Anthropometry in Forensic Medicine and Forensic Science- 'Forensic Anthropometry'

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Citation

Abstract

Anthropometry is a series of systematized measuring techniques that express quantitatively the dimensions of the human body and skeleton. Anthropometry is often viewed as a traditional and perhaps the basic tool of biological anthropology, but it has a long tradition of use in forensic sciences and it is finding increased use in medical sciences especially in the discipline of forensic medicine. It is highly objective and reliable in the hands of trained anthropometrists. The significance and importance of somatometry, cephalometry, craniometry and osteometry in the identification of human remains have been described and a new term of 'forensic anthropometry' is coined. Some of the recent studies which employ various techniques of anthropometry are discussed. The ultimate aim of using anthropometry in forensic medicine/science is to help the law enforcement agencies in achieving 'personal identity' in case of unknown human remains.

INTRODUCTION

All the human beings occupying this globe belong to the same species i.e. Homo sapiens. No two individuals are exactly alike in all their measurable traits, even genetically identical twins (monozygotic) differ in some respects. These traits tend to undergo change in varying degrees from birth to death, in health and disease, and since skeletal development is influenced by a number of factors producing differences in skeletal proportions between different geographical areas, it is desirable to have some means of giving quantitative expression to variations which such traits exhibit. Anthropometry constitutes that means, as it is the technique of expressing quantitatively the form of the human body. In other words, anthropometry means the measurement of human beings, whether living or dead or on skeletal material.

Although, there are numerous methods of measurement used in biological anthropology, but 'anthropometry' is uniquely its contribution and peculiar to it. Other methods have been borrowed from anatomy, medicine, physiology, biochemistry, genetics and statistics [1].

Forensic medicine is an interdisciplinary science which in everyday practice applies all the knowledge that medical sciences, have accepted as reliable and scientifically solid facts or processes, and qualitative and quantitative definitions with the help of which accurate and reliable statements can be made [2]. The use of anthropometry in the field of forensic science and medicine dates back to 1882 when Alphonse Bertillon, a French police expert invented a system of criminal identification based on anthropometric measurements. His system was based on three fundamental ideas- the fixed condition of the bone system from the age of twenty till death; the extreme diversity of dimensions present in the skeleton of one individual compared to those in another; the ease and relative precision with which certain dimensions of the bone structure of a living person can be measured using simply constructed calipers. This system of identification spread rapidly through much of the world but the system was not accepted much in view of some major drawbacks and discovery of other identification systems e.g. dactylography [3].

As anthropometry is an important part of biological/physical anthropology, hence the persons specializing in anthropometry are familiar with range of biological variability present in the human populations and its causes, and are well trained in comparative osteology, human osteology, craniometry, osteometry, racial morphology, skeletal anatomy and function. They are well aware of the knowledge of archaeological field techniques and methods which serve well in crime scene recoveries involving buried and surface remains [4]. The term 'forensic anthropometry' can be coined for this branch of applied physical anthropology, involving the use of methods/techniques of anthropometry in

forensic/legal context. In other words, "forensic anthropometry is a scientific specialization emerged from the discipline of forensic anthropology dealing with identification of human remains with the help of metric techniques".

Anthropometric characteristics have direct relationship with sex, shape and form of an individual and these factors are intimately linked with each other and are manifestation of the internal structure and tissue components which in turn, are influenced by environmental and genetic factors. Anthropometric data are believed to be objective and they allow the forensic examiner to go beyond subjective assessments such as 'similar' or 'different'. With measurement data, the examiner is able to quantify the degree of difference or similarity and state how much confidence can be placed in this interpretation [5].

The main aim of an anthropometrist employed in the forensic medicine/medico-legal department, working with unknown variables, is to describe the remains in such terms so that one can achieve the goal of estimating age at the time of death, sex, stock/race/ancestry/ethnicity, stature, body weight/body build, details of individualizing characteristics i.e. amputations, fractures, ankyloses, deformities and bone pathologies and to some extent the cause of death if reflected in the remains/bones. The objective is to enable the law enforcement agencies to achieve the ultimate goal of personal identification.

