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Editorial: Age Estimation

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Assessing and interpreting dental and skeletal age-related changes in both the living and the dead is of interest to a wide range of disciplines (e.g. see Bittles and Collins 1986) including human biology, paediatrics, public health, palaeodemography, archaeology, palaeontology, human evolution, forensic anthropology and legal medicine.

Estimating biological age from growth, maturity or age-related changes is a relatively new subject despite a long history of descriptive studies of childhood growth and development (Tanner, 1981; Ulijaszek et al. 1998). In contrast, age estimation in skeletonised remains has a long history of research, with early studies focussing on cranial suture closure, dental development and eruption, and the pubic symphysis (for an overview see Ubelaker 2010).

Assessing maturity or age-related changes allow us to predict where an individual is on their journey to maturation or what their biological age is. This allows us to infer chronological age. However, one of the features of growth, development and ageing is that individuals vary. Individuals at the same measurement of growth or maturity can have different chronological ages. Similarly individuals of the same chronological ages can be very different in growth, maturity or skeletal degeneration.

The morphological descriptions of age-related changes, an understanding of the factors that influence such changes and the interaction between different maturing body systems help to explain individual variation with age or variation between groups. Methods of estimating age are based on reference data from descriptive studies of age-related changes; these methods need to be tested for validity, reliability and performance. Until fairly recently, an evidence based approach to estimating age was sparse, however, the growing importance of a rigorous, questioning attitude has led to several advances in estimating age, particularly the importance of a reference sample of documented age and sex (Scheuer and Black, 2000; Hoppa and Vaupel, 2002; Usher, 2002) and the development of appropriate statistical methodologies (Boldsen et al. 2002; Kimmerlee and Jantz, 2008).

The topical questions in age estimation research include reliability and validity of the way the maturing skeleton is assessed, how maturation of different parts of the body is combined, how best to statistically express estimated age, the use of appropriate reference data, the factors affecting age-related changes and the expression of uncertainty and likelihood including the error in our assessment. Debating these questions leads to a better evaluation and improvement in the way we estimate age and the impact of this in particular for the courts in the context of forensic odontology and forensic anthropology.

This special issue of Annals of Human Biology, arises from the 55th annual symposium of the Society for the Study of Human Biology in association with the British Association for Biological Anthropological and Osteoarchaeology held in Oxford, UK, from 9th to 11th December 2014. Only a selection of the presentations are included here which encompass some of the major advances recently in age estimation from the dentition and the skeleton. Some of these are review papers, others are research papers. The reviews include maturation in living children, skeletal age indicators in adults in particular in bioarchaeology, issues regarding the report of age estimates and age assessment in forensic anthropology. Research papers are grouped into those that relate to the skeleton or in combination with developing teeth: radiographic and magnetic resonance imaging (MRI), fitting multivariate categorical data, combining results from bones and teeth, accuracy of age estimates and evidential value for assessing age of majority. The latter half of the research papers relate to tooth development including controversies in dental age estimation, age estimation of dentine collagen used for isotope analysis and age estimation in fossil hominins.

Nöel Cameron reviews the definition of maturity indicators, the criteria governing their identification and use and the problems of their interpretation. He points out that the widespread use of maturity indicators to determine age poses considerable interpretive challenges (Cameron, 2015).

Nicholas Marquez-Grant reviews the perspectives and practical considerations of forensic anthropology both in the living and in the dead, highlighting some of the challenges facing forensic anthropologists working from the crime scene to the laboratory, emphasising the need for reliable, repeatable age estimates within the justice system (Marquez-Grant, 2015).

Jo Buckberry reviews the misuse of adult age estimations in osteology by discussing the over-use of ordinal age categories in osteoarchaeology, highlighting inherent biases when developing, testing and applying age-estimation methods without fully considering the impact of 'age mimicry' and individual variation. She argues for the need to use individual-specific age ranges and probability densities to describe age (Buckberry, 2015).

Simon Mays reviews the effect of factors other than age upon skeletal age indicators in the adult, showing that age-related changes in the adult skeleton often only have a moderate correlation with age; other factors including vitamin D status, metabolic factors, biomechanical variables, and genetics also contribute to the variation seen (Mays, 2015).

Tangmose, Arge, Dyrgaard and Lynnerup present a review of cases of age estimation of the living performed in Denmark in 2012, showing that although there is broad agreement between age indicators as reported via traditional age ranges, there is a need for a transition analysis type approach, allowing for probability of age to be given (Tangmose et al. 2015).

Davies, Hackman and Black describe the changing perceptions of the epiphyseal scar in relation to the radiographic skeletal age estimation (Davies et al. 2015). They investigate the level of persistence of the epiphyseal scar with age and between anatomical regions and urge caution interpreting the epiphyseal scar in relation to skeletal age.

Urschler, Grassegger and Štern describe an automated method using MRI of the hand and wrist in males. This promising method evaluated age estimation performance including bone and epiphyseal gap volume localization and individual bone age predictions (Urschler et al. 2015).

Konigsberg describes parametric models for age estimation from ordinal categorical data presenting a robust statistical framework for analysing multiple ordinal categorical variables (age of transition of cranial suture closure), focussing on the issue of the assumption of independence of variables (Konigsberg, 2015). These raw reference sample data and code are available for download.

Gelbrich, Frerking, Weis, Schwerdt, Stellsiz-Eisenhauer, Tausche and Gelbrich compare the correlation in the error of age estimates from radiographs of hand bones and third molars and show a reduced error when combining age estimates from third molars and the wrist (Gelbrich et al. 2015).

Cole provides a succinct argument relating to the evidential value of developmental age imaging for assessing age of majority. He points out why bone age assessed by the hand-wrist should not be used to estimate age of majority and shows that the mature appearance of MRI wrist scans and third molars provide evidence of being over-age and the immature appearance is uninformative with more than a third of assessments incorrect (Cole, 2015).

Liversidge discusses several controversies in age estimation from developing teeth and assesses the performance of different methods estimating age from the developing second molar (Liversidge, 2015). This papers considers the choice of tooth staging, pooled-sex versus sex-specific reference data and statistical approaches.

Beaumont and Montgomery provide a simple method for assigning age to sequential dentine samples to investigate the isotopic life histories of individuals (Beaumont and Montgomery, 2015). Variations in consecutively forming teeth can be aligned using this method to extend the dietary history of an individual, or to identify an unknown tooth by matching profiles.

Dean and Liversidge compare dental development in early *Homo* with modern humans and note that S7-37, from Sangiran, Java, KNM-WT 15000, from Kenya and StW 151 from South Africa, age estimates for later stages of tooth formation fell within the modern sample range with a pattern consistently around the more advanced modern humans (Dean and Liversidge, 2015).

Conclusion

This special issue brings together expert review and research papers reflecting the diversity of interest in this field, the limitations of estimating age from maturity, new developments and techniques, but it also highlights how active this area of research is and possible future directions. It is hoped that this issue will encourage a more rigorous approach to include new imaging methods, a better understanding of the factors affecting age-related changes in the skeleton, models for age estimation combining age indicators and expressing uncertainty in estimated age.

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