about the deceased, who is no longer present. At the very least, we could try to differentiate between fetuses/infants, children, adolescents, and adults.

Materials and Methods

During the surveys in 2016–2018, more than 1,000 burial sites and other structures were recorded in Aigai's necropolis database[85]. Approximately 180 of them included measurements of the sarcophagus or grave structure[86]. The site number, outer and inner measurements of the complete sarcophagi or graves and any comments were recorded in an Excel spreadsheet. 122 features were then used for further analysis. Data were visualised in length and breadth correlation diagrams, both for the inner and outer dimensions. Furthermore, a correlation diagram between inner and outer length was generated. Regression analyses were carried out for each diagram.

In the former German Democratic Republic, anthropological measurements of the contemporaneous population were intensively collected, recorded and published in an atlas for industrial purposes[87]. This data set is the basis for recent body heights and maximum shoulder breadths used in this chapter. It should be noted, however, that the average body height in the eastern Mediterranean is lower than in central Europe.

Results

Figure 25 shows the number of burials for 5 cm length classes. It can easily be observed that most lengths are above 150 cm. In fact, we can observe a dense cluster between 160–220 cm, containing mostly adults.

Using the internal lengths of sarcophagi and cist graves from Aigai's necropolis (n = 122), the subadult and adult populations can be reconstructed as follows (fig. 28): The largest group are the adults (> 20 years of

81 See the contribution by Verger – Sezgin – Pace (in this volume).

82 I am grateful to Ute Kelp and the Aigai necropolis survey team for access to the sarcophagus and grave measurements. Any errors are, of course, my own.

83 See e. g. Johnston 1962; Kósa 1978; Stloukal – Hanáková 1978; Ferembach et al. 1980; Teegen – Schultz 2017; Gowland – Walther 2018.

84 See e. g. Rösing 1988 (with older references); Siegmund 2010. As outlined above, the formulae by Karl Pearson 1899 were used. Recently, Aytek 2020a has compiled stature estimations for Anatolian populations from the late Paleolithic up to modern times (see Appendix 1).

85 See the contribution by Verger – Sezgin – Pace (in this volume); pers. comm. Ute Kelp (June 2022).

86 A list of the structures and the original measurements will be published in the final report.

87 Flügel et al. 1986.

age) with 64.8%. The frequency of 35% subadults very much resembles common subadult frequencies in palaeodemographic studies[88]. The results of the analysis for Aigai therefore seem plausible.

As is to be expected, the percentage of adolescents (13–20 years of age) with sarcophagi and grave lengths around 150 cm is quite low. Children (3–12 years of age) can be found in sarcophagi with an internal length between 75 and 140 cm. Infants from 45–70 cm long sarcophagi, i. e. between late fetal stages and birth and 2 years of age, are quite underrepresented. This corresponds to the burials studied (see above).

Figure 26 shows 5 cm classes for the burial breadths and the Gaussian normal distribution. There is a small cluster of smaller breadths visible, below 40 cm. According to recent data[89], only breadths below 35 cm are indicative for children and breadths below 25 cm for infants.

Analysing internal sarcophagus and cist grave lengths against breadth (fig. 27), the regression is not significant at $r^2 = 0.2823$. The analysis of the internal measurements of sarcophagi from late Roman Trier yielded a somewhat better correlation of $r^2 = 0.48$, with the regression axis ($y = 0.295x + 4.1018$) running between 60/22 cm and 220/70 cm[90].

The correlation between external and internal sarcophagus lengths seems to be quite good with a regression of $r^2 = 0.88$. In late Roman Trier it is nearly linear with $r^2 = 0.98$[91].

