

# Recent research in Forensic Anthropology

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## SUMMARY

Examination of recently published articles in four leading journals featuring forensic anthropology reveals strong research interest in the estimation of age at death and sex, trauma analysis and various other techniques of analysis. The 782 articles examined document the dynamic and evolving nature of forensic anthropology and strong research interest in all of the major components of the field.

**Key words:** Forensic Anthropology – Publications – Age at death – Methods

## INTRODUCTION

Forensic anthropology represents a mature science with a solid scholarly foundation. The academic roots are anchored in the fields of human anatomy and biological anthropology, and extend back into the nineteenth century. As early pioneers became involved in high profile casework, the need for new research, documented comparative collections and improved techniques became both recognized and addressed. In the twentieth century, forensic anthropology became a recognized subdiscipline of forensic science and biological anthropology. Key textbooks emerged (e.g. Krogman, 1962; Stewart, 1979), and a physical anthropology section was formed at the American Academy of Forensic Sciences along with the first certification program. Currently, the field is global in scope with certification programs in place in Europe, Latin America and the UK, in addition to

North America.

While these historical developments are impressive as forensic anthropology has matured, the field remains dynamic and evolving. Increased involvement in global humanitarian and human rights projects, as well as participation in recovery and identification efforts after mass disasters and acts of terrorism, present new challenges. New technology, especially expanded computer and related statistical capability have ushered in new methods. Concern about cognitive bias and probabilities associated with case results have triggered new research. Questions about population variation in many of the variables addressed by forensic anthropologists have led to the formation of new global collections and research in many world areas. With growth in student and professional interest in forensic anthropology, funding sources have opened up and publication outlets have expanded. This chapter focuses on the recent advances of this dynamic field.

## MATERIALS AND METHODS

To capture recent professional interest in key research areas, publications within four professional journals featuring forensic anthropology were examined. The following journals were selected due to their prominence in the fields of forensic anthropology and forensic science: *Journal of Forensic Sciences*, *International Journal of Legal Medicine*, *Forensic Science International* and *Forensic Sciences Research*.

Twelve methodological subfields of forensic anthropology were identified: “age at death”; “miscellaneous”; “trauma”; “sex”; “time since death (post-mortem interval)”; “taphonomy”; “stature”; “detection and recovery”; “ancestry”; “facial image-

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**Table 1.** 2016-2019 Trends in Forensic Anthropology: Analysis of article topics from four major forensic science journals

	<i>Journal of Forensic Sciences</i>	<i>International Journal of Legal Medicine</i>	<i>Forensic Science International</i>	<i>Forensic Sciences Research</i>	Total
<b>Age at Death</b>	34	82	84	1	<b>201</b>
<b>Miscellaneous</b>	57	13	67	13	<b>150</b>
<b>Trauma</b>	31	49	48	1	<b>129</b>
<b>Sex</b>	26	28	48	0	<b>102</b>
<b>Time Since Death (Post Mortem Interval)</b>	3	22	25	2	<b>52</b>
<b>Taphonomy</b>	22	4	16	3	<b>45</b>
<b>Stature</b>	6	2	17	0	<b>25</b>
<b>Detection and Recovery</b>	9	0	13	1	<b>23</b>
<b>Ancestry</b>	12	3	4	0	<b>19</b>
<b>Facial Imagery</b>	12	0	1	2	<b>15</b>
<b>Animal v. Human</b>	3	5	4	0	<b>12</b>
<b>Stable Isotope Research</b>	3	1	4	1	<b>9</b>

ry”; “animal vs human”; and “stable isotope research”. These subfields are listed in the order of frequency of article occurrence. The four journals listed above published from 2016 to 2019 (four years) were examined for articles focusing on these topics. Of course, many articles addressed more than one of these topics, but an effort was made to discern the primary topical focus of the article. Only one topic was scored for each article. In this study, 782 articles published between 2016 and 2019 in the four journals were examined.