Krogman[6] in his monumental publication (later on revised with Iscan[7]) "The Human Skeleton in Forensic Medicine" describes that the use of anthropometry may arise under several sets of circumstances i.e. Natural, intentional and accidental (war dead cases, air crash, road and train accidents, earth quake, flood, fire; deliberately mutilation, disfigurement, pounding, gouging etc. of the dead body).

Forensic anthropometry incorporates most of the techniques originating with the analysis of human skeletal material from archaeological sites; the two disciplines have been closely linked. A good forensic anthropologist must, by definition, be a good skeletal biologist[8]. He helps a forensic pathologist to reconstruct the biological nature of the individual at the time of postmortem examination, and sometimes giving clues and reconstructing the circumstances surrounding death. He is prepared for this by his training in describing the prehistoric skeletons from archaeological sites and usually by special experience in identifying unknown modern skeletons [9].

Anthropometry can be subdivided into Somatometry including Cephalometry and Osteometry including Craniometry.

SOMATOMETRY

It is the measurement of the living body and cadaver including head and face. Somatometry is considered as a major tool in the study of human biological variability including morphological variation. Studies of morphological variation, by their very nature have a comparative focus in which variation within and among populations is the central theme.

Somatometry is useful in the study of age estimation from different body segments in a given set of individuals. The sample selected should be described adequately for all key relevant factors. Although, the description will vary from study to study, it should include data of examination, birth date, age, sex, ethnic group, geographic location, socio-economic status etc. Age should be expressed in days up to the age of one month, thereafter, decimals of years should be used, employing, if necessary, tables for their computations [10]. Attallah and Marshal[11] described a method to estimate chronological age from different body segments in British boys and girls using somatometric techniques. They used seven body measurements to estimate the chronological age of a child and evaluated the accuracy of the estimation and discussed applicability of the method on both live individuals as well as on cadavers.

Many authors have made use of somatometry extensively in the estimation of stature from different body segments. One of the foremost studies is by Bhatnagar et al[12] on Punjabi males. In their study, in addition to stature, three anthropometric measurements were taken on left and right hands separately. Regression equations were calculated to estimate stature from these hand measurements. A similar kind of study was conducted by Abdel-Malek et al[13] on Egyptian subjects. They took two somatometric measurements of the hands and successfully determined stature by computing multiple regression equations. Jason et al[14] estimated stature from the length of cervical, thoracic, lumbar, thoraco-lumbar and cervico-thoraco-lumbar segments of the spine in white and black American autopsy sample. Regression formulae were calculated which help in estimation of stature from these segments. Krishan and Sharma[15] conducted a study on the bilateral asymmetry and estimation of stature from arm length and its segments on a Punjabi population and computed regression equations and

lines. Krishan and Vashisht[16] also conducted a similar study on adult male Gujjars of North India. They took six measurements of limbs and computed bilateral asymmetry and calculated regression equations for estimation of stature and they recommended that in view of the marked bilateral asymmetry of the limbs, it is necessary that while estimating stature of a person from amputated limb or any of its segments, we must first identify the side (whether left or right), then apply the appropriate formula. Duyar and Pelin[17] established relationship between tibial length and stature. They proposed a new method for height estimation. They made three different groups on the basis of short, medium and tall stature and computed regression equations between stature and these three different groups. Ozaslan et al[18] conducted another study on the estimation of stature from body parts. They analyzed anthropometric relationship between stature and seven somatometric measurements of the lower limbs and computed regression coefficients and standard error of estimate used to calculate stature.

All the somatometric measurements (including measurements of the head and face) and standard procedures described by Olivier [19], Weiner and Lourie[10], Lohman et al[20], Hall et al[21] can be used for estimating stature from different body segments.

