Indian Internet Journal of Forensic Medicine & Toxicology
ISSN 0973-1970, Vol.6, No.4 (2008) *Review Article*

Forensic Anthropology in biological profiling of human skeletal remains

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Introduction

The anthropological analysis for biological profiling of the skeletal material from forensic context is of paramount importance and forms a basic step in forensic anthropology. Forensic anthropology is an applied discipline of anthropology wherein standard scientific methods and techniques developed in skeletal biology, osteology and physical anthropology are applied for medico legal purpose. It forms an integral part of identification process as it allows relatively fast and accurate data that could narrow down the investigators search field. Traditional anthropological assessment of biological identity remains an essential component in the process, serving to limit misidentification and provide additional information upon which to base and support positive identification[1].

Forensic anthropology is a relative new discipline and has been gaining more and more relevancy in recent years. In view of the growing rate of crime, clandestine immigration etc. the number of forensic cases requiring expertise in identification of both dead and living individuals has increased manifold and so is the case with the increased demand of experts dealing with the retrieval, recovery and study of badly decomposed mutilated or damaged human remains[2]. A forensic anthropologist uses the anthropological and archaeological techniques and methods for analysis of such human remains and also for determination of PMI in an attempt to construct an accurate biological profile and positive identification as the identification of such remains is important for both legal and humanitarian reasons. He may be required to work in conjunction with forensic pathologists, Odontologists and homicide investigators to identify a decedent, to discover evidence of any foul play and to calculate postmortem interval[2].

With the advent of DNA profiling from bones, it was wrongly presumed that in near future osteomorphological assessment of skeletal remains will become obsolete but the analysis of skeletal biology continues to be an integral part of identification process despite the success of molecular techniques as the anthropological assessment of morphological traits is quick to perform, less expensive, reliable and just accurate and draws indispensable inference about the identity of an individual.

Biological Profiling/ Identity of an Individual

The four main attributes of biological identity are sex, age, stature and ethnic background of an individual. To create a biological profile or to generate the osteobiography of an individual human

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skeleton is one of the most ancient areas of interest. Successfully determining the identity of a decedent is of considerable significance from the ethical, legal, criminal and sometimes political perspective and forms a basis for investigating offences, mass disasters or war related crimes. The profile of a decedent can be easily determined from a complete or almost complete skeleton, however, it depends upon the age of the specimen, completeness of the skeleton, intrinsic variability and lastly the expertise of the investigator. As the populations differ in body size, shape and architecture of skeletal framework, accordingly, these differences can effect the metric and non-metric assessment of their profile. Non-metric or non-discrete features of the skeletal remains are important for forensic anthropological analysis but the metric features are frequently used as populations differ metrically in both size and proportions.

In cases of mass disasters, war crimes and multiple burials of commingled remains, to the ability to assign skeletal elements to specific individuals and to correct side of the body becomes important by studying the relative size and robusticity of the bones, their pathological conditions or skeletal trauma and callosities. The ability to separate commingled remains depends upon the detailed knowledge of human osteology. An anthropologist can detect the related materials to recognize incongruities among the osseous elements because of inconsistencies in this developmental status. However, the reliability and accuracy of main attributes of the biological profile of an individual depends upon the presence and state of preservation of any particular skeletal part of the body and its maturity.

Determination of sex

Gender/sex determination of skeletal remains is one of the main attributions of forensic anthropologists and forensic odontologists engaged in anthropological analysis of skeletons, parts and fragmental bones. It is the first step of identification process and the subsequent methods of profiling an individual are dependent upon it, thus halving the search for an unknown, missing or dead individual. It is of prime importance in case of unknown human skeletal remains found in both forensic and archaeological situations[3]). Sex and age determination are mutually dependent and conjugated and their indicators are related to each other[4]. Identification of sex from human skeletal materials is an imperative element of any medicolegal investigation and is a challenging task for both forensic experts and physical anthropologists[5].

While determining sex, forensic anthropologists rely upon expected size differences (or sexual dimorphism) between males and females and among populations which is important for effectiveness of metric standards[6]. Both the magnitude of sex-related differences and general robusticity of skeleton are population specific, so it becomes a vital prerequisite to know the origin of skeletal remains so that available sex determination methods can be adjusted accordingly[4]. Sexual dimorphism varies among human populations because of nutritional and environmental factors[7].

