Chapter

Forensic Anthropology

Purva Wagisha Upadhyay and Amarnath Mishra

Abstract

Physical anthropology has been making progress in the field of forensic science. Forensic anthropology is the study of identifying and establishing identity of the skeletal remains present at the crime scene. The purpose of the chapter is to throw a light on the field of forensic anthropology as it seeks data like age, sex, ethnic groups, and other characteristic features after the examination of the skeletal remains. Forensic anthropology helps in determining the manner and cause of death, and if the body is still in the decompositions stage, time since death can also be estimated. Advancement in forensic anthropology will not only help to solve the case but it will also increase the opportunity to work in this area. In this chapter, there is an explanation of some of the methods used in forensic anthropology for the analysis of identification and other purposes.

Keywords: anthropology, archeology, osteology, skeleton, skull

1. Introduction

Anthropology is the scientific discipline of all features of creature progress and interface. It studies tools, language, ethnicity and social interactions, and how we relay to other societies. Physical anthropology studies human differences, especially those by which we can be acknowledged.

Forensic anthropology studies this identifying distinctiveness on the remnants of a person. These distinctive characters can be used to exhibit the sex, ethnic group, height, and physical health of a victim from his or her remains. Forensic anthropology is the application of the science of physical anthropology to the lawful process. Forensic anthropologists apply standard scientific techniques developed in physical anthropology to categorize human remains and to aid in the recognition of crime [1]. Forensic anthropologists are skilled like physical anthropologists who apply their expertise to solve cases of homicides by identifying the ethnic group; sex; age; stature; antemortem, postmortem, and perimortem injury time since death; and facial reconstruction (2D and 3D). Their job with law enforcement personnel includes scene search, excavation and recovery, questions of recognition, cause of death, manner and mode of death, and evaluation of time since death. The practice scope of this order is the identification of skeletonized remains, badly decomposed cadaver, anonymous human remains, and aging of persons, mass disaster and homicide victims, and unfairness of commingled skeletons or bones. Forensic anthropology is divided into subfields such as forensic archeology, forensic osteology, and forensic taphonomy [2].

Forensic archeology is a division of forensic science in which the appliance of archeological method is used in the examination of a scene of crime to recognize evidence and for the crime scene reconstruction. The work of a forensic

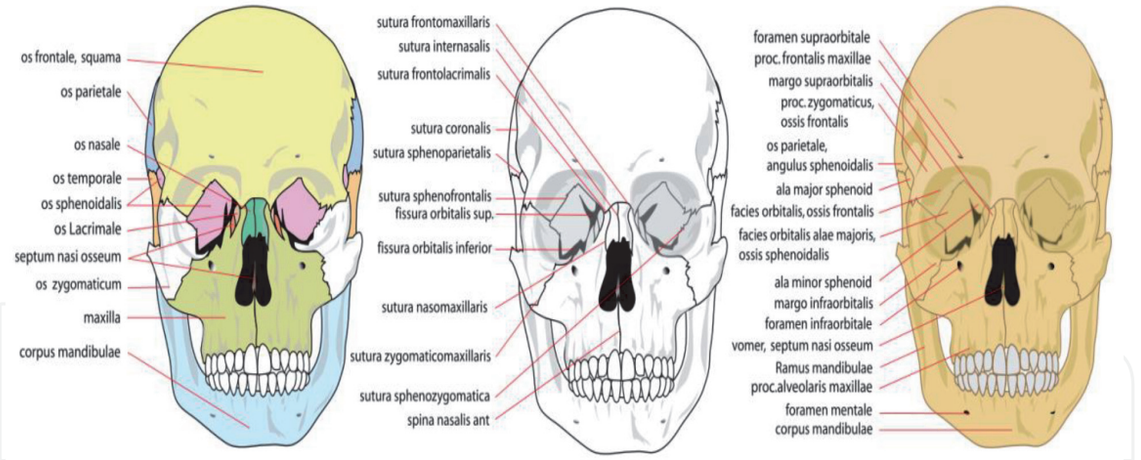

Figure 1.
The skull.