OSTEOMETRY

It includes the measurements of the skeleton and its parts i.e. the measurements of the bones including skull. It is defined as a technique to take measurements on the skeletal material. Through this technique, a forensic scientist can study variation in bony skeleton of different populations of the world. The technique has been successfully used in the estimation of stature, age, sex and race in forensic and legal sciences. These four parameters i.e. age, sex, race and stature are considered as the "Big Fours" of forensic anthropology. Various studies have been conducted and are in progress in many parts of the world in this regard.

ESTIMATION OF STATURE

There are various ways to estimate stature from bones but the most easiest and the reliable method is by regression analysis [22], [23]. In the past, scientists have used each and every bone of the human skeleton right from femur to metacarpals in estimation of stature. They all have reached a common conclusion that stature can be estimated with great accuracy even from the smallest bone, although, they have encountered a small error of estimate in their studies. Some authors have used fragments of the long bones i.e. upper or

lower end etc. but most of the time, long bones have been used in the determination of stature because they relatively give better accuracy in prediction of stature.

The major difficulty in developing a stature estimation formula is the non-availability of skeletal series with known body height data [23]. The Harmann-Todd, Terry collection and the Raymond Dart Pretoria skeletal collection[24], [25] are the best collections in this regard.

Various studies conducted on the estimation of stature indicate that every part of the skeleton has been used for estimation. One of the foremost and famous studies on estimation of stature from long bones of American whites and blacks is by Trotter and Gleser[26]. Since then, scientists have carried out extensive work on the estimation of stature from a variety of bones throughout the world. Kate and Majumdar[27] successfully estimated stature from lengths of femur and humerus by regression method and autometry in an Indian sample. Boldsen[28] statistically evaluated the prediction of stature from length of the long bones in different European populations. Rother et al[29] conducted a study on the estimation of stature from fragments of the femur and devised some regression formulae. Mysorekar et al[30] also estimated stature on the basis of lower end of femur and upper end of radius. Badkur and Nath[31] reconstructed stature by measuring 12 anthropometric parameters on ulna and multi-linear regression equations were computed. Simmons et al[32] provided regression equations for the estimation of maximum femur length and stature from three well defined and easy to measure segments of the femur in a sample from Terry collection. Holland[33] calculated strong linear regression equations for estimation of stature from measurements of condyles of tibia in a sample from Harmann-Todd collection. Introna et al[34] correlated stature with several parameters of the skull and obtained multiple linear regressions for estimation of stature. The study sample consisted of 119 adult black and white males from the Terry collection. Meadows and Jantz[35] developed regression equations from two samples of metacarpal specimens; one of 212 individuals from the Terry collection and the other of 55 modern males and concluded that in spite of the differences noted, the Terry equation perform acceptably on modern individuals. Jantz et al[36] presented results in the estimation of stature from tibia and critically commented upon the method of measurement of tibia by Trotter and Gleser[26]. Ousley[37] commented that should we estimate biological or forensic stature? He recommended that forensic stature estimation is generally less precise than Trotter and Gleser stature

