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PRINT: ISSN 0972-0073 ONLINE: ISSN 2456-6802
Anthropologist, 5 (3): 119-125 (2003)
DOI: 10.31901/24566802.2003/05.02.10

Assessment of Sex from Cross Sectional Area of Femoral Head

Ruma Purkait

INTRODUCTION

Assessment of sex from skeleton parts is of particular importance to Forensic Osteology and relies heavily on up-to-date techniques to provide accurate information to Medico legal system (Krogman and Iscan, 1986; Iscan, 1988; Iscan and Helmer, 1993). With time the nature of assessment has undergone a shift from visual analysis to analysis based on anthropometric measurements which when processed through modern statistical techniques (like discriminant function analysis) has made sex determination more objective.

But still many of the traditional anthropological methods suffer from certain fundamental deficiencies. For example, traditionally measurements on the bones are done without any reference as to how the bone lies approximately in anatomical position in the living. This is liable to deprive the worker of the identity of the points of the stress and strain which leave their imprints on the bone. It has also been observed that various authors (Pearson and Bell, 1917/19; Ingalls, 1924; Martin and Saller, 1957; Krogman and Iscan, 1986; Singh and Bhasin, 1989)) have recommended that certain lines can be drawn on the bone to represent the axis by 'Eye judgment'. In a study on collo-diaphyseal angle of femur (Purkait, 1989, 1996) it has been proved that such judgment will always have contributory individual 'observer error' more so when one is looking for minute difference in the measurements.

Based on the above argument an attempt to investigate the sexual dimorphism in the head of the femur is undertaken. The study is based upon the logic that axial skeleton weight of male is relatively and absolutely more than that of female (William et al.,1989). It is further influenced due to the anatomical modification of female pelvis because of its reproductive function. The muscular forces moving across the hip joint specially the Abductor muscle acting between the pelvis and the Greater Trochanter also has its impact on the femur head (Hirsch and Frankel, 1960; France, 1988). Also the first brunt of the axial with upper appendicular weight is borne by the head of femur which it dissipates. Thus the effect of stress and strain will be reflected in its size and shape. To evaluate the hypothesis, study of cross sectional area of the head and the exposure of the data to critical statistical analysis is considered.

How true as early as in 1960 Montagu commented that

> "New methods based on sound principles may always be devised by an investi-gator to meet the demands of his particular problem. Measurements based on genuine functional biological relations are those most to be encouraged. The development of such biologically based measurements is to be preferred to the slavish repetition of those embalmed in anthropometric manuals, not excluding the present one."

MATERIAL AND METHOD

The present study was conducted at Medico legal Institute of Bhopal in Madhya Pradesh where sets of bones are examined, classified and stored systematically in separate iron boxes. Medicolegal Institute has a collection of bones from unclaimed specimens and medicolegal cases. A majority of the sample are medicolegal specimens. Every care has been taken by the author to include bones from a homogenous population. Some of the specimens were remains of unclaimed bodies, which were skeletonized in the department. Data of the present study composed of a total of 95 adult femora belonging to 95 individuals out of which 60 were males and 35 were females. The bones were well documented for sex, race and age belonging to residents of Madhya Pradesh. They were without soft tissue or cartilage and dried. Abnormal and pathologically deformed bones were excluded from the present study. The diameters were recorded to the nearest 0.01 m.m using a Mitutoyo Dial Caliper.

Suspending the bone in the anatomical position (Purkait, 2001) the highest point on the head was identified and becomes the acquired landmark (Fig 1). This was one point of measurement labelled as 'B'. A plumb line drawn from the point 'B' in coronal plane wherever cut the lower extreme articular margin was marked as 'A'. When the points 'A' and 'B' were joined together running over the surface of the head and was extended till the superior articular margin of the head, was labelled as point 'C'. The line ABC is in coronal plane.

The Maximum Vertical diameter was taken along the vertical plane ABC so obtained. Keeping the bar of the Dial caliper in that plane, the caliper was moved along the vertical plane till the maximum reading was obtained. The Maximum Horizontal diameter was measured at right angles to the vertical plane ABC wherever the maximum reading was obtained.