Three broad categories of methods are generally used to sex unidentified skeletal remains[4,8,9]. The first approach relies upon visual inspection and evaluation of macroscopic morphological sex traits specific to various parts of the skeleton primarily to skull and pelvis. This method is subjective in nature, less work-intensive but with higher error rates. The 2nd approach relies upon molecular DNA profiling of skeletal remains (mainly in juvenile skeletons) which is more complicated, time consuming and requiring more sophisticated equipments but is more reliable. The third approach relies upon discriminate function analysis and multivariate regression analysis of various skeletal measurements, which reduces subjective judgment as well as level of expertise and experience needed for sex determination.

The decision to use a particular method depends upon the completeness of the skeleton, clarity of the morphological indicators in a specific skeleton, the level of precision required and sometime simply on experience and practical consideration of the investigator[4]. Physical anthropologist traditionally employs both qualitative and quantitative strategies to estimate osteological profile[10] but to this very nature, osteometric analysis is more reliable and best choice of effective sex assessment[11].

It is rarer that a skeleton is sexed wrongly when it is almost complete of a known population and when all the three approaches are applied in their complexity. If the skeleton is badly unrecognizable and is not suggestive of sufficient sex diagnosis, it is advisable to supplement the morphological methods with quantitative and molecular methods.

In case of children and adolescent's skeletons, the sex has been assessed on the basis of morphological examination of discrete traits of cranium and pelvis ([12] teeth[13] mandible[14] and robusticity indices of long bones[15] but these estimates cannot be applied to every population.

Pelvis, skull and long bones are the most studied bones of adult human skeleton in sex determination and are the best indicators of the gender. Mays and Cox[16] claimed of 98% sexing accuracy from pelvis only, 80% from skull alone and 90% from skull and mandible. To these one would add the ribs[17-19], vertebral column[20], humerus[21-24],radius[25,26], hand foot bones[27,28], Femur[29,30], clavicle[31], sternum[32,33,5], tibia[34,35] etc.

The osseous skeleton which resists putrefaction for a long-time is useful for sexing but there is still a great prevalence of errors of different methods used on different populations usually with different statistical parameters[36].

Mandible is the largest and hardest facial bone that retains its shape and can be used to distinguish between sexes and among ethnic groups in forensic medicine and physical anthropology[37]. Length measures of hand and foot bone are more appropriate than robusticity measures in sex determination[38].

In case of badly damaged or older skeletal remains, the analysis of morphological traits becomes difficult in sexing them. Use of any skeletal method is limited to identical or very similar populations as secular changes and population specific genetic differences usually complicate the implementation of such method to some other populations[39].

The advent of DNA profiling, its isolation and amplification from bones has somewhat changed the scenario of sexing the skeletal methods[40-43]. It has been established that profiling of DNA from skeletal remains of unknown sex and age give better and more precise results free from any systematic bias than the morphological assessment[4] but in forensic context, molecular method is rarely chosen at the cost of morphological method especially in adult skeletons because there are certain qualitative difficulties working with molecular methods like contamination with DNA of the investigator, inter-contamination between skeletal remains and corpses found in same graves, insufficient volume of DNA and certain new mutations while comparing with living relatives etc.[44].

Determination of Age

Assessment of age at death from skeletal material of individual/individuals is one of the most difficult problems in forensic and physical anthropology especially in cases of mutilated, decomposed,

burnt, recondite or dismembered bodies and bones of dead[45]. Forensic age estimation of skeletons and unidentified cadavers for identification purposes is very essential from archaeological, palaeoanthropological and forensic point of view as it is to be estimated as accurately and as precisely as possible[46]. For anthropological contexts, it is also necessary for unbiased palaeoanthropological studies of development, demography, pathology and burial practices of past people so that a valid and meaningful statement can be made for past populations. A reliable age estimation of skeletal material of a particular population is a fundamental condition to develop its demographic profile as different populations have their certain specific population standards. Age estimation of skeletal remains and of living persons are two distinct areas of study and are very important from forensic anthropological point of view and have significant social and legal ramifications for both the individuals and the community as a whole[47].

Age estimation of unidentified cadavers and skeletons for identification and biological profiling has been a traditional feature of forensic anthropological analysis. Age estimation of living individuals for the purpose of criminal civil, old age pension and asylum proceedings is also a critical aspect for both forensic and anthropological contexts[48].

Currently many individual techniques developed from a variety of approaches and source materials of varied complexity are available to assist professionals in this endeavour but comprehensive approaches of age estimation using multiple age indicators are found to be superior to isolated individual techniques[49]. Parameters of skeletal age estimation at death vary greatly within the successive developmental phases from infancy to adulthood but ageing becomes less accurate with increasing years as regression error of estimate increases with age[50,4] Development of new methods & improvement in the existing methods of estimation of age from skeletal. There are three basic methods of age estimation; morphological method, histological method and the combined method[51].