estimation but is more accurate for modern forensic cases because a forensic stature is the only stature available for a missing person. Compobasso et al[38] used scapular measurements for estimation of stature. They took seven anthropometric parameters of scapula and developed multiple and linear regression equations. Mall et al[39] correlated humerus, ulna and radius lengths with stature and concluded that the linear regression analysis for quantifying the correlation between the bone lengths and the stature led to unsatisfactory results with large 95% confidence intervals for the coefficients of high standard error of estimate. Ross and Konigsberg[40] devised new formulae for estimating stature in the Balkans. They compared the data obtained from 545 white males from World War II with East European sample of 177 males including the Bosnian and Croatian victims of war. Bidmos and Asala[41] derived regression equations for estimation of stature from nine calcaneal measurements. The sample consisted of 116 complete skeletons (60 males and 56 females of South African blacks) from Raymond Dart collection. Hauser et al[42] established the relationship between stature and greatest length of femur and computed correlation coefficients and regression equations to predict stature. Pelin et al[43] evaluate the possibility of prediction of living stature from the coccygeal vertebral dimensions in adult male population of Turkey. They recommended the use of combined variables of the different coccygeal vertebral segments for accurate prediction of stature. Raxter et al[44] revised Fully's technique for estimation of stature and tested the accuracy and applicability of his method and clarified measurement procedures. Sarajlic et al[45] developed formulae from the lengths of femur, tibia and fibula for estimation of stature in Bosnian population. Krishan and Sharma[46] gave linear and multiple regression equations for estimation of stature from dimensions of hands and feet in North Indian Rajputs. Krishan and Kumar[47] calculated regression equations for estimation of stature from cephalo-facial dimensions in Koli adolescents of North India. They also suggested that future researchers should categorize their adolescent sample into various age groups for better reliability and practical utility of stature estimation.

Due to substantial diurnal variation in stature, one should avoid taking stature measurements at different times of the day[48] . It means, while making standards or reference data of stature estimation, careful consideration should be given to the time of the day at which the measurements are to be recorded.

DETERMINATION OF SEX

Sex is considered as one of the easiest determinations from the skeletal material and one of the most reliable if essential parts of the skeleton are available in good condition[7]. The most often chosen bones for the determination of sex are the pelvis and the skull although the round heads of the ball joints also provide very reliable means of determining sex[49], [50]. Sex determination is also supposed to be reliable when the remains are from long bones and up to 95% accuracy can be achieved.

Anthropometry is being used more often in sexing the skeletal remains. Worldwide, various studies have been conducted on the determination of sex from variety of human bones i.e. skull, pelvis, long bones, scapula, clavicle, and the bones like metatarsals, metacarpals, phalanges, patella, vertebrae, ribs etc. The most popular statistical model in sex determination is recently developed discriminant function analysis which encouraged many forensic scientists to assess their anthropometric data accordingly 23.

Iscan et al[51] used seven anthropometric parameters of tibia including tibial length, diameters and circumferences for determination of sex from 84 Japanese skeletons. They used multiple combinations of measurements to develop formulae for determination of sex and the average prediction accuracy ranged from 80% to 89%. They further conclude that the accuracy of prediction was higher in males (96%) than females (79%). Falsetti[52] made assessment of sex from dimensions of metacarpal in three samples i.e. The Terry collection, sample from Royal Free Medical School, forensic collection of Maxwell Museum of Anthropology, University of New Mexico. He designed five measurements for the metacarpal and found different accuracy rates in different samples. Trancho et al[53] made use of 132 femora of adult Spanish population for determination of sex by discriminant function analysis. They measured femur for five anthropometric variables and achieved between 84% to 97% accuracy when each variable was considered independently. 99% accuracy was obtained when two variables of the epiphysis were combined. Smith[54] utilized metatarsals, proximal pedal phalanges and the first distal phalanx of the foot in determination of sex from The Terry and Huntington Collections of the Smithsonian Museum of the Natural History. The anthropometric measurements include lengths and medio-lateral and dorso-plantar widths of these foot bones. He recommended the use of combination models for correct assignment of sex as he achieved 87% accuracy with

this model.

Asala[55] used femur head to determine sex in South African whites and blacks from Raymond Dart collection. He took two variables i.e. vertical femoral head diameter and transverse femoral head diameter and concluded that these can be used successfully for sex determination in absence of complete bone. He further concluded that the sex from this bone must be calculated separately for each population. Mall et al[39] measured various anthropometric dimensions of humerus, ulna and radius to determine sex by using discriminant analysis. They concluded that radius (94.93%) is the best bone for sex determination, followed by humerus (93.15%) and ulna (90.58%).