The Horizontal diameter cuts the Vertical diameter at right angles. The point of intersection 'O' is the centre of the head. This centre of head was joined to the centre of the Quadrate tubercle 'P'. This line 'OP' was considered as the long axis of the head and neck of femur (Purkait 1996).

The fixed needle 'X' of specially fabricated caliper (Fig. 2, Purkait, 1989; Patent number 185305/2001, Goverment of India) was introduced in the bore hole made by 1 millimetre Drill bit at the centre of the head of femur 'O' along the axis of head and neck 'OP'. To ensure that there is no obliquity in the long axis of the head and neck 'OP', the long limb of the caliper was kept perpendicular to 'OP'. The mobile needle 'Y' recording the measurements at right angles to long axis was fixed first at 5mm, then at 12mm and 20mm and moved along the head to draw the three segments A,B and C respectively .

The radial distances (called 'Presumed radius') from the central long axis 'OP' were measured. Such twenty readings were taken five in each quadrant for each segment (A,B,C) and their mean was considered as Radius. The cross sectional area was calculated with the help of formula πr^2.

To check the accuracy of the cross sectional area found by Caliper method, twenty femur

Fig. 1. Anterior view of Femur in Anatomical position.

Fig 2. 'Improved Caliper' devised to measure the radial distance from the long axis of the head and neck at various depth from the centre of the head.

Fig. 3. Sections of the head of femur (male) cut at an interval of 5mm, 12mm and 20mm. A is nearer the centre while B and C are away from it. The cross sectional area are shown on the right side of each section in square millimeter.

Fig. 4. Section C of the head of the femur (female). The area shown in the right side of the sections are in square millimeter.

head (ten of each sex) were sectioned at these three segments. Sectioning was performed using a Circular steel saw. The cross sectional area was measured by making an imprint on a graph paper. This was repeated in all the three segments (Fig.3 and 4).

The cross sectional area obtained by the imprint method was compared with cross sectional area obtained by 'Improved caliper'. The data of the cross sectional area of all the three segments in males was compared with the females. Data was further analysed using SPSS subroutine package (1980). Discriminant analysis employing the measurements to determine the optimal combination of variables was used for assessment of the sex of the femur. Direct approach was adopted to enter single variables in the analysis.

To check the accuracy of the discriminant functions in the classification of unknown bones, 51 male and 30 female femora which were not part of the original sample were randomly chosen from same population as Test group.

RESULTS

Table 1 presents the difference in the cross sectional area obtained by two different techniques for the pilot study. F-ratio indicate that the differences are statistically insignificant for all the segments.

The data of cross-sectional area shows a high statistically significant sex difference (Table 2).

While in males the area increases gradually from section A to C in most females though the area of sections A and B shows similar trend as in males it decreases as we go from Section B to C. This is more obvious in the case of index B/C which shows a highly significant sex difference compared to other two indices.

The results of the stepwise discriminant function analysis appear in Table 3. Of the first three measurements entered into the function, only Area B and C were selected. In this case, the F-ratio gives the quantum of variation that exist within and between the sexes and the significance level of the variance. Wilk's Lambda calculate how useful a given variable is in the stepwise discriminant function and determine the order of variables to enter the function. Once the area C was entered in the analysis, in the second step the remaining variables were reassessed and selected according to the Lambda level. In the step 2, area B having the least Lambda value was entered from the remaining variable. After step 2 the analysis was terminated because of the extremely low value of F-ratio which was below the critical value for entrance. This may be because of the high correlation existing among the variables which prevent the third variables entry.

Table 4 presents all the functions and their coefficients. The Raw coefficients are used to calculate the discriminant scores for all the functions. The product of the predictor variable and its coefficient are added to the constant to calculate the discriminant score. Values above zero classify an individual as male and below as female. The second column representing standardized coefficient indicate the relative importance of each variable in contributing to discrimination between the groups, the higher the value of this coefficient, the more it contributes to the discriminant score relative to other variable. It gives the importance of the variable to the function as it is conditioned by the presence of other variables. In the present study Area C has the maximum discriminating power.

To get a better idea of what a variable contributes to a function on its own, we need a third set of coefficients referred to as Structure coefficients. It defines the relationship between the function and the variables irrespective of the group difference (i.e. with regard to what the group have in common). Again Area C has the highest correlation (0.99).