archeologist is to excavate and recover the human remains, weapons, etc. The procedure of forensic archeology is generally the same as that used by the conventional archeologist. In earlier 10 years, the fields of forensic archeology have developed as a key coordinator in the cases of mass death. In 1976, Morse, Crusoe, and Smith were the first to describe the theory of forensic archeology. As per the evolution in forensic archeology, the archeologist has transferred the technical approach for investigate and rescuing evidences to a forensic procedure. The archeological practices such as excavation, evidence identification, recovering the remains, and the study have followed a new approach to the particular type of scene of crime. Forensic archeologists apply their understanding of excavation steps just to be sure that the skeletal remains are collected in a particular manner and they are acceptable as evidence in the court of law. Forensic archeologists also establish the site of grave which might had been overlooked. The archeologist can situate the site of grave which can be seen in the soil's dissimilarity by the darker and looser organic soil in the region of those areas [3] **Figure 1**).

1.1 History

In Europe in the 1800s, the genesis of the ethnic groups of humans was intensely agitated. Scientists began with skull dimensions to make a distinction among those. The differences between male and female framework, and the evolution, aging, and fusing of bones were also examined, laying the structure for today's awareness. Jeffries Wyman (1814–1874) represents a key early pathfinder of forensic anthropology evidence. Wyman had a medical degree from Harvard University and was the first administrator of the Peabody Museum of American Archeology and Ethnology in 1866. His evidence in the trial of Harvard professor of chemistry John W. Webster, accused of the murder of Dr. George Parkman, captivated widespread media, and scholarly notice. At Harvard in 1894, Thomas Dwight gave his lecture about the study of human skeletal remains in a lawful setting (i.e., forensic anthropology). Thus, he was rightfully hailed as the "Father of Forensic Anthropology [4]."

Another nineteenth century murder trail brought well-known notice to anthropological testimony. In Chicago, Adolph Luetgert, a sausage producer, was hold responsible of assassinating his wife and disposing of the dead body by inserting it in a solution of potash in one of the factory vats. Investigation of the remains exposed minute remains that were bought to the notice of Dorsey of the Field

Columbian Museum in Chicago. In the Luetgert trial of 1897–1898, Dorsey testified that the small remains recovered from material connected with the sausage vat were matched from a human female. His testimony was cruelly blamed by defense expert who argued that such determinations could not be through with poise from such minor evidence. In 1932, the FBI declared the opening of its first crime lab. The Smithsonian Institute became a working partner, aiding in the recognition of human remains. In 1939, the FBI published' Guide to the Identification of Human Skeletal Material".

Anthropologist William Krogman made available his book, "of Guide to the Identification of Human Skeletal Material," in 1962. Forensic anthropologists use this textbook even today. "Skeletal age change sin young American males" was in print in 1954 by Tom Mckern and T. Dale Stewart. In this report, Mckern and Stewart recognized skeletal aging approach based on facts from skeletal remains of Korean War military. In the early 1960s, the computer was discovered; this enabled forensic anthropologists to use discriminant purpose study, a statistical system to categorize sex and origin of skeletal remains. More recently, a new practice in DNA originated in the mitochondria of cells has been used in detection. Thomas Wingate Todd was in charge for the compilation of human skeletons in 1912. In total, Todd got skulls and skeletons of humans, anthropoids and other mammals. Todd also developed age estimation based on physical individuality of the pubic symphysis. Though the principles have been bringing up to dated, these estimates a range of skeletonized remains.

2. Biological profiling of skeletal remains

2.1 Demography

All skeletal examinations start with Krogman's "big four"- age, sex, ethnic group, and stature. Each feature narrows the pool of possible "matches" considerably- sex alone cuts it by half. If a skeleton is absolute and unharmed, these aspects can be assessed with great correctness. Using the most recent systems, sex can be established with assurance, age estimated to within about 5 years, and stature approximated with a typical deviation of about 1.5″ (3.5 cm). However, forensic anthropologists are more likely to be dealing with incomplete, fragmented specimens so they must be equipped to glean as much information as probable from every bone. Demographic characteristics include ethnic group, age, sex, stature and build [5].