The histological method is complex and just accurate and includes aspartic acid racemisation, bone-tooth histology and counting of layers in dentine whereas morphological method is simple but inaccurate and includes long bones growth, epiphyseal union closure, dental eruption and calcification, pubic symphysis surface, illium articular surface, phase analysis of sternal end of ribs, general level of wears and closure of certain cranial sutures etc[52].

In case of scattered or historical skeletal remains, the histological method is usually preferred but it is influenced by time since death[53]. Cranial suture closure, occlusal wear and tear of tooth and counting of dentine layers etc. are the only precise and advisable methods for forensic purposes but they also need to be tested for reliability on different populations and on larger samples of known age and sex[54].

In children skeleton, mineralization status of teeth and its different stages is the most precise and accurate method of age estimation. Another suitable indicator is the length of long bones[55,56]. Development of epiphyses is the preferred biological process for age estimation of adolescent's bones and is commonly used in osteology[57,58] but it is not suitable for forensic skeletons. Before forensic age diagnosis of long bones is carried out, it is essential to know their origin and burial period[4]. When dentition is not available for age estimation and is highly affected by environmental influences, other features of skeleton should be used in case of sub-adults[59]. When dentition is not available for age estimation and is highly affected by environmental influences, other features of skeleton should be used in case of sub-adults[59].

In case of adult skeletons, racemisation of aspartic acid is one of the best and precise methods of age estimation and is superior to morphological methods[47,60]. Equally good but moderately accurate methods of age estimation in adult skeletons is dentine layer count and bone histology[61-63]. Combined examination of histological, macroscopic and radiological features of skeleton are equally good[64,47], skull sutures[65,66], bone loss and changes in appearance of joints[67], pubic symphysis[68-70], phase analysis of sternal end of rib[71,72] etc. are the third ranking but not useless methods of age estimation routinely used for visual assessment but are not accurate enough for forensic identification[68].

Epiphyseal union research usually utilizes radiographic assessment than dry bone evaluation as the two methods produce different results[73]. Rib phase analysis is best method for ageing individuals more than 50 years of age[51]. The socioeconomic status, genetic make up or any secular change must be taken into account white using epiphyseal union timings in age estimation. Dermirjian method of teeth and Greulich and Pyele method of wrist and hand are the two methods of age estimation that have been tested on the largest number of different populations[74].

Age estimation in living individuals

Here usually an accurate age is to be estimated with limited range of methods to know whether a person to be examined is underage or overage than a specific, legally relevant age threshold In recent years, forensic anthropological expertise has been increasingly asked for identification and ageing of living individuals for the purpose of criminal, civil, old age pension, asylum proceedings, physiognomic comparisons, pedopornographic age estimations etc. It is also becoming crucial because of increase in illegal immigrations and influx of individuals without any valid identity document of their date of birth. But while estimating age of living persons, their genetic-geographic origin and socio-economic status should be taken into account as these factors affect their age indicators considerably[75-77]. 2ndly, principles of medical ethics and legal regulations have to be taken into consideration. Legal age threshold for most of the countries lie between 14-22 years of age, so main problem comes in age estimation of old-age pension proceedings where morphological methods do not render any sufficient, reliable and accurate result.

The administrative and judicial system often demand age estimation of unknown individuals so that proper procedure may be followed in processing any administrative or court case pertaining to that individual. Anthropological, radiological and odontological assessment of age of living subjects is usually done by physical examination, X-ray of left hand and wrist, dental examination and orthopantomogram and sometimes CT of medial clavicle[36]. Radiological examination of shoulder, elbow and wrist, and teeth are the most widely used and best indicators of age in living individuals[78].

There are two reasons that need for some accurate and reliable method of age estimation has arisen in recent years because of current socio-political developments. Firstly the increase in number of unidentified cadavers and human skeletal remains and secondly because of increased cases of age estimation in living individuals without any valid proof of their date of birth. But very few attempts have been made to find common standardization, calibration and evaluation procedures and means of quality assurance for methods of age estimation. So attempts should be made to assure quality standards to this legal and social issue of age estimation in forensic medicine and physical anthropology[47]. New methods should be applied to various skeletal remains of other populations to check their validity on other population. A successful method may give good results on other skeletal remains also than for which it is formulated.