Table 5 presents the prediction matrices for

Table 1: Comparision of area of segments by caliper and stamping methods

Segments	*Sex*	*Caliper*		*Stamping*		*F-ratio**
		Mean	*S.D.*	*Mean*	*S.D.*	
Segment A	M	816.2	87.8	800.3	89.5	0.1598
	F	642.1	96.3	669.3	111.6	0.3405
Segment B	M	1344.3	147.8	1406.1	144.8	0.8909
	F	1035.9	106.1	1062.1	112.3	0.2872
Segment C	M	1561.7	200.1	1583.7	194.5	0.0619
	F	1018.8	186.1	1024.4	163.3	0.0052

*P > 0.05

Table 2: Summary statistics of the variables

Variables	*Males*		*Females*		*F-ratio**
	Mean	*S.D.*	*Mean*	*S.D.*	
Area A	832.13	112.16	566.11	1 11.98	124.5
Area B	1411.95	139.37	1005.21	84.69	244.7
Area C	1607.79	169.57	996.56	165.19	292.7
Index A/B	76.68	3.68	74.66	6.1	3.9
Index A/C	71.92	4.15	75.49	7.59	8.7
Index B/C	93.78	2.73	101.10	5.71	70.5

Total number of Males = 60 ; Total number of Females = 35; *P<0.001

Table 3: Summary of stepwise discriminant analysis

Step	*Variables Entered*	*Wilks' Lambda*	*Equivalent F-ratio*	*Degrees of Freedom*
1	Area C	0.2411	292.673	1,93
2	Area B	0.2363	148.681	2,92

Table 4: Canonical discriminant function coefficients

Variables in Function	*Raw Coeff.*	*Stand. Coeff.*	*Struc. $ Coeff.*
1. Area A	0.008921	1.00000	1.00000
Constant -	6.23712		
2. Area B	0.008179	1.00000	1.00000
Constant -	9.88606		
3. Area C	0.005953	1.00000	1.00000
Constant -	7.751977		
4. Area A	0.001430	0.16030	0.64624
Area C	0.005386	0.90472	0.99082
Constant -	8.013065		
5. Area B -	0.002322	0.28380	0.90224
Area C -	0.004488	0.75394	0.98674
Constant -	8.65027		

$ The Sectioning Point is 0.0 for all the functions

Table 5: Percentage of correct group membership

Functions	*Males (60)*	*Females (35)*	*Average*
1. Area A	90.0 (54)	88.6 (31)	89.5
2. Area B	96.7 (58)	100.0 (35)	97.9
3. Area C	100.0 (60)	94.3 (33)	97.9
4. Area A + Area C	100.0 (60)	94.3 (33)	97.9
5. Area B + Area C	100.0 (60)	100.0 (35)	100.0

Numbers in parentheses represent correctly predicted cases

accuracies of prediction for each function. In all the function except area B the accuracy was higher for males compared to females. The functions can be grouped into two categories, the first using one variable and the second using two variables in combination. In the first category the accuracy ranges from 89.5% to 97.9% and the best discriminators are area B and C giving the same accuracy. In the second category only two combinations are possible. High correlation between the variables area A and B prevent their entry together. The combinations with variable Area B and C achieves cent percent accuracy.

When the discriminant functions of the original sample was applied on the test cases as shown in Table 6 the success rate of identification was found to be slightly less than the original sample. This supports the view that the discriminant function derived from a sample gives better accuracy than for another sample drawn from the same population (SPSS Statistical Guide, 1980)

DISCUSSION

Brickmann et al. (1981) considering the surface area of the femur head quoted that head of male is 30 percent larger than female. They calculated the surface area by Least square method considering the head of femur as a sphere.

