Lidia Vitale

The Life Cycle

Age from the Perspective of Human Osteoarchaeology

Abstract

During the life course, the human body experiences a series of significant changes that are part of the individual maturation cycle. The processes of growing and ageing, as well as diet, diseases, climate, and activities have distinct impacts on the skeleton – the marks of which are still visible after death. The discipline of osteoarchaeology aims to analyse the developmental signs 'imprinted' in the human bones of past populations in order to reconstruct the biological profile and lifestyle of individuals and groups. A fundamental component of this reconstruction is the age-at-death assessment: it is a focal point for the study of identities and paleo-demography, and contributes to the understanding of funeral rites, life conditions and perception of age. The primary purpose of this paper is to explore the main techniques for the estimation of the age-at-death, based on the evaluation of the physiological changes that normally occur in certain areas of the human skeleton, and to outline how the results of such analyses could be linked to findings of the humanities to contribute to a fuller investigation of the life cycle.

1 Introduction

Life is a long individual process of growing, developing, and maturing, not just mentally and spiritually, but physically as well. From early infancy to adolescence, teeth appear and bones form, shape, and fuse. During adulthood and old age, parts of the human body carry on fusing, metamorphosing, and degenerating. The body changes over the whole lifetime, undergoing a sequential chronological transformation. The specific features of old age appear during the last step of this cycle, namely the period of senescence. The life-span is limited, and the maximum age achieved by humans so

Lidia Vitale: The Life Cycle. Age from the Perspective of Human Osteoarchaeology, in: Christian Alexander Neumann (Hg.), Old Age before Modernity. Case Studies and Methodological Perspectives, 500 BC–1700 AD, Heidelberg: Heidelberg University Publishing 2023 (Online-Schriften des DHI Rom. Neue Reihe | Pubblicazioni online del DHI Roma. Nuova serie, vol. 8), pp. 279–289. https://doi.org/10.17885/heiup.1086.c14946 (CC BY-SA-4.0)

far was about 120 years.[1] From a biological perspective, ageing is a degenerative process influenced by genetic disposition.[2] All these alterations are investigated through the approach of human osteoarchaeology: the study of human skeletal remains from archaeological contexts.

The objective of this paper is to explore the life cycle from this perspective, discussing the principal methodological approaches for determining the age-at-death of historical populations based on the evaluation of the physiological changes that are commonly evident in certain areas of the skeleton. It will be pointed out how these modifications are 'read' for their chronological value. Despite the difficulties of determining the age-at-death in elderly subjects, osteoarchaeologists have developed a specific range of techniques that allow for a more accurate view of how old people lived, and what their social and historic role was in past communities.

After an overview of the field of research and an explanation of the subject and purpose of human remains analysis, this paper will focus on the main assessment procedures of the age-at-death for the different stages of human life. In order to estimate age, many factors such as health and lifestyle, nutrition, activity, and occupation have to be considered, in addition to the subjective observer bias. In the last part, it will be explained to what extent human osteoarchaeology and related sciences have been combined in an interdisciplinary fashion with historical research to date, and how research may develop in the near future.

2 Human Osteoarchaeology. A Brief Definition

Human osteoarchaeology is defined as the study of human remains from archaeological sites.[3] More commonly in the UK, the term can be used interchangeably with that of "bioarchaeology", which was coined by the archaeologist Grahame Clarke in 1972.[4]

1 Jean-Marie Robine / Michel Allard / François R. Herrmann / Bernard Jeune, The Real Facts Supporting Jeanne Calment as the Oldest Ever Human, in: Journal of Gerontology. Medical Sciences 74 (2019), pp. 13–20.

2 Douglas E. Crews, Human Senescence. Evolutionary and Biocultural Perspectives, Cambridge 2003 (Cambridge Studies in Biological and Evolutionary Anthropology 36).

3 For a complete overview and an essential bibliography of the discipline cf. Kristina Killgrove, Bioarchaeology, in: Oxford Bibliographies Online – Anthropology, Oxford 2013.

4 Clark J. D. Grahame, Star Carr. A Case Study in Bioarchaeology, Reading, Mass. 1972 (Addison-Wesley Module in Anthropology 10).