## RESULTS AND DISCUSSION

Table 1 lists the numbers of articles on each of the 12 topics in each of the four journals. With 331 publications, *Forensic Science International* is the primary publication outlet, followed by the *Journal of Forensic Sciences* with 218, the *International Journal of Legal Medicine* with 209 and 24 for the comparatively new journal *Forensic Sciences Research*. The topics are listed in Table 1 in the order of their total occurrence in the four journals. The table reveals that 201 articles focus on issues of “age at death”, while only 9 feature “stable isotope research”. These results are similar to those revealed by Bethard and Digangi (2019), who found contributions on the biological profile to have the highest frequency of articles in their survey of the *Journal of Forensic Sciences* from 2000 to 2018. The table also reveals considerable variation among the four journals in the topics featured. While articles focusing on “age at death” are most popular in the *International Journal of Legal Medicine*, *Forensic Science International* and *Forensic Sciences Research*, other areas of analysis are mostly featured in the *Journal of Forensic Sciences*. The following provides a discussion of recent

research for each of the 12 topics in the order of their popularity in the journals. In addition, one article for each category is featured to illustrate current trends in research.

### **Age at Death (201 articles)**

Different techniques are involved in assessing age at death at different life stages (e.g. fetal, child, adolescent, young adult, old adult). For this reason, many publications and research orientations are involved. In addition, new research in estimating age at death recognizes some population variation in the aging process that must be considered in casework. New technology and recently developed documented collections have fueled research leading to significant advances. Research also has focused on different areas of the skeleton in recognition that many cases involve fragments or isolated bones.

Winburn (2019) investigated the changes of the acetabulum as a valid method of age estimation and its susceptibility to be impacted by factors such as physical activity and demographic qualities. Variables of the acetabulum were examined in 409 modern European-Americans. Variables were analyzed for association with osteoarthritis, Body Mass Index (BMI), age and metabolic intensity of physical activity. Results highlight a significant positive correlation among acetabulum changes, osteoarthritis and age. Correlation tests also illustrate no associations between acetabular changes and BMI or metabolic levels. This study demonstrates that the degenerative changes of the acetabulum are valid markers for age that remain unaffected by variations in demographic traits.

### **Miscellaneous (150 articles)**

The “miscellaneous” category includes areas of

**Fig 1.** Relevant tables from: Bethard, JD and EA DiGangi (2019) From the laboratory to the witness stand: Research trends and method validation in forensic anthropology. In: Fulginiti LC, Hartnett-McCann K, Galloway A (eds.). *Forensic Anthropology and the United States Judicial System*, pp 41-52. Reproduced with permission, © 2019 John Wiley & Sons, Ltd.

#### 44 Forensic anthropology and the United States judicial system

**Table 3.1** Topical breakdown of Anthropology contributions published in the *Journal of Forensic Sciences* from January 2000 to July 2018.

	Frequency	Percent
Biological profile	300	39.5
Taphonomic studies/Postmortem interval estimation	104	13.7
Skeletal trauma analysis	73	9.6
Facial approximation	61	8
Positive identification	54	7.1
Histology/Bone anatomy/Bone identification	21	2.8
Human rights/Humanitarian issues	21	2.8
Field methods/Forensic archaeology	19	2.5
Isotopes/Elemental composition	17	2.2
DNA analyses	16	2.1
History	16	2.1
Osteometrics/Laboratory procedures	15	2
Skeletal pathology	11	1.4
Commingling	10	1.3
Processing/Maceration	7	0.9
Legal issues	7	0.9
Ethics/Theory	6	0.8
Secular change	2	0.3
<b>Total</b>	<b>760</b>	<b>100</b>

**Table 3.2** Breakdown of topics focused on the biological profile published in the *Journal of Forensic Sciences* from January 2000 to July 2018.