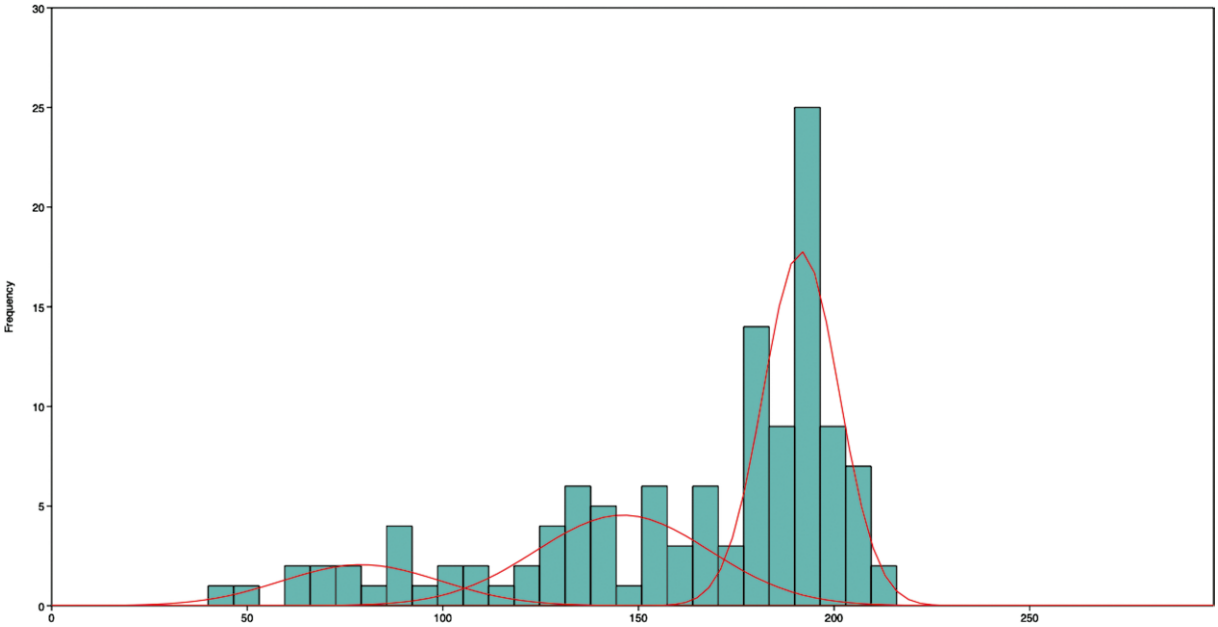
Discussion

The results of the Aigai necropolis survey are quite encouraging. The internal measurements of the sarcophagi and cist graves are very helpful for the palaeodemographic reconstruction of the former occupants. The results can be compared with those for late Roman sarcophagi from the Empire's western capital Trier. The subadult : adult ratio is 35 : 65, a common ratio in anthropological analyses. This means, however, subadults are quite underrepresented. Looking at the subadult age distribution, this means that infants and especially neonates and small infants under 12 months of age are absent. The same is true for anthropological analysis of ancient skeletons from Aigai and Pergamon, where they are also underrepresented (see discussion above). At the moment we do not know where most of the small infants were buried.