Bioarchaeology was initially applied to zooarchaeological research before, in the United States, it was adopted and used to refer almost exclusively to the study of human skeletons. Later, in the 1970s, the anthropologist Jane Buikstra defined the term independently as the study of human remains from archaeological contexts, as a line of research that focusses on paleodemography, diet, disease, mortuary analysis, social organisation, and social activities.[5]

Human bones and teeth reflect the combined action of genes and environment, 'recording' in themselves body growth and development, and preserving in their shape, morphology and chemical composition evidence of disease, stress, diet, nutrition, climate, activity, and injury that occur during the lifetime. The main purpose of osteoarchaeology is the reconstruction of the individual life and lifestyle, allowing the outline of the biological profile through the estimation of sex, age-at-death, stature, and pathologies. In addition, it explores the collective population histories, analysing groups of individuals to determine mortality profiles, evidence for immigration and spread of disease. A biocultural approach analyses human biology in the context of the interaction between the natural and cultural environments. It is based on a multidisciplinary perspective combining archaeology, biology and cultural anthropology with theories and methods from sociology, demography, statistics, chemistry, forensics, and medicine.[6]

3 The Work-Routine

The methodology of standard osteoarchaeology applies several different elements from field work and laboratory procedures to the interdisciplinary study of skeletons and burials. The process starts with the uncovering of the remains, which can be recovered in scheduled archaeological excavations. Additionally, finds can also be made by resuming fieldwork or through accidental discoveries. Differences between burial contexts as well as variations in preservation and the state of decomposition require different approaches. However, the general steps described in the following can be applied in most instances.

5 Jane E. Buikstra, Biocultural Dimension of Archaeology Study. A Regional Perspective, in: Robert L. Blakely (Ed.), Biocultural Adaption in Prehistoric America, Athens 1977 (Southern Anthropological Society Proceedings 11), pp. 67–84.

6 Clark S. Larsen, Bioarchaeology. Interpreting Behaviour from the Human Skeleton, Cambridge 1999 (Cambridge Studies in Biological Anthropology 21).

After being uncovered, exposed, and recognised, skeletons are recorded by drawing, photography, stratigraphic and taphonomy documentation, and subsequently excavated and retrieved.[7] Afterwards, samples are collected and transported to a laboratory where the analysis continues. In the laboratory, the human remains are washed and dried, after which the fragmentary bones are restored by checking the joins and stabilised with a consolidating agent. The bones are subsequently identified and labelled. Other steps include photographic documentation, compilation of a bones and dental inventory, and the recording of skeletal completeness for each individual. Finally, standard analysis such as sex, age-at-death and stature determination are carried out, and a report of pathologies, anomalies and trauma is drafted.[8]

4 Age-at-Death Assessment. Methods and Techniques

Age-at-death estimation is an essential parameter of skeletal analysis. It refers to a close approximation of the biological age, which is proposed to coincide with the individual chronological age. The main methods rely on age-range systems based on the measurement of growth, physical remodelling, changes, and degeneration that normally occur in specific parts of the human body during the life course. A certain phenomenon is thus given a chronological value. However, the timescale of skeletal modifications varies slightly between individuals, as it is dependent on genetic factors that influence growth and senescence, and systematic influences from the environment, nutrition, and disease can also affect the assessment.

As there are no standardised terminology and age ranges to categorise individuals, it is necessary to specify which system is applied or how age classifications were determined. In 1994, Jane E. Buikstra and Douglas H. Ubelaker proposed the following age categories, dividing the human life span into seven stages (see table 1):[9]

7 Henry Duday, The Archaeology of the Dead. Lectures in Archaeothanatology, London 2009 (Studies in Funerary Archaeology 3).

8 Tim D. White / Michael T. Black / Pieter A. Folkens, Human Osteology, New York [3]2011.

9 Jane E. Buikstra / Douglas H. Ubelaker, Standards for Data Collection from Human Skeletal Remains, Fayetteville 1994 (Arkansas Archaeological Survey Research Series 44).

Tab.: Age Categories according to Buikstra and Ubelaker

Age Category	Range of Years
Foetus	Before birth
Infant	0–3 years
Child	3–12 years
Adolescent	12–20 years
Young Adult	20–35 years
Middle-Aged Adult	35–50 years
Old Adult	50+ years

Although these categories are most commonly employed, in modern practice diverse and alternative categories are adopted that adapt the age ranges used to the research questions or to the state of preservation of the samples. Methods for determining age-at-death can be conducted on several different parts of the human body. Age estimation is, indeed, a multifactorial process and osteoarchaeologists tend to use as many techniques as possible to gain the most accurate results and limit the possibility of associated errors. The choice of the method(s) is also determined by the state of completeness and preservation of the skeletons. The common techniques mostly employ macroscopic visual observations of biological changes, even though chemical analyses such as DNA or radiographic analysis are sometimes used. Beyond these content-related considerations, the choice of techniques is also conditioned by practical issues such as the available budget, as some methods are particularly costly.[10]

To explore the techniques in more detail, I will proceed by dividing them into three age-classes – pre-birth to adolescence, young adulthood and adulthood and old age – as similar processes are observable within each group.