	Frequency	Percent
Age	119	39.7
Sex	112	37.3
Ancestry	38	12.7
Stature	22	7.3
Parturition	3	1
Body mass	4	1.3
Handedness	2	0.7
<b>Total</b>	<b>300</b>	<b>100</b>

analysis not featured by the others. Sub-topics within the "miscellaneous" category include the following: identification techniques using specific bones and features; DNA extraction techniques from bone; alternative measurement techniques;

region specific status of forensic anthropology; hazards and risks; historical trends; victim identification in mass disasters, bone pathology; accuracy of three dimensional reproduction of bones; commingling; osteometric pairing; the relationship

between hard and soft tissue, prior information bias in analysis; observer reliability; reanalysis of anthropological records; skeletal collections; site survey techniques; legal and public health issues in the management of human remains; fragment reconstruction and variation in specific bone features.

Bertsatos and Chovalopoulou (2019) introduced a toolkit that features a new approach to long bone shape analysis as an alternative to computed tomography and the latex cast method. Known as the long-bone-diaphyseal-CSG-Toolkit, this procedure employs 3D laser scanning and 3D photogrammetry software to create 3D models of the diaphyseal cross-sectional geometric properties of long bones. The toolkit allows for the graphical analysis of diaphyseal cross section geometric properties and reduces inter- and intra-observer error by creating well-defined and accurate orientation of the bone and its contours. This new approach can facilitate osteometric sorting to address commingling issues.

### **Trauma (129 articles)**

Trauma research has focused on issues related to recognition of antemortem trauma and distinguishing it from perimortem trauma and post-mortem alterations. Experimental research has resulted in key new information on the biomechanics of bone fracture and the factors involved. New microscopic and imaging techniques improve capability to recognize trauma in decomposed and burned cases and to clarify the timing of injuries sustained. Advances are registered in understanding the relationship between soft and hard tissue alterations.

Rickman and Shackel (2019) tested two hypotheses on the formation of conoidal wounds from projectile impact on scapulae; the plug and spall hypothesis, and the cone crack hypothesis. Twenty-eight pig scapulae were impacted with 6-mm carbon-steel spheres at varying velocities. This study delves deep into the morphological features of conoidal fractures and presents an extensive analysis of specific fracture formations due to varying speeds of a projectile. They found that numerous features of conoidal fractures were consistent with the cone cracking method. However, a central component of the plug and spall hypothesis was rejected. Beveling occurred in the absence of a projectile exit, which was stated otherwise in the aforementioned hypothesis. Projectile trajectory and its impact on bones is a critical aspect of medicolegal interpretation.

### **Sex Estimation (102 articles)**

Estimation of sex continues to be a vital component for the establishment of the biological profile of recovered human remains. Research focuses on exploration of new areas of the anatomy offering information, testing of previous methods to

clarify error rates and the probabilities involved, use of new technology and documenting population variation. Estimating sex of the immature from skeletal remains continues to be problematic, but methods for adults are both accurate and useful, especially if the pelvis is available for examination.

Oner et al. (2019) introduced a new sexing technique using artificial neural networks (ANNs) focusing on lengths of manubrium sterni (MSL), processus xiphoideus (XPL), corpus sterni (CSL) and sternal angle (SA), using computerized tomography (CT) images on an orthogonal plane. Measurements of the MSL, XPL, CSL, and SA were analyzed with a multilayer ANN that used a stochastic gradient descent (SGD) and two hidden layers. They discovered that measurements of the MSL, XPL, SA and CSL were all larger in males than females. The approach offers improved accuracy over linear models.

### **Time Since Death (Post-Mortem Interval) (52 articles)**

Research in this area of forensic anthropology focuses on experimental studies of soft tissue decomposition and skeletal alterations, and use of the radiocarbon bomb-curve and other new approaches. The former efforts involve decay facilities that utilize donated human remains or non-human animals to document the diverse factors that influence the post-mortem changes. The latter methods focus on absolute methods to assess time since death using markers preserved in human tissues.