2.2 Ethnic group

Ethnic group may be defined as coarse classificatory machinery for biological characteristics. Caucasoid, Mongoloid, and Negroid are the three foremost ethnic groups. However, there will always be ambiguous cases because of admixture. Moreover, there is huge variation within each group, and skin color is one of the aspects in racial categorization. In the skeleton, cranio-facial morphology is the finest pointer of racial phenotype. An extended, low, slender skull exhibiting alveolar prognathism and a broad, flat nose with gentle sills is typically negroids. Racial differences can be found in other parts of the body. Caucasoids have forward curvature of the femur but negroids have straight femur bone. Negroids have narrow pelvis, but measurements tell better. Size differentials reproduce disparities in total body proportions. Negroids have proportionally longer limbs than Caucasoid; the reverse holds true for mongoloids (**Figure 2** and **Table 1**) [6, 7].

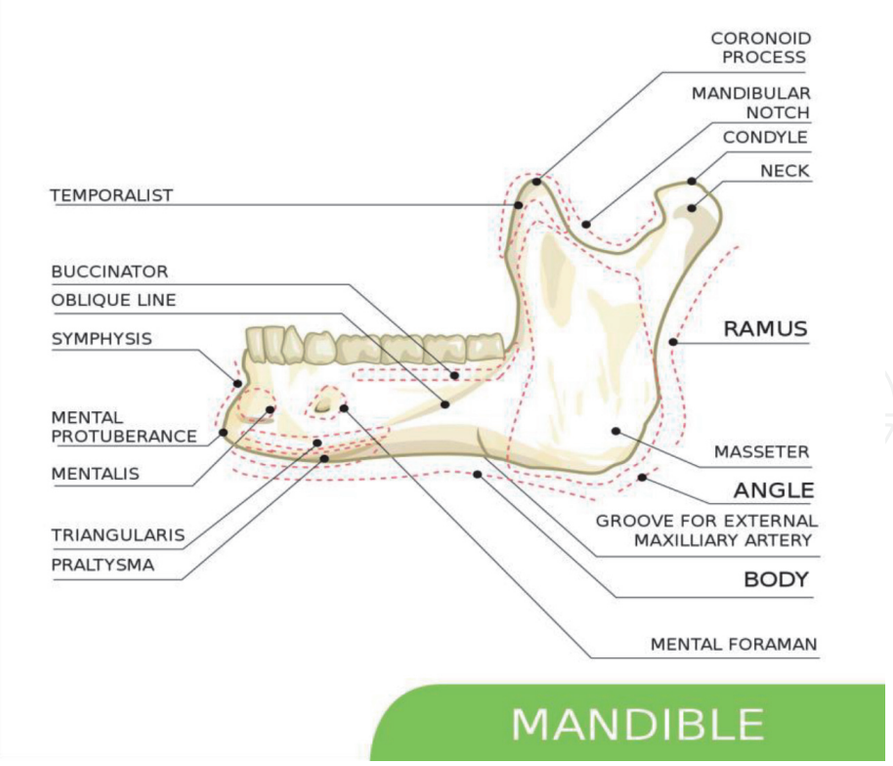

Figure 2.
Mandible.

Characteristics	Europeans origin	Asian origin	African origin
Protrusion of jaws [7]	Orthognathic	Prognathic	Prognathic
Nasal spine	Prominent, large, or long	Medium, tilted	Little or no nasal spine
Nasal aperture	Narrow	Medium	Wide
Nasal sill	Single and sharp	Single and sharp	Double or guttered
Zygoma	Single	Forward projecting (extra bone present)	Single
Dentition	More crowded	Less crowded	Less crowded
Palate	Narrow	Wide	Intermediate palate width
Dental row	Parabolic curve	Simple elliptical (rounded)	Hyperbolic curve (U-shape)
Incisors	Blade shape	Shovel shape	Blade shape
Palatal suture	Arched or jagged	Straight	Not straight
Maxillary molars	Carabelli's cusps	Four cusps	Four cusps
Cranial suture	Simple	Complex and/ or with sutural bones	Simple
Chin	Square and projecting	Blunt	Retreating
Cranium	High	Low and sloping	Low and with post-bregmatic depression
Anterior curvature of femur Bone	More curved	Straighter	Straighter

Table 1.
Differentiating features and points between ethnic groups.

2.3 Sex

If the adult skeleton is absolute or at least has an unbroken pelvis, the sex can usually be determined with 100% accuracy. However, as mentioned earlier, forensic skeletons are hardly ever complete, and the available bones may not be obviously dimorphic. There is no marker that helps in the distinction of primary sexual features. Although gender differences have been quantified in immature skeletons, they remain subtle until secondary sex characteristics begin increasing during adolescence. Attempt at sexing pre-pubescent bones have been completed by means of measurements of growth-based differences between males and females, but the outcome is far from reality. In adults, sex can be determined by the evaluation of pelvis [6].