4.1 Techniques for Estimating Age below Adulthood

Age assessment for subadult individuals is based on developmental changes of the teeth and bones. As the patterns of growth are biologically determined, the development of

10 The paper will focus on the most common macroscopic methods utilised, as they are frequently applied in research.

especially the first year of life can be determined quite precisely and accurately. Since teeth are usually well-preserved in archaeological finds, and their formation and eruption occur regularly, preference is usually given to the examination and observation of the stage of dental maturity. By means of visual observation or radiographic images, the precise development stage for each tooth can be accurately recorded.[11] The assessment includes the registration of the completeness of all crowns and roots (known as formation) and the place of each tooth relative to the alveolar margin (known as eruption).

There are four distinct periods of human dentition.[12] During the first period, from birth to two years of age, most of the deciduous teeth appear. Between six and eight years, the two permanent incisors and the first permanent molars erupt. Between 10 and 12 years, most permanent teeth such as canines, premolars and second molars emerge, while between 14 and 18 years, the third molars appear.[13] Individual variables include an earlier eruption or a different order dependent on sex and population differences.

The second most common method is to record the state of ossification and epiphyseal plates or, in older people, the epiphyseal lines across the skeleton. The fusion of bones is, indeed, progressive and scored as "unfused", "partially fused" or "fully fused". Ossification and epiphyseal union occur from the first month after birth through to the early thirties, providing a relative indicator of age within a comparatively short time range.[14] For the assessment, it is important to consider that maturation processes vary according to ethnic affiliation and gender, and are also susceptible to the effects of genetic, nutritional, and social factors.

Other techniques include the comparison of the length of long bones and of bone elements which should always be done with reference to the same, or a closely related, skeletal collection. The assessment is based on seriation. However, it is important to consider that most data on the relationship of the length of long bones and age is derived from modern individuals and that past individuals are more likely to have suffered from debilitating illnesses that could have hindered development, thereby leading to reduced bone length.[15]

11 B. Holly Smith, Standards of Human Tooth Formation and Dental Age Assessment, in: Mark A. Kelley / Clarke S. Larsen (Eds.), Advances in Dental Anthropology, New York 1991, pp. 143–168.

12 Teeth formation begins in the embryo about 14–16 weeks after conception.

13 Douglas H. Ubelaker, Human Skeletal Remains. Excavation, Analysis, Interpretation, Washington, D. C. ³1999 (Manuals on Archaeology 2), p. 172.

14 Louise Scheuer / Sue Black, Developmental Juvenile Osteology, London 2000.

15 Ibid., pp. 252–395.

4.2 Techniques for Estimating Young Adulthood

Age estimates for young adults are mostly based on the recording of the epiphyseal fusion of three different bones: (1) The medial aspect of the clavicle – a fusing flake that appears between 16 and 21 years. A total coverage is achieved by 24–29 years and a complete fusion by 30 years. (2) The sacrum – if there is a space between the first and second sacral segment, the individual is less than 27 years old.[16] (3) The jugular growth plate in the cranium, of which there is no fusion prior to 22 years and a fusion occurs unilaterally between 22 and 34 years in both sexes.[17]

4.3 Techniques for Estimating Adulthood and Old Age

When the processes of bone and teeth growth end during adulthood, the body progressively starts deteriorating. In adult and older individuals, physiological age change is seen against the backdrop of, and is affected by, several internal and external variables such as sex, genetics, nutrition, health, occupation, and lifestyle activities. A combination of different methods is usually better and more accurate. The estimation of age is based on macroscopic observations of progressive degenerative processes and different skeletal parts are commonly studied for this. One of the most used techniques is the observation of the metamorphosis of the symphyseal surface of the pubic bone of the *os coxae*. Brooks and Suchey illustrate six phases of its erosion and general deterioration. Variabilities are observed in male and female individuals; for women one factor of the decay of the bone is usually childbirth.[18]

A second technique is the analysis of the auricular surface of the *ilium*. This surface changes during ageing and visual observation are usually performed to evaluate the changes in order to categorise an individual. Age-related changes in the auricular surface include granulation, micro and macro porosity, transverse organisation, billowing and

16 Ibid., p. 213.

17 George J. R. Maat / Rob W. Matwijk, Fusion Status of the Jugular Growth Plat. An Aid for Age at Death Determination, in: International Journal of Osteoarchaeology 5 (1995), pp. 163–167.