Future Trends in forensic Anthropology

It is one of the fastest growing medico-legal disciplines both in its contribution to the practical needs of the legal system and research accomplishments. New modified anthropological standards for population of different regions have been developed to estimate biological profile, PMI, to estimate culture specific causes of skeletal trauma and other forensic phenomena. Forensic anthropologists are increasingly consulted for skeletal trauma analysis, facial reconstruction, photographic reconstruction, crime scene recovery etc. The number of scientists working in the field of forensic anthropology and its degree of co-operation with other sub-disciplines of forensic science is increasing. Renewed global efforts are being made for standardization and quality assessment of its techniques and methodologies. It is presumed that in near future forensic anthropology in conjunction with forensic medicine will play an even more important role in the elucidation of acts of crime and accurate biological profiling of human skeletal remains. Efforts in future must be made to encourage the study of forensic anthropology and its allied discipline to improve its methodologies, techniques and diagnostic procedures and to promote its knowledge and research, High standards of ethics, conduct and professionalism should be encouraged in the medico-legal study of human remains by the forensic anthropologists.

Forensic anthropology in Forensic Medicine

As far as human skeletal remains of forensic interest are concerned, forensic anthropologists and forensic pathologists work in conjugation with each other. A forensic pathologist is more concerned with estimation of time and cause of death of a cadaver found at the scene of crime whereas a forensic anthropologist restricts himself/herself to the search and proper retrieval of skeleton using standard scientific methods and techniques of anthropology and forensic archaeology. An anthropologist can assist a pathologist in identifying and detection of any skeletal trauma and thus establishing cause and manner of death as the former is comparatively well versed in human osteological and culture-specific skeletal variations of different populations.

It is a fact that medical forensic community does not have adequate anthropological and osteological information in handling skeletal remains as compared to physical anthropologists who, in turn, are unable to work with human remains still bearing some soft tissue or found in a modern criminal context[36]. Forensic anthropology is increasingly becoming a multidisciplinary field. The scientific achievements of both forensic medicine and classical anthropology mutually promoted and benefited each other especially in identification of skeletons of unknown origin. Both the disciplines do not differ in their osteological examination methods, but in the subject and objective of examination they differ considerably. The osteological research in anthropology is predominantly taken at random and is a characteristic of basic research but in forensic medicine the objective, motives and results of such a research are of prime interest due to its role in criminology and administration of justice. Forensic medicine is an interdisciplinary science which uses reliable and scientifically solid facts or processes and qualitative or quantitative definitions etc. to make the most accurate, reliable and valid statement.

In USA and some other Western European developed countries, the discipline of forensic anthropology is a more organized field where examination of skeletonised bodies or parts of skeletons is not carried out from criminological point of view by the forensic pathologists but by specially trained forensic anthropologists who is generally not a physician but a biologist.

In India, forensic anthropology has not yet acquired its own distinct status amongst the forensic sciences as there exists a distinct professional void with the experts dealing with human skeletal remains Forensic anthropology as a sub-field of forensic science cannot be compared with entomology, odontology or toxicology as the latter disciplines are restricted in their form and application.

Most pathologists having experience of forensic material, ability to construct an accurate profile or positive identification from bone morphology etc., understandably have no expertise in classical anthropological methods and techniques because of intensive nature of their training. On the other hand, anthropologists certainly do not have medical expertise. So there is an urgent need of bringing the expertise of two disciplines closer by setting aside their differing perspectives in order to create excellent anthropological expertise for the purpose of justice. Though a pathologist may not be familiar with precise expertise of analysis of bones and skeletons of unidentified persons but responsibility of the former expert is always greater than that of a forensic anthropologist who may have mistaken the profile of skeletons unearthed from a cemetery or collected from somewhere else.[79]. Determination of cause and manner of death is the sole prerogative of a forensic pathologist and under no circumstances, a forensic anthropologist is supposed to certify a death unless he/she is a physician also[80].

It still remains a question of debate among scientific community to decide that to what extent and in what form the anthropological research results should be applied in forensic medicine practice and how forensic medical osteological research work will help in the development of the discipline of classical forensic anthropology.