Frutos[56] measured maximum length and circumference of the mid shaft of the clavicle and height and width of the glenoid fossa of the scapula for sex determination in Gautemalan contemporary rural indigenous population. They made use of jackknife method (leave-one-out method) and it produced classification success rates ranging from 85.6% to 94.8%. An investigation by Bidmos and Dayal[57] is based upon anthropometric study of 60 male and 60 female tali of South African white from Raymond Dart collection. They concluded that by using discriminant analysis, the level of average accuracy of sex classification was 80% to 82% for the univariate method, 85% to 88% for the stepwise method, and 81% to 86% for the direct method. Rissech et al[58] analyzed four variables of the ischium by polynomial regression in order to determine sex during and after growth. They calculated growth curves for ischium length, horizontal diameter of ischium acetabular surface, vertical diameter of ischium acetabular surface and ischium acetabular index and concluded that the ischium length is the best variable for determination of sex in west European collections.

Frutos[59] conducted a study based on 118 complete humeri from Guatemalan forensic sample. He studied six anthropometric dimensions and concluded that the classification accuracies for the univariate functions range from 76.8% to 95.5% and for stepwise function procedure was 98.2%. Kemkes-Grottenthaler[60] evaluated the reliability of patella anthropometry in sex determination in a material from different archaeological samples. He achieved almost 84% accuracy in sex determination. Patil and Mody[61] conducted a lateral cephalometric study on central Indian population to devise a model for determination of sex. They took ten measurements on the radiographic cephalograms of 150 normal healthy individuals and determined sex by

discriminant function analysis. They concluded that the variables provided 99% reliability in sex determination. Patriquin et al[62] designed nine measurements of pelvis and analyzed sex differences in South African white and black population. They made use of stepwise discriminant function analysis and presented anthropometric standards of the pelvis of South African white and blacks. They further concluded that the ischial length is the most sexually dimorphic dimension in whites (averaged accuracy 86%) and acetabulum diameter is the most diagnostic in blacks (averaged accuracy 84%). Purkait[63] conducted a study on 280 femora from central India. She used the points of traction epiphysis on the upper end of the femur and the triangle was drawn on the posterior aspect of the femur using the apex of two traction epiphysis and the lateral most point on the articular margin of the head. Each length of the triangle was analyzed. She observed that all dimensions were greater in females. The accuracy rate ranged from as little as 63% for the distance between the point on the femoral head and the greater trochanter to 85% for the distance between the greater and lesser trochanters. Slaus and Tomicic[64] used 180 tibiae from six medieval archaeological sites in Croatia in sex determination. They measured six anthropometric dimensions on tibia and showed that complete tibiae can be sexed with 92.2% accuracy. Rissech and Malgosa[65] used coxal bones of 327 individuals taken from four documented skeletal series i.e. The St. Bride's Collection, London; Esqueletons identificados, Coimbra; The Lisbon Collection, Lisbon; and UAB Collection, Barcelona in sex determination. The measurements include ilium width, ilium length, ilium index, horizontal diameter of the ilium acetabular area and vertical diameter of the ilium acetabular area and they concluded that the ilium width is the best variable fore sex determination.

DETERMINATION OF RACE

Determination of race is not so simple. In spite of several multivariate statistical studies of specific measurements of the skull and a few long bones, this is still one of the most problematic areas skeletal identification [66, 67]. Race determination is further complicated by another major factor i.e. one may encounter intrinsic variability within each major genetic breeding population or endogamous group.

PRACTICAL IMPLICATIONS AND RELIABILITY IN ANTHROPOMETRY

Precision in anthropometry is of utmost importance as it requires lot of practice. Reliability of the measurement

should be established and the best order for recording the measurements selected for a particular study or a particular problem should be determined. The most common errors in anthropometry are positioning of the body or bones, reading measurements and recording. In other words, these errors are also termed as personal error and technical error of measurement respectively. In order to minimize these errors, standard procedures for recording these measurements should be used which are internationally recognized.

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