A systematic data of cranial morphology can allow experts to come up to 90 to 95% accuracy. However, the observer must be well known with population-specific variants because sex-linked distinctiveness varies from one group to another. In adult males, it has been observed that the posterior ramus has a separate angulations or flexure at the level of the occlusal surface of the molars, whereas females maintain the straight, juvenile arrangement.

2.4 Age

The bony skeletal arrangement is not absolute at beginning, but somewhat begins with the configuration and development of centers of ossification. Till the commencement of teenage years, there are diaphysis (shaft) and epiphyses at both the ends of long bones. These are linked by cartilaginous metaphysis or emergent regions that are replaced with bone when development is absolute. Because development at every bony joint is finished at different ages and in a set order, following the succession of epiphyseal union will permit age estimation to within 1 year from about 13 through 18 years. If adolescent is between 13 and 18 years, merging of lower epiphysis and opening of proximal epiphysis in the humerus bone is observed. Age is then determined by fusion of joints in the body. Once development is inclusive, age estimation becomes a great deal and more difficult because post maturity age changes are subtle, uneven, and often extremely variable from one individual to the next because remodeling rates and patterns are sensitive to a many of internal and external factors. The sterna end of the rib is proving to be the mainly reliable form of age estimation. In evaluation of pubic symphysis and ribs from the similar persons indicated that the rib was two times as possible to imitate age accurately (**Figure 3** and **Table 2**) [8, 9].

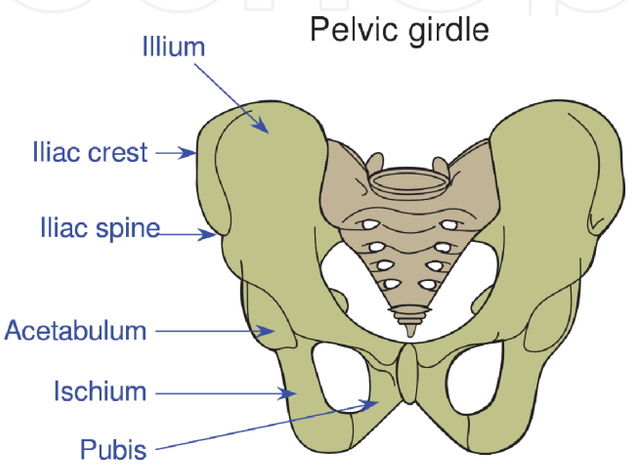

Figure 3.
The pelvic girdle.

Characteristics	Male	Female
Occipital protuberance [7]	More prominent	Less prominent
Mastoid process	Larger	Smaller
Supraorbital ridges	Prominent	Absent
Upper orbital margin	Rounded	Sharper
Ramus of mandible	Wide, sharply angled, flared	Narrow, chin less angled
Chin	Squared, protuberant	Rounded or pointed
Ossification of ribs	Marginal	Central
Ribs' ends' appearance	Crab claw-like	Rough planar end
Pelvis	Larger and more robust	Wider and larger pelvic inlet
Pubic body	Triangular	Rectangular
Subpubic angle	Narrow	Wide
Subpubic concavity	Absent	Developed
Parturition pits	Absent	Developed
Characteristics	**Male**	**Female**
Ilium [7]	Narrow	Wide
Sciatic notch	Narrow and deep	Wide and shallow
Sacrum	More curved, longer, and narrower	Flatter, broader, and smaller
Muscle attachment in pelvis	More	Less
Humerus head diameter	>47 mm	<43 mm
Radius head diameter	≥24 mm	≤21 mm
Femur head diameter	47.5 mm	42.5 mm
Q-angle in femur bone	Smaller (11.2 ± 3)	Larger (15.8 ± 4.5)
Knee	Larger	Smaller
Zygomatic arch	Broader	Narrower
Sternum	Body is more than twice as large the manubrium length	Body is less than twice the manubrium length

Table 2.
Differentiating features between male and female for sex determination.