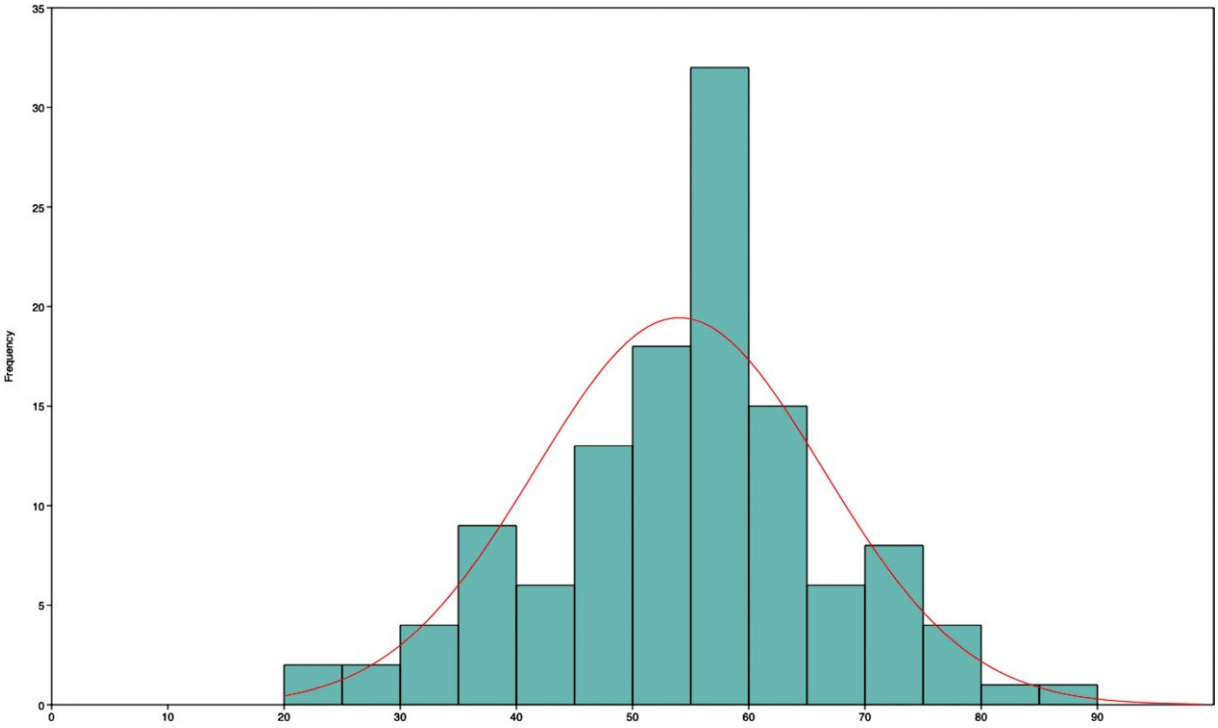
Conclusions

The internal dimensions, such as lengths and breadths, of sarcophagi, stone cists and other burials are a useful proxy for palaeodemography, when human remains are not preserved or not available for study. As burials with preserved skeletons have shown, their internal dimensions are quite dependent on the height of the body buried in them. Body height is dependent on age. Lengths of 170 cm and above are quite typical of adults, while lengths below 150 cm are characteristic of subadults.

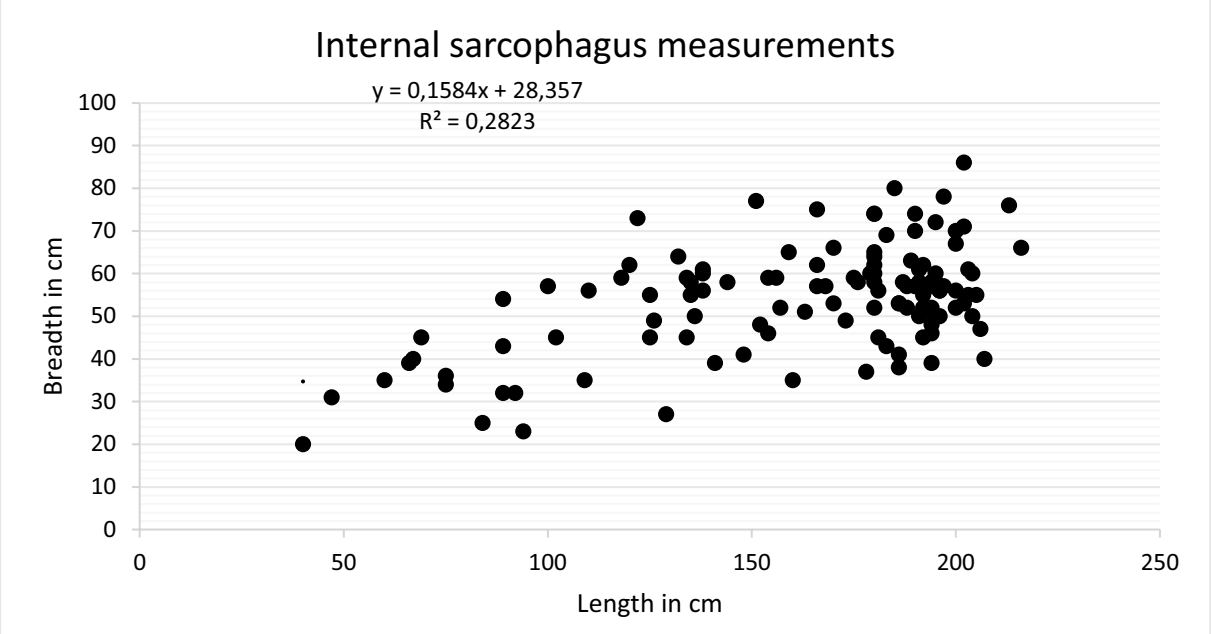
88 E. g. Aytek 2020b, 99 f. tab. 11. 12.
89 Flügel et al. 1986.
90 Unpublished data; for a general discussion of sarcophagus measurements and palaeodemography at late Roman Trier see Teegen 2022a, 104.
91 Unpublished data.