Role of Forensic Anthropology

The major role of forensic anthropologist is to study and identify the human skeletal remains and to assist the medical and legal specialists. The contribution and importance of this discipline has increasingly been documented in recovery and identification of victims of war crimes and mass disasters such as Kosovo and World Trade Center[81-83]. Forensic anthropological methods and techniques are used for study and identification of both human skeletal remains and the living individuals[36]. When a skeleton is found in a remote woody area or unearthed during road or building excavations, an anthropologist is generally asked to establish identity of the individual/individuals i.e. age, sex, stature, race, skeletal trauma, any damage or alteration of the skeleton etc. Although most anatomists and skeletal biologist are well versed in classical methods of profiling of such skeletal remains but a forensic anthropologist is expected to be more skilled and cautious in a forensic context as here osteology requires more focus, more accuracy levels than archaeological / anthropological situations and there are more significant legal consequences of such identification. A forensic anthropologist has a thorough and sound knowledge of physical anthropology, human osteology, and subtle variations in skeletons of different populations and interpretation of skeletal morphology on the basis of these variations. After combining all the evidence, he/she determines their possible significance to legal and medical authorities[2]. Both the crime scene investigation and task of a forensic anthropologist has become more complex and more sophisticated with the passage of time. Following are some important areas where the role of a forensic anthropologist is necessary and indispensable in cases of forensic importance:-

1. Construction of an accurate biological profile of human remains by estimating age, determining sex, calculating stature, assessing racial affiliation etc.

2. Personal and positive identification with the help of anthropological methods and techniques such as comparing bone morphology, skeletal trauma analysis, DNA analysis, facial features comparisons etc.

3. Retrieval, search and recovery of mutilated/charred/dismembered human remains and examination of bodies in a state of advanced decomposition at the scene of crime and identification of victims of mass disasters, bomb explosions, train accidents, plane crashes, war crimes etc.

4. Study of skeletal trauma i.e. blunt injury, gunshot wounds, sharp force injury, and estimation of species of origin and post-mortem internal in cases of charred/burnt/buried skeletal remains. A forensic anthropologist can distinguish and analyze whether a bone injury or lesion is ante-mortem or post-mortem in origin. Species identification is done by DNA or protein analysis but protein analysis is preferred.

5. Ageing and identification of living individuals for the purpose of criminal, civil, old-age pension, asylum proceedings, ageing of juvenile perpetuators etc.

6. Anthropological analysis of ethnic origin of unidentified bodies from evidence gathered from apparels/clothing of the deceased and cultural analysis of skeletal traumas, if any.

7. Establishing physiognomy and identification of suspect from the images of a video-surveillance system by comparing and verifying his/her morphological and metric characteristics[36]. This is comparatively a very recent and somewhat completely different aspect of forensic anthropology, wherein it is presumed that no two persons have either same physiognomic features or same skeletal features. Facial approximation and resemblances performed manually or with computer software, have increased the reliability of forensic anthropology[84,85].

After construction of an accurate biological profile, the identification of the victim by comparing the bone morphological peculiarities such as callosities, osteophytes etc.,[86] becomes easier. Positive identification by others means like DNA analysis is important not only for administrative and ethical reasons but also because of serious legal consequences.

Forensic Anthropology and Law

Forensic anthropologists engaged in osteological analysis of unknown or known skeletal remains are increasingly called upon to provide expert witness testimony in civil and criminal cases of investigations throughout the world especially in USA, Canada and other European countries. They are usually hired by medical pathologists, lawyers, forensic science organizations and law enforcement agencies to provide expert view in skeletal analyses. There are certain legal, ethical, sometimes political implications, responsibilities and ramifications which forensic anthropologist is supposed to comply with during the entire process of examination of all types of human skeletal remains including fresh, decomposed, burnt, mutilated dismembered and skeletonised remains[87]. Sex and age attribute of unknown human remains are the generally asked for analyses that a forensic anthropologist is to present at trial. A forensic anthropologist must ensure that findings are appropriate and techniques used are based on sound principles and methodology producing an assessment that is statistically significant than by chance[88]. If he/she is not conversant with the appropriate methods and techniques, then serious mistakes can jeopardize his authority as well as investigation of the

case. If the techniques utilized by the forensic anthropologists are not based on reliable principles and methodologies, the accuracy and error estimates are not known, then the credibility of the expert and his professional report may face certain legal problems[89].

Sometimes legal fraternity may pressurize the anthropologist to give views beyond his expertise or beyond the limit of the data which support his interpretations. In such cases, he should stand by his expert opinion and no unverified information should be included in the report to be submitted in a court of law. As far as biological profile of unidentified human remains is concerned, he must be well conversant with this osteological or anthropological terms and jargon. An anthropologist should be cognizant of unique nature of the discipline which require certain responsibilities towards the victim, the relatives, the law enforcement agencies, the legal fraternity and the society[80]. If warranted by any court, the forensic anthropologist as an expert witness should present the findings in an impartial, clear, concise and complete fashion, minimizing ambiguity and misinterpretation and in a language understandable to the lay jury[89]. The limitation of analysis or interpretation should be explained openly and estimates should be detailed, accurate and free from jargon as possible.

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