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Estimation of Various Measurements of Hyoid Bone and its Co-Relation with sex of the Individual– An Autopsy Study

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Abstract
Establishing the Identity of a person is one of the biggest challenges faced by forensic pathologist in cases where the body has either decomposed or has been mutilated by the perpetrator of a crime. Without the establishment of the identity of the body the investigation cannot proceeds further. When a mutilated or decomposed body have been recovered then the Identification of the individual can be done in a step by step approach, in that identification of sex is one of the most important steps. Sex can be established by various methods. Determination of the sex by bones is one of the important steps when a bag of bones have been recovered. Most bones are used to identify the sex of the unidentified bag of bones. Most of the bones shows sexual dimorphism and various studies have been conducted using various bones. In the present study we have used Hyoid bone for correlating the bone with the of sex of the individual. In this study 116 hyoids were studied which were collected from the autopsies conducted at the mortuary of a Medical College in Western Maharashtra. The collected hyoids had 58 Males and 58 Females. The minimum age of the subjects was 20yrs and the maximum age was 80yrs. Present study was able to establish the sexual dimorphism of the hyoid bone with respect to the five parameters measured. In the present study the discriminant function analysis developed using all the five variables showed 91.4% accuracy in classifying male hyoids correctly and 100% accuracy in classification of female hyoids. This discriminant function can be used for determination of sex of the recovered hyoid bone.
Keywords: *Hyoid bone, Sex determination, Discriminate Function, co-relation.*

Introduction

Identification is the determination of the individuality of a person it may be in living or dead. Identification is necessary in living persons, recently dead persons, decomposed bodies, badly burnt bodies, mutilated bodies and if only a part of the body if found or only a bone or bone fragments are found[1].

The identity of the dead is an essential part of post-mortem examination, for various reasons. These include the ethical and humanitarian need to know which individual has died and to establish the fact of death in respect of that individual, for official, statistical and legal purposes. Identity is also needed to discharge the legal claims and obligations in relation to property, estate, debts

and it is also needed to prove claims for life insurance contracts, survivor's pensions, and other financial matters. The establishment of identity may be required in Intact fresh corpses, Decomposed Corpses, Mutilated and dismembered corpses and Skeletonised material[2].

Sex, age and stature are primary characteristics of identification. Sex has to be determined in cases of heirship, marriage, divorce, legitimacy, impotence and rape etc[3]. Determination of sex is the first and crucial step in the process of identifying human remains in forensic casework. Sex determination from skeletal remains is a well studied and extensively documented subject. The hyoid bone, however, has drawn less attention in studies of this nature[4].

Sex determination is one of the key questions addressed when formulating the human profile as its knowledge immediately eliminates 50% of the population from the process of identification[5]. Finding out age and sex from human skeletal remains is a routine procedure in the forensic medicine departments in India and plays a key role in solving the medico-legal disputes. Determination of sex from analysis of human skeletal remains has been an age old problem, especially if it is from an isolated bone[6].

Sex can be established from a gross examination of the skeleton using either metric or morphological techniques. Although there is some overlap between the two approaches, they are used in conjunction to produce the most accurate and complete assessment of sexual dimorphism. This is particularly critical for individuals whose skeletal dimensions and characteristics do not lie at the extremes of sexual expression[7].

According to Krogman, the degree of accuracy in sexing adult skeletal remains is: entire skeleton 100%, Pelvis alone 95%, Skull alone 90%, Pelvis plus Skull 98%, Long bones alone 80%[3].

The hyoid bone may be felt a few centimetres below and behind the chin, especially if the neck is extended. It may be palpated between finger and thumb and moved from side to side. The hyoid bone lies approximately at the level of the third cervical vertebra. The most obvious palpable feature in the front of the neck below the hyoid bone is the thyroid cartilage, and the prominent midline subcutaneous laryngeal prominence or Adam's apple, which indicates the line of fusion of the two thyroid laminae. In the male, the prominence is usually clearly visible, whereas in the female it is not usually apparent, even when the neck is viewed from the side[8].

Material & Methods

The study consisted of 116 hyoids collected from autopsies conducted at the medico legal autopsy centre of Armed Forces Medical College, Pune between the periods of July 2014 to May 2016. The sample consisted of 58 Males and 58 Females. The hyoids were collected from age between 20 to 80yrs. Cases in which the intact hyoid couldn't be recovered were excluded from the study.

The dissection of the neck was done by "V" incision then reflecting the neck muscles layer by layer to reach the hyoid.

The hyoid bone was cleaned from soft tissue using scissor and scalpel. The remaining soft tissue was removed using bleaching powder solution. The bone was kept in bleaching powder solution for 5-6 days and then the bone was cleaned using scissor and scalpel leaving a minimal soft tissue at the joints to preserve the morphology of the hyoid. The cleaned bone was then dried for one day.

After the bone was dried the following measurements were taken using a digital caliper.

Ser No	Description
1.	Width of hyoid (BC) : Distance between the distal ends of greater horns **(Picture 1)**
2.	Length (AP) : Distance in the anteroposterior plane from the anterior middle of the body of hyoid to the point lying mid-way between the tips of the greater horns **(Picture 2)**
3.	Length of cornu (CR): distance from the junction of horn and body to the tip of greater horn (left side) **(Picture 3)**
4.	Width of the hyoid body at its midpoint (AW) **(Picture 4)**
5.	The distance between the distal ends of the two lesser horn (DR) **(Picture 5)**

Each measurement was taken using a digital caliper. The measurements were taken three times and the average of these measurements was taken as the final value for the study.

Results & Observation

Age group was divided into three groups in Males and Females. First group contains cases between 20-39yrs, Second group between 40-59yrs and Third group 60-80yrs of age. In Males Group I had 24 cases amounting to 41.38%, group II had 24 cases amounting to 41.38% and group III had 10 cases amounting to 17.24%. The majority of the Hyoids belonged to the age group of 20-39yrs and 40-59yrs. In Females Group I had 20 cases amounting to 34.48%, group II had 18 cases amounting to 31.03% and group III had 20 cases amounting to 34.48%. In females majority of the cases belong to the age group of 20-39yrs and 60-80yrs.

The mean age in Males was 44.69yrs with Standard deviations 15.12yrs. The maximum age was 80yrs and minimum age was 20yrs in Males. The Mean age in Females was 48.17yrswith Standard deviations 18.40yrs. The maximum age was 80yrs and minimum age was 20yrs in Female. The mean age in Females was