18 Sheilagh T. Brooks / Judy M. Suchey, Skeletal Age Determination Based on the Os Pubis. A Comparison of the Acsádi-Nemeskéri and Suchey-Brooks Methods, in: Human Evolution 5 (1990), pp. 227–238.

striations.[19] Another widely applied method consists in observing the three components of age-related changes at the sternal end of the fourth rib: pit depth, pit shape, rim, and wall configuration. Six numbered stages are distinguished for each of these components. The accuracy of this technique both depends on preservation – ribs are fragile – and a positive identification of the fourth rib.[20]

Other methods are sometimes also used, even if they are less accurate than the techniques described above. One method is the observation of the progressive cranial suture closure. The suturing process starts at the age of 20 and continues until its complete obliteration. A numerical score is given to each suture segment: score 0 is given when there is no evidence of any closure; score 1 when there is a minimal closure; score 2 when a significant closure can be seen and score 3 is given when the process has finished. Obliteration is considered to be a very general indicator of either young or advanced adulthood, as some diseases might cause a premature suture closure and obliteration. However, the cranium is often the best-preserved part of the skeleton in archaeological contexts, which is why this method is still used.[21]

A final comment has to be made here regarding the measurement of dentition. The age-assessment of teeth in adult individuals is based on the rate and patterns of wear visible on a tooth once the permanent eruption is completed. Seriation based on dental attrition often relies on studies done on modern populations. Estimations based on teeth therefore tend to be rather imprecise, as the observed attrition might be influenced by nutrition, dental pathology[22] and, in specific populations, the use of the teeth as a 'third hand' supporting work.[23]

19 C. Owen Lovejoy / Richard S. Meindl / Thomas R. Pryzbeck / Robert P. Mensforth, Chronological Metamorphosis of the Auricular Surface of the Ilium. A New Method for the Determination of Adult Skeletal Age at Death, in: American Journal of Physical Anthropology 68 (1985), pp. 15–28.

20 İşcan M. Yaşar / Susan R. Loth / Ronald K. Wright, Metamorphosis at the Sternal Rib End. A New Method to Estimate Age at Death in White Males, in: American Journal of Physical Anthropology 65 (1984), pp. 147–156.

21 Richard S. Meindl / C. Owen Lovejoy, Ectocranial Suture Closure. A Revised Method for the Determination of Skeletal Age at Death Based on the Lateral-Anterior Sutures, in: American Journal of Physical Anthropology 68 (1995), pp. 57–66.

22 Don R. Brothwell, Digging up Bones. The Excavation, Treatment and Study of Human Skeletal Remains, Oxford ^{3}1981.

23 Graham Turner / Trevor Anderson, Marked Occupational Dental Abrasion from Medieval Kent, in: International Journal of Osteoarchaeology 13 (2003), pp. 168–172.

5 Main Implications of Human Osteoarchaeology for the Humanities

In recent decades, multifaceted investigations integrating human osteoarchaeology (and related disciplines such as paleodemography)[24] and the humanities demonstrated that the lives of past populations and their biological profiles could be reconstructed more precisely. The assessment of aspects like sex, age, stature, and pathology provided more meaningful and comprehensive interpretations. Socially conditioned inequalities between diet, lifestyle, access to medical treatment and working conditions can be assessed, combined, and compared with historical and archaeological information in order to elucidate the social roles of individuals at various stages of their lives.[25] Beyond social differences, categorisations of the stages of life and age limits also depend on social contexts, even within one social group or class. Questions of gender may also be investigated with reference to foot binding, food preparation, labour or other activities that leave their mark on the skeleton. Rather than allocating people into strict pre-defined categories, patterns of gender construction should receive more attention.[26]

When analysing funerary contexts from different perspectives, one of the most common concerns is the divergence between social, historical, and archaeological age categories – all of them constructions that define the stages of life differently – and the results of osteoarchaeological analysis. These discrepancies can be attributed to the outcome of the age-at-death estimations that often tend to be rather broad, and to many different kinds of categorisations of age. In addition, the fundamental differences between prehistoric or historic societies and today's society should be taken into consideration. It is very unlikely that individuals from non-literate societies knew their precise chronological age; it may not have been too relevant to them as they gave more importance to generational or birth order and marital and reproductive status.[27] However, age identity can be

24 Brenda J. Baker / Osbjorn M. Pearson, Statistical Methods for Bioarchaeology. Applications of Age Adjustment and Logistic Regression to Comparisons of Skeletal Populations with Differing Age-Structures, in: Journal of Archaeological Science 33 (2006), pp. 218–226.