Ishikawa et al. (2019) presented a new method to assess time since death in individuals immersed in seawater. In their study of dental enamel, they found that, with increasing immersion time, the quantity of diatoms and the elements O, Si, Mg, K, Al and S increased along with a decrease in Ca and P. The documented changes allowed them to develop a new regression equation that can be useful in estimating time since death in remains recovered from seawater.

### **Taphonomy (45 articles)**

Observations on taphonomic changes are useful to assist in estimating the post-mortem interval and to examine the after-death history of remains. Studies on human taphonomy are diverse, ranging from research on scavenging and scattering of remains to the effects of burial, sunlight and water exposure.

Ross and Hale (2018) focused on the decomposition of juvenile and infant remains with a strong emphasis on examining the environmental variables most influential in decomposition, as well as testing if the adult methodology of quantifying decomposition was applicable to sub-adult remains. Thirty-five pigs were used as proxies for human infant and juvenile remains, and were deposited in five depositional styles (bagged, blanket wrapped,

and surface control fetal remains, surface juvenile remains, and buried juvenile remains). Soft tissue decomposition was examined and scored, and after completion and skeletonization, femora from the remains were collected and analyzed using the Oxford Histological Index (OHI). Results illustrate that standardized time variables employed in quantifying decomposition such as accumulated degree days (ADD) can be impacted by seasonal variation, especially by soil moisture. When examining quantification methods, the study also found that the total body score (TBS) was not as highly correlated to ADD and time in days, revealing it to be inapplicable to juvenile remains. The study emphasizes that juvenile decomposition is heavily driven by body mass, style of burial, and seasonal variations.

### **Stature (25 articles)**

Estimates of living stature add to the biological profile, but have limited value in the identification process. Progress involves noting errors in the reported statures of missing persons, especially those involving self-reporting and estimates of family members. New research involves formulae for individual bones and incomplete skeletal remains, as well as approaches derived from new documented collections from previously understudied world regions.

Spies et al. (2019) addressed the issue of determining stature from incomplete remains through the formulation of sex- and population-specific regression equations. The study focused on creating equations to assist in calculating the total skeletal height (TSH) of a black South African population when examining fragmentary tibial remains. The total skeletal heights for 99 female and 99 male complete skeletons were calculated using the anatomical method. Additionally, eleven measurements of different areas of the tibia were recorded from the intact tibia and used to form univariate and multi-variate equations to establish TSH. Both types of equations created using the fragmentary measurements were found to significantly positively correlate with TSH. The study highlights the importance of formulating sex- and population-specific equations to address the issue of estimating stature from incomplete remains.

### **Detection and Recovery (23 articles)**

The location and proper recovery of human remains represents a key feature of the activity of forensic anthropology. Errors made during recovery can negatively impact later analysis and interpretation. Progress is marked by the inclusion of forensic anthropologists and archeologists in search and recovery teams and recognition of their positive contributions. Activity in global humanitarian and human rights initiatives, often focusing on the location of mass graves, identifies new research directions for detection and excavation.

New geophysical testing technology stimulates new research in subsurface detection.

A study by Wisniewski et al. (2019) exemplifies the numerous methods and technologies that can be applied to assist in detection and recovery. The study utilized a multiphase geophysical approach in searching for a clandestine grave, focusing specifically on a reported 30-year-old vertical burial in a wooded area. Beginning with bulk ground conductivity and metal detectors, magnetics and ground penetrating radar (GPR) surveys were then administered as they were deemed best for the specific soil type. They utilized a tight grid pattern and investigated any electromagnetic anomalies. The study emphasizes the use of multiphase geophysical surveys as the best methodological approach to execute thorough and careful cold case searches.

### **Ancestry (19 articles)**

Progress in the estimation of ancestry involves increased recognition of the social dimensions of ancestral categories, as locally defined. Recent research also presents enlarged and more representative databases using both metric and non-metric observations on teeth and different elements of the skeleton. Use of proper, carefully defined terminology has emerged as an important issue, as well as advanced technology, advanced statistical approaches and comprehensive approaches that combine different types of biological data.