Several methods are there for the estimation of age with their advantages and disadvantages. No aging technique is even close to 100% accuracy. There are two sources of fault: (1) individual difference as reported in the standard deviation of the way and (2) differences between the sample population and the population of origin. No aging process should be used without help unless there is no choice. Choice of method is, of course, limited when partial or fragmentary remains are the only material accessible. Always offer a range when estimating age. It is far better to include a 10- to 12-year age range, particularly in big individuals, and be successful in matching the lost person by other individuality than to give a 3- to 5-year range and miss the recognition entirely (**Table 3**) [10].

Characteristic	Age estimation
Metopic suture fusion [7]	Closure by 1–2 years, fusion by 7–8 years
Lateral portion of occipital bone fusion with squamous bone	1–3 years
Basioccipital fusion with occipital	5–7 years
Fusion of occipital with sphenoid	11–16 years (in females), 13–18 years (in males)
Mandibular symphysis fusion	6–8 months
Medial clavicular epiphysis	Mid-twenties or 15–35 years
Coracoid Process in scapula	15–17 years
Glenoid epiphysis	17–18 years
Acromial epiphysis	~20 years
Ribs' head epiphysis	17–25 years
Segment 3 and 4 of sternum	4–10 years
Segment 2 with 3–4 of sternum	11–16 years
Segment 1 with 2–3–4 of sternum	15–20 years
Xiphoid to body	40+ years
Xiphoid appearance	3–6 years
Transverse lines (S1 and S2) in sacrum	Mid-twenties or later
Humerus distal epiphysis	11–15 years female, 12–17 years male
Humerus proximal epiphysis	13–17 years female, 16–20 years males
Radial distal epiphysis	11–13 years female, 14–17 years male
Radial proximal epiphysis	14–17 years female, 16–20 years male
Ischiopubic ramus	5–8 years
Acetabulum	11–17 years
Ischial tuberosity	16–20 years
Femoral distal epiphysis	14–18 years female, 16–20 years male
Femoral head fusion	12–16 years female, 14–19 years male
Tibial distal epiphysis	14–16 years female, 15–18 years male
Tibial proximal epiphysis	13–17 years female, 15–19 years male

Table 3.
Age determination in male and female.

2.5 Stature

Usually and together, the femur and tibia are the majority significant main elements of height. Therefore, the greatest evaluation of height is acquired from regression formulae resultant from femoral and tibial lengths. These equations have been intended for all of the long bones and long bones give more preciseness than arm bones, it may be the only parts establish attempts have been made to amplify accurateness by using the combined assistance of multiple bones. Body proportions differ by both ethnic group and sex. Negroids, for instance, have long limb bones comparative to stature than Caucasoid. Thus, it is essential for determining sex and ethnic group in sort to make use of the correct regression formulae for the

evaluation of stature. Trotter standards are used for Caucasoid and negroids. Smooth bony surfaces and minute muscle origins are trait of a gracile or sedentary individual. It is significant to keep in mind that although males inherently have extra muscle mass than females, males will not have as well-developed attachment sites as female body builders. All small people do not necessarily have slender builds; conversely, huge height is not always linked to massiveness. Although standard weight can be approximated for a known height, there is no technique to establish obesity from the skeleton. The formulae for stature estimation differ by sex and ethnic group, so it is worthwhile to know the sex and ethnic group of the focus before commencement of stature analysis. Long bones are often measured on an osteometric board. The large sliding calipers used for measuring tree diameters are also extremely helpful. Most long bone measurements are easy utmost lengths. This includes the measurement of the humerus, radius, ulna, femur, and fibula. The tibia is a bit extra complicated. The femur is now and then measured with both condyles in contact with the osteometric board. This is called the bicondylar length or oblique length and is particularly helpful because it orients the femur in anatomical location. Bicondylar length provides information about sex as well as stature. After measuring each bone according to directives, insert the measurement into the suitable formulae (**Figure 4** and **Table 4**) [6, 10].