Similarly Ruff (1990) offers a geometric formula for calculating surface area of the femur sliced just below the diameter. He used the depth of femur head and the average of two diameters taken in two planes to calculate the surface area. But the assumption being the head of femur is a partial sphere when many other (William et al., 1989; Cathcart, 1971; Clarke and Amstutz, 1975; Rockwood and Green, 1975; Walker, 1980; Walmsley, 1928) had specifically described it as a spheroid. Godfrey et al. (1991, 1995) gave an alternative procedure which uses curved head measurements and head diameters in two planes to calculate the surface area. The author accepts the fact that as the two orthogonal arc lengths and diameters are never identical the articular surface could not be a true spherical cap. Clarke and Amstutz (1975) while measuring the sphericity of femur head had concluded that the head is egg shaped in which the equatorial plane is virtually circular as compared to the radii of meridian. It thus stands to reason that cross sectional area of a spheroid can not be calculated using radius in one or two planes only. Thus in the present study taking into consideration the shape of the femur head twenty readings (Presumed radii) were taken from each segment along the surface of the femur head. Average of these readings were considered as the radius of the femur head at that particular depth from the centre of the head.

While comparing the cross sectional area of the segments, it is observed that the section C in male is bigger than section B but this trend is opposite in case of female (Table 2). In female at

Fig. 5 Cross sectional areas of femur head-section C (35 females and 60 males)

Table 6: Percentage of correct prediction for test sample

Functions	*Males (51)*	*Females (30)*	*Average*
1. Area A	88.2 (45)	86.7 (26)	87.7
2. Area B	94.1 (48)	96.7 (29)	95.1
3. Area C	98.0 (50)	93.3 (28)	96.3
4. Area A + Area C	98.0 (50)	93.3 (28)	96.3
5. Area B + Area C	98.0 (50)	96.7 (29)	97.5

Numbers in parentheses represent correctly predicted cases

a depth of 20mm from the centre of head, the cross section in the inferior aspect goes out of the articular margin of head and encompasses certain portion of neck (Fig. 4). The area of section C shows a distinct sex difference and least overlapping between sexes (Fig. 5).

The advantage of 'Improved Caliper' (Fig. 2) is that it can be used to measure precisely the cross sectional area at any depth of point of a sphere or spheroid without sectioning the bone. The difference between the area measured by actually sectioning the femur head and by the Caliper was found to be statistically insignificant (Table 1). Thus a method is presented where data could be collected without sacrificing the bones. This method also saves the valuable specimen for future research.

As no other study on cross section of femur head done by similar method as in the present study is available, the results of our study can not be compared with reference to the method.

The studies so far conducted on the head of femur has never achieved such a high percentage of accuracy with one variable (97.9%) and 100% accuracy by combining two variables. To test the validity of the result when the discriminant functions of the original sample was applied on an independent sample (Table 6) the accuracy achieved was similar.

The method suggested in this study was expected to give better result for sexual dimorphism as the measurements are taken with reference to the weight bearing plane and the changes brought about as a result of stress and strain can be best studied in this plane. Though the conclusions must be limited to the population sampled, the results show that the measurements of the femur head might prove effective in sexing other populations as well.

ACKNOWLEDGMENT

The study is dedicated to the memory of my Mentor, Philosopher and Guide, Late Prof. Heeresh Chandra (Founder Director of Medicolegal Institute, Medicolegal Advisor to the Govt. of M.P. and Professor of Anatomy and Forensic Medicine &Toxicology, Gandhi Medical College, Bhopal.

KEY WORDS Sex assessment. Femur Head. 'Eye Judgement'. Anatomical Position. Cross Sectional Area.

ABSTRACT The present study evaluates the possibilty of sex assessment from the cross sectional area of various segments of the femur head. An instrument was devised which could measure the cross sectional area without cutting sections of the femur head. The result obtained with the instrument devised was physically checked with a pilot study by making sections at designated spots in twenty femur head specimens (ten of each sex). Both the methods were found to produce similar results. The study was further extended on 60 male and 35 female Indian femora. The data exposed to discriminant function analysis using SPSS package produced an accuracy of 97.89% with single variable. The discriminant functions so obtained when applied on a test sample of 51 males and 30 females produced similar result. The present study is based on the principle postulated in assigning the bone in anatomical position and identifying anatomical landmarks and not by 'Eye Judgement'.

REFERENCES

Brinckmann, P., Hoefert, H. and Jongen, H. Th. : Sex differences in the skeletal geometry of the human pelvis and hip joint. *J. Biomech.,* **14 (6):** 427-430 (1981).

Cathcart, R.F.: Shape of the femoral head and preliminary results of clinical use of a non-spherical hip prosthesis. *J. Bone Jt. Surg.,* **53A:** 397 (1971).