Kranioti et al. (2019) examined metric variation of the tibia as a method for estimating ancestry. Multinomial regression models were created from a reference sample and then applied to a validation sample in an attempt to classify individuals into one of six Mediterranean populations. With the first model examining three variables of the tibia and the second model examining six variables, they found that the second model featured higher classification accuracy. The Greek sample and Turkish sample were two of the groups with the highest classification accuracy in both the reference and validation samples, while the greater morphological overlap shared by the Spanish, Portuguese and Italian groups led to a decrease in accuracy. This research highlights the high variation of the tibia among populations, but emphasizes avoidance in using it as the sole feature to estimate ancestry. This study also draws attention to the field's expanding focus from cranial and dental features to the postcranial skeleton as a means of estimating ancestry.

### **Facial Imagery (15 articles)**

Forensic applications of facial imagery involve features for positive identification, techniques of craniofacial photographic superimposition and facial approximation. Facial approximation is used in studying a recovered skull to estimate what a

missing person looked like to seek leads from the public. Techniques of craniofacial photographic superimposition are employed to compare a recovered skull with facial images of a missing person, usually to either exclude or recognize the possibility of inclusion. Recent research involves providing new data on the relationship of soft and hard tissues of the head, development of standards, recognition of the probabilities and errors involved in the process and use of new technology and computerized approaches.

Flores et al. (2019) introduced a novel landmark-positioning approach for facial photoanthropometry (FPA). They suggested that the classic methods of positioning landmarks in FPA led to inconsistencies in reproducibility due to unclear definitions. The novel method presented provides additional marking procedures that reference visible facial features. This addition was successful as research illustrated that both examiner groups, with and without professional anatomical knowledge, were able to have lower landmark dispersion levels and higher reproducibility compared to classic methods. This new approach emphasizes the importance of refining traditional methods to increase accuracy and reduce variation of interpretation.

#### **Animal vs Human (12 articles)**

While distinguishing human bones and teeth from those of other animals is usually an easy task based on comparative morphology, the process can become challenging with fragmentary or burned remains. With such difficult cases, methods involving histology, molecular analysis or protein radioimmunoassay can provide insights. Recent research focuses on histological variation recorded in different bones and parts of bones of various species.

The Wang et al. (2019) article is an example of the new technologies being explored and employed in the field. This study examined the use of Fourier Transform Infrared (FTIR) spectroscopy and chemometrics methods to survey the spectral variances of human and non-human bones with principal component analysis (PCA), and utilized partial least squares discriminant analysis (PLS-DA) to analyze the data. Results illustrate that pig bones were the most sensitive to external factors, such as boiling and decomposition, compared to the other non-human bones used. This is an important discovery, as it calls into question the accuracy of using pig bone as proxy for human bone in forensic studies. The technology is reliable, as the spectral variance is mainly caused by stable inorganic portions of the bones. The study highlights the movement from a narrow focus on morphological features to the use of molecular examination when differentiating between human and non-human bones in an attempt to increase accuracy and save time and resources.

#### **Stable Isotope Research (9 articles)**

Stable isotopes, especially those of carbon and nitrogen have been used extensively in the past to examine dietary issues. More recently, forensic anthropologists have used isotopes of those elements and others to determine the geographical origin of recovered remains. This approach is especially useful in cases related to immigration and terrorism. Detailed isotopic analysis can determine if recovered remains are from a local individual or a person from another locality. New research using multiple elements aims at formulating isoscapes that suggest the geographic region of origin.

Warner et al. (2018) utilized isoscape refinement to predict the region of origin. Isoscapes, which are isotopic ratios specific to certain geographical areas, were determined through the isotopic analysis of 57 tap water samples collected across Mississippi. After performing isotopic analysis on the third molars of individuals with a known residential history, results demonstrate the high accuracy of region-of-origin assignment for Mississippi residents. Using this isoscape distribution, a linear regression equation was then formulated in an attempt to create a conversion factor for the southeastern US, with lower success rates for Georgian residents. The further refinement of isoscape equations and the use of various isotopes can lead to increased accuracy of the method.