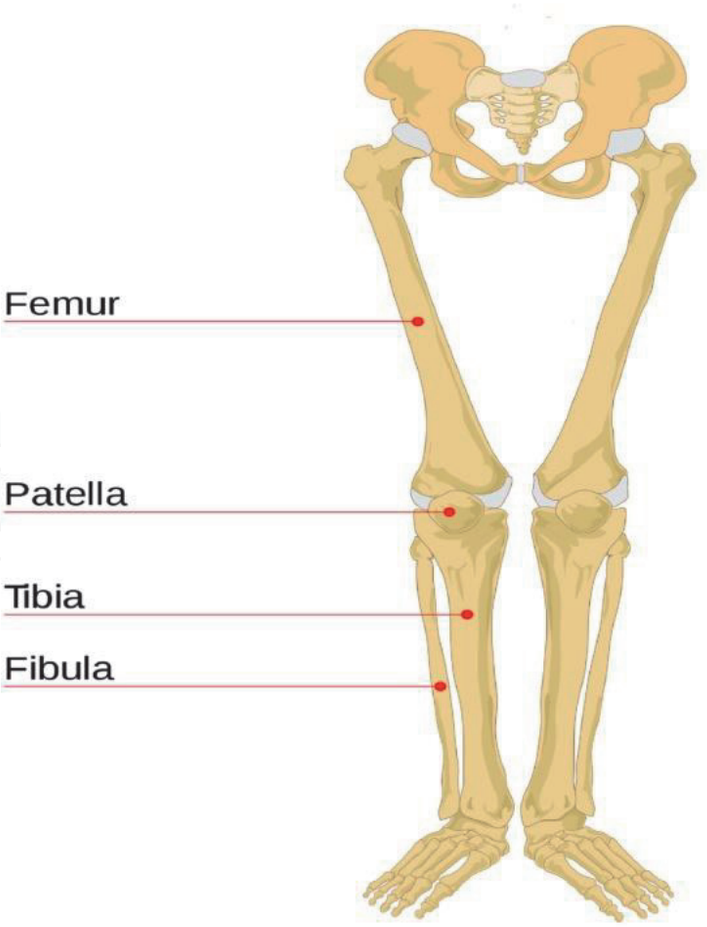

Figure 4.
Lower limb bones.

Ethnic group	Bone	Male	Female
European	Humerus	2.89 * L + 78.10 ± 4.75	3.36 * L + 57.97 ± 4.45
	Radius	3.79 * L + 79.42 ± 4.66	4.74 * L + 54.93 ± 4.24
	Ulna	3.76 * L + 75.55 ± 4.72	4.27 * L + 57.76 ± 4.30
	Femur	2.32 * L + 65.53 ± 3.94	2.47 * L + 54.10 ± 3.72
	Tibia	2.42 * L + 81.93 ± 4.00	2.90 * L + 61.53 ± 3.66
	Fibula	2.60 * L + 75.50 ± 3.86	2.93 * L + 59.61 ± 3.57

Table 4.
Stature estimation using Glesser formula.

3. Methods used in forensic anthropology investigation

In the field of forensic science, successful recovery and examination of DNA has a massive impact. In forensic anthropology, exact knowledge related to sex of the unidentified remains can be represent and offer to identity to it through molecular examination. The molecular analysis is also being used for establishing ancestry evaluation and for detection of species. Determining identification with the help of DNA has played the most important role in the field of analysis. Whether the tooth or the bone needs to be analyzed during the examination of skeletal remains. As DNA test is costly as well as destructive also, these are decisive and influences the outcome of the analysis. For Human Identification from the skull is generally classified as:

A. Reconstruction Method: Reconstruction method proposes only possibilities and probabilities without certainty of as many criterions of individualization from the skull, like ethnic group, age, sex, stature, etc., as possible. Types: (a) Modeling clay method (3D), (b) computer software programs (2D), and (c) manual sketching method (2D).

B. Comparative Method: Comparative method gives a high degree of reliability and precision where the photographs and radiographs are used for evaluation with the skull. Types: (a) Metric measurements and (b) superimposition: (i) Negative SI and (ii) Video SI. Evidential value of superimposition technique in the court of law is corroborative [10].

Radiography: Sex determination is one of the most confused puzzles, which needs to be solved by radiographic examination. Sexual dimorphism represented by the skeletal system determines the accuracy with which the skeleton can be identified. There are different morphological features between males and females. For example, in negroids, left side frontal sinuses gave accuracy in sex determination by 60% [11, 12].

Radiocarbon dating: It is one of the most used methods for determining the age of the skeleton. The amount of Carbon-14 obtained from the skeleton remains or any other part helps in determining the age of the remains [13, 14].