Clarke, I.C. and Amstutz, H.C.: Human hip joint geometry and hemiarthroplasty selection. In: *The Hip: Proceedings of the Third Open Scientific Meeting of the Hip Society.* C.V. Mosby Co., St. Louis (1975).

France, D.L.: Osteometry at muscle origin and insertion in sex determination. *Am. J. Phys. Anthropol.*, **76:** 515-526 (1988).

Godfery, L.R., SutherLand, M.R., Boy,D.S. and Gomberg, N.: Scaling of limb joint surface areas in anthropoid primates and other mammals. *J. Zoo. London,* **223:** 603-625 (1991).

Godfrey, L.R., Sutherland, M.R., Paine, R.R., Williams, F.L., Boy, D.S. and Vuillaume Randriamanatenantena, M.: Limb Joint Surface Areas and their ratios in the malagasy lemurs and other mammals. *Am. J. Phys. Anthropol.,* **97:** 11-36 (1995).

Hirsch, C. and Frankel, V.H. : Analysis of forces producing fractures of the proximal end of the femur. *J. Bone Jt. Surg.,* **42B:** 633-640 (1960).

Ingalls, N.W.: Studies on the femur. *Am. J. Phys. Anthropol.,* **7:** 207-255 (1924).

Iscan, M.Y. : Rise of forensic anthropology. *Yr. Book Phys. Anthropol.,* **31:** 203-230 (1988).

Iscan, M.Y. and Helmer, R.P. (Eds.): *Forensic Analysis of the Skull: Craniofacial analysis, Reconstruction and Identification.* John Wiley, New York (1993).

Krogman, W.M. and Iscan, M.Y. : *The Human Skeleton in Forensic Medicine.* Charles C Thomas, Springfield (1986).

Martin R. and Saller K.: *Lehrbuch der Anthropologie.* Vol.I and II, Gustav Fisher Verlag, Stuttgart (1957).

Montagu, M. F. : *A Handbook of Anthropology.* Charles C Thomas, Springfield (1960).

Pearson K. and Bell J.: The study of the long bones of the English skeleton - I - The Femur. In: *Drapers' Co. Research Mem.* University of London Chapters 1-4 Biometric Series X (1917/19).

Purkait R.: *Sex Determination from Human Long Bones of Madhya Pradesh, India*, Ph.D. Dissertation, University of Delhi, Delhi (1989a).

Purkait, R.: A new tool in physical anthropology. *J. Anat. Soc. India*, **38 :** 72-75 (1989b).

Purkait, R.: Standardisation of the technique of measuring the collo-diaphyseal angle. *Med. Sci. Law,* **36:** 290-294 (1996).

Purkait, R. : Review of anthropolmetric techniques. pp 123-129. In : *Advances in Forensic Science.* M.K Bhasin and S.Nath (Eds). University of Delhi, Delhi (2001).

Rockwood, A.C. and Green, D.P.: *Fracture.* Vol. 2, J.B. Lippincott Co. (1975).

Ruff, C.B.: Body mass and hindlimb bone cross sectional and articular dimensions in anthropoid primates. 119-149, 1990. In : *Body Size in Mammalian Palaeobiology.* J. Damuth and B.J. MacFadden (Eds.) Cambridge University Press, Cambridge (1990).

Singh I.P. and Bhasin M.K. : *Anthropometry.* Kamla-Raj Enterprises, Delhi (1989).

SPSS/PC – A Statistical Guide for IBM PC/XT/AT and PS/2, SPSS Inc. Chicago (1980).

Walker, J.M.: Human foetal femoral head spherecity. *Clin. Orthop. Rel. Res.,* **147:** 301-305 (1980).

Walmsley, T. : The articular mechanism of the diarthroses. *J. Bone Jt. Surg.,* **10:** 40-45 (1928).

William, P.L., Warwick, R., Dyson, M. and Bannister, L.H.: *Gray's Anatomy.* Churchill Livingstone, Edinburgh (1989).

Author's Address : **Ruma Purkait**, Department of Anthropology, Saugar University, Saugor-470003, Madhya Pradesh, India. E-mail : rpurkait@sancharnet.in