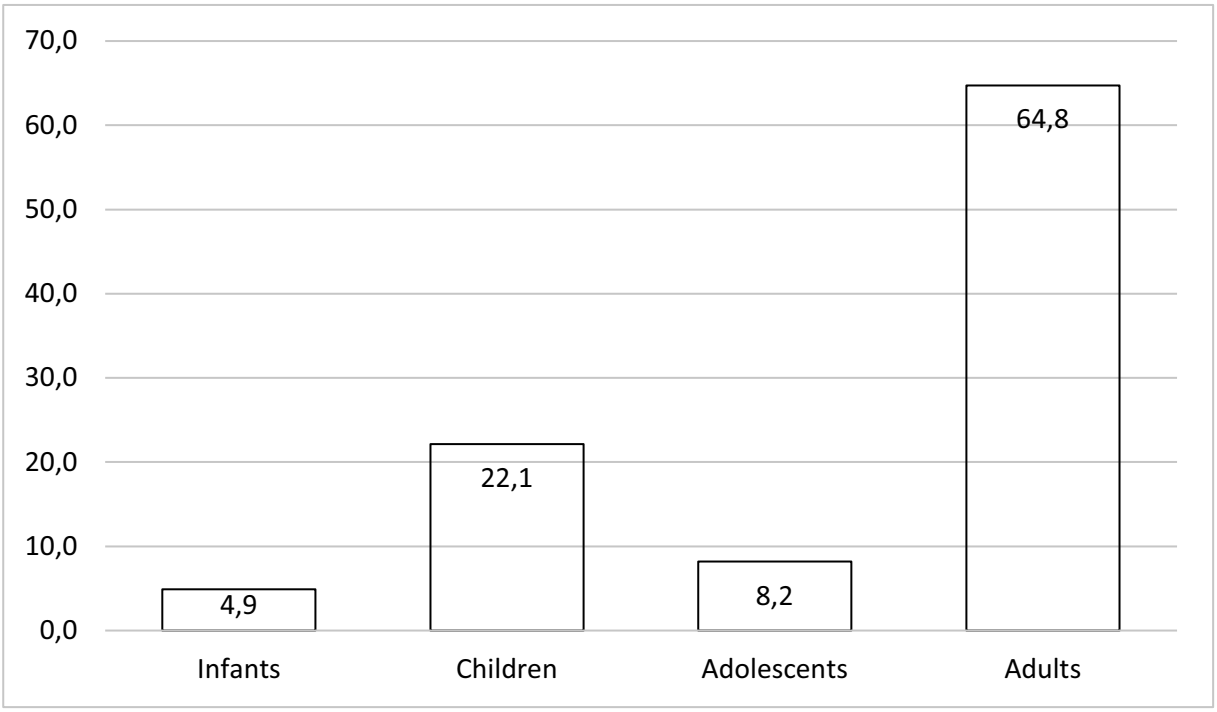
25 Aigai, Necropolis. Internal sarcophagus lengths in 5 cm classes and mixture analysis in three groups



26 Aigai, Necropolis. Internal sarcophagus breadth in 5 cm classes



27 Aigai, Necropolis. Internal sarcophagus lengths vs. breadth (in cm)



28 Aigai, Necropolis. Reconstruction of the subadult and adult population (in percent), using internal sarcophagus lengths (n = 122)

Abstract

In the NekroPergEol project, the skeletal remains of Hellenistic burials from all social strata were analysed. In total, 60 individuals were studied. Poor bone preservation made the project difficult. Radiocarbon dating gave important insights, indicating both older (classical) and more recent (Roman, Byzantine) burials, including the reuse of tombs. The (mostly) Hellenistic people from Pergamon, Elaia, and Aigai studied so far suffered from a wide range of diseases. The diseases observed were also present in Roman (Pergamon) and Byzantine (Pergamon, Aigai, Kyme) individuals. The high incidence of unspecific stress markers like enamel hypoplasia in élite burials indicates diseases in infancy and childhood, and possibly also the use of wet nurses. The presence of infections of the paranasal sinuses indicates poor heating during winter, and indoor air pollution. Stable isotope analyses revealed a higher protein intake in people buried in monumental tumuli, sarcophagi, and stone cists, than in individuals from other burial types.

In Appendix 1 the health status of individuals from different sites at Aigai is discussed. Appendix 2 presents inner sarcophagus and burial measurements as a tool for palaeodemography at Aigai.

Keywords: anthropology, Asia Minor, Hellenism, paleodemography, paleopathology

Illustration Credits

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