X-Ray fluorescence (XRF): X-Ray fluorescence is used for the determining of mineral content of bone such as Zn, Pb, and Fe. The presence of these elements at different quantity helps in determination of diet of an individual and the abundance

of these elements in the bones also helps in determining the area to which an individual belongs. The main advantage of this technique is that this technique takes very less time for examination [15].

4. Conclusion

Forensic anthropology has many disciplines, one of which is forensic osteology. Forensic anthropology is mainly for the study of basic identification like estimating age, ethnic group, sex, and stature from the skeletal remains. Anthropologists might get several evidences that may indicate the cause of death and manner of death, and if the flesh is found on the skeleton, which means the body is still under the decomposition stage, the time since death can be narrowed down easily by gathering all the necessary information from the skeletal remains; a biological profile of the individuals can tell us how they lived and the manner of their death [16]. Forensic anthropology has already made progress in its field. The advancement in forensic anthropology is only possible and dependent on the advancement of the older technique and by creating new techniques based on the type of cases. Forensic anthropology plays a major role in identifying and establishing the identity in an investigation. The main application of anthropology is to process the sight of crime, inspect the remains, and to generate a profile of the skeletal remains found at the scene of crime to testify it in the court of law.

Author details

Purva Wagisha Upadhyay and Amarnath Mishra*
Amity Institute of Forensic Sciences, Amity University Uttar Pradesh, Noida, India

*Address all correspondence to: amishra5@amity.edu; drmishraa1@gmail.com

References

[1] Adams BJ, Byrd JE. Recovery, Analysis and Identification of Commingled Human Remains. Totowa: Humana Press; 2008

[2] Byers SN. Introduction to Forensic Anthropology. 3rd ed. Boston: Allyn and Bacon; 2008

[3] Dupras TL. Forensic Recovery of Human Remains: Archaeological Approaches. 2nd ed. Boca Raton, Fla: CRC Press; 2012

[4] Black S. Forensic anthropology–regulation in the U.K. Science and Justice. 2003;**43**:187-192

[5] Cattaneo C. Forensic anthropology: Developments of a classical discipline in the new millennium. Forensic Science International. 2007;**165**:185-193

[6] Hill I. Physical appearance. In: Thompson T, Black S, editors. Forensic Human Identification: An Introduction. London: CRC Press; 2007. pp. 87-97

[7] Identification of Skeletal Remains (PDF). November 5, 2010. Available from: forensicjournals.com [Accessed: 19 August 2015]

[8] Differences between Male Skull and Female Skull. September 24, 2008. Available from: juniordentist.com [Accessed: 19 August 2015]

[9] Nawrocki SP. An Outline Of Forensic Anthropology (PDF). June 27, 2006. Archived from the original (PDF) on 2011-06-15 [Accessed: 21 August 2015]

[10] James SH, Nordby JJ. Forensic Anthropology. Forensic Science: An Introduction to Scientific and Investigative Techniques. 3rd ed. Boca Raton, Fla: CRC Press; 2009. pp. 101-135

[11] Erhisenebe D, Eboh O, Ogbeide OU, Ivwighren T. Radiographic anthropometric study of frontal sinus for sex determination in Benin City, South-South Nigeria. Journal of Forensic Dental Sciences. 2017;**9**(1):31-35

[12] Mostafa EM, El-Elemi AH, El-Beblawy MA, Dawood AE-WA. Adult sex identification using digital radiographs of the proximal epiphysis of the femur at Suez Canal University Hospital in Ismailia, Egypt. Egyptian Journal of Forensic Sciences. 2012;**2**(3): 81-88

[13] Lynnerup N. Forensic anthropology and human identification. Scandinavian Journal of Forensic Science. 2019;**19**(1): 16-38

[14] Ramsey CB. Dealing with outliers and offsets in radiocarbon dating. Radiocarbon. 2009;**51**(3):1023-1045

[15] Gonzalez-Rodriguez J, Fowler G. Chemical anthropology: A study on the discrimination of human skeletons using X-ray fluorescence and chemometric tools. Forensic Science International. 2013;**231**(1–3):407

[16] Schmitt A, Cunha E, Pinheiro J. Forensic Anthropology and Medicine Complementary Sciences from Recovery to Cause of Death. Totowa, NJ: Humana Press; 2006