#### **Conclusions**

Clearly, the field of forensic anthropology is expanding and evolving. A majority of the articles examine research on new approaches to traditional methods in the hope of improving accuracy, reducing error and utilizing new technology. While current research continues to focus on core issues such as age estimation, scope has expanded dramatically to include interpretations of trauma and region of origin. Methodological approaches include traditional measurement and observation but also involve increased controlled experimentation. Progress is also marked by formation of large databases, advanced statistical analysis and the involvement of the growing number of students and highly qualified professionals.

#### **REFERENCES**

- BERTSATOS A, CHOVALOPOULOU ME (2019) A novel method for analyzing long bone diaphyseal cross-sectional geometry. a GNU octave CSG toolkit. *Forensic Sci Int*, 297: 65-71.
- BETHARD JD, DIGANGI EA (2019) From the laboratory to the witness stand: research trends and method validation in forensic anthropology. In: Fulginiti LA, Hartnett-McCann K, Galloway A (eds). *Forensic Anthropology and the United States Judicial System*. John Wiley and Sons Ltd, Hoboken, pp 41-52.
- FLORES MRP, MACHADO CEP, GALLIDABINO MD,

- DE ARRUDA GHM, DA SILVA RHA, DE VIDAL FB, MELANI RFH (2019) Comparative assessment of a novel photo-anthropometric landmark-positioning approach for the analysis of facial structures on two-dimensional images. *J Forensic Sci*, 64(3).
- ISHIKAWA N, MIAKE Y, KITAMURA K, YAMAMOTO H (2019) A new method for estimating time since death by analysis of substances deposited on the surface of dental enamel in a body immersed in seawater. *Int J Legal Med*, 133(5): 1421-1427.
- KRANIOTI EF, GARCIA-DONAS JG, KARELL MA, CRAVO L, EKIZOGLU O, APOSTOL M, CUNHA E (2019) Metric variation of the tibia in the Mediterranean: implications in forensic identification. *Forensic Sci Int*, 299: 223-228.
- KROGMAN W (1962) *The human skeleton in forensic medicine*. Charles C Thomas, Springfield.
- ONER Z, TURAN MK, ONER S, SECGIN Y, SAHIN B (2019) Sex estimation using sternum part lengths by means of artificial neural networks. *Forensic Sci Int*, 301: 6-11.
- RICKMAN JM, SHACKEL J (2019) Crack propagation through sandwich bones due to low-velocity projectile impact. *Int J Legal Med*, 133(5): 1443-1459.
- ROSS AH, HALE AR (2018) Decomposition of juvenile-sized remains: a macro- and microscopic perspective. *Forensic Sci Res*, 3(4): 310-319.
- SPIES AJ, BIDMOS MA, BRITS D (2019) Using tibial fragments to reconstruct the total skeletal height of black South Africans. *Forensic Sci Int*, 298: 424.e1-424.e9.
- STEWART TD (1979) *Essentials of forensic anthropology, especially as developed in the United States*. Charles C Thomas, Springfield.
- WANG Q, LI W, LIU R, ZHANG K, ZHANG H, FAN S, WANG Z (2019) Human and non-human bone identification using FTIR spectroscopy. *Int J Legal Med*, 133(1): 269-276.
- WARNER MM, PLEMONS AM, HERRMANN NP, REGAN LA (2018) Refining stable oxygen and hydrogen isoscapes for the identification of human remains in Mississippi. *J Forensic Sci*, 63(2): 395-402.
- WINBURN AP (2019) Validation of the acetabulum as a skeletal indicator of age at death in modern European-Americans. *J Forensic Sci*, 64(4): 989-1003.
- WISNIEWSKI KD, COOPER N, HEATON V, HOPE C, PIRRIE D, MITTEN AJ, GEO M, PRINGLE JK (2019) The search for "Fred": an unusual vertical burial case. *J Forensic Sci*, 64(5): 1530-1539.