25 Giovanna Belcastro / Elisa Rastelli / Valentina Mariotti / Chiara Consiglio / Fiorenzo Facchini / Benedetta Bonfiglioli, Continuity or Discontinuity of the Lifestyle in Central Italy During the Roman Imperial Age-Early Middle Ages Transition. Diet, Health and Behaviour, in: American Journal of Physical Anthropology 132 (2007), pp. 381–394.

26 Elizabeth Berger / Liping Yang / Wa Ye, Foot Binding in a Ming Dynasty Cemetery Near Xi'a, China, in: International Journal of Paleopathology 24 (2019), pp. 79–88.

27 Nancy Scheper-Hughes / Margaret M. Lock, The Mindful Body. A Prolegomenon to Future Work in Medical Anthropology, in: Medical Anthropology Quarterly 1 (1987), pp. 6–41.

explored through a multifactorial approach that studies burial remains to elucidate the social roles of individuals at various stages of their lives.

Being part of the analysis of human remains, the determination of the age-at-death is a fundamental component in the investigation of mortuary practices, health, and well-being, and for the creation of demographic models of mortality. As with the other stages of life, this can also be done for the period of old age. The degenerative processes that normally affect the human body are often linked to a loss of physical strength and the inability to reproduce any longer, which most probably results in a change of social roles. Mature individuals may have been denied access to resources and treatment, or they may have had an increased exposure to diseases due to their old age. Signs of trauma, such as a depressed cranial fracture, often identifiable on the skeletons of the elderly, hint at domestic violence.[28] In contrast, marks of surgical treatments left on the bones or the laying out of the (old) body (prothesis) can help us to better understand reactions to physical impairment and the affection towards elderly people, as a long life in disablement surely required special care from members of the family or other forms of social support.[29]

6 Final Considerations

While techniques to estimate age in juvenile subjects are based on the growth and development of different parts of the skeleton, those for the age assessment of adults take degenerative modifications of the bones into account. Age-related changes do not occur at the same pace throughout life but do so rather rapidly in the first third of life and then become increasingly slower throughout the greater part of an individual's lifetime. As immature or adolescent individuals undergo relatively profound alterations in a short period of time, the determination of their age is mostly fairly accurate, as small fluctuations and variations in the developmental sequence only insignificantly affect the results. Contrary to this, degenerative processes in adult human skeletons happen slowly and progress in a nonlinear manner, which means that variability is quite high, and only broad ranges of age estimations are possible.

28 Joanna E. P. Appleby, Why We Need an Archaeology of Old Age and a Suggested Approach, in: Norwegian Archaeological Review 43 (2010), pp. 145–168, at p. 157.

29 Diana E. Hawkey, Disability, Compassion and the Skeletal Record. Using Musculoskeletal Stress Markers (MSM) to Construct an Osteobiography From Early New Mexico, in: International Journal of Osteoarchaeology 8 (1998), pp. 326–340.

Many factors could influence the reliability of the different age assessment methods, including sex, genetics, nutrition and health status, occupation, and lifestyle activities.[30] It is therefore suitable to combine several methods to increase the percentage of accuracy in determining age. There are also other macroscopic aspects that can help to assign skeletal remains to a category, such as bone size or chemical composition or specific pathologies normally linked to adults or old people. Without also concentrating on diseases, age assessment is not reliable.

Despite the error-prone nature and variabilities connected with the discussed techniques, age-at-death assessment represents a valuable resource for the investigation of past individuals and communities. It contributes to addressing and enriching a variety of archaeological and historical questions related to different aspects of the human life course, such as health condition, social status, and identity. The continuous development of the discipline is interwoven with the emergence of new methods that are constantly introduced and tested. In general, it can be stated that age assessment is becoming ever more precise, especially regarding old subjects. The focus has been put on identifying morphological variations that are more strongly correlated with chronological age-at-death rather than other elements that can mark human bones. At the same time, a revision of the standard markers for old age is ongoing, which may result in a higher precision for determining age and thereby change the chronological limits of old age.[31] A further integration of osteoarchaeological and archaeological / historical data and finds in the future would increase the chance to understand the complexity of the life cycle in a more accurate and reliable way.

30 Simon A. Mays, Age-Related Cortical Bone Loss in Women from a 3rd–4th Century AD Population from England, in: American Journal of Physical Anthropology 131 (2006), pp. 352–362.

31 Kelly J. Knudson / Christopher M. Stojanowski, New Directions in Bioarchaeology. Recent Contributions to the Study of Human Social Identities, in: Journal of Archaeology Research 16 (2008), pp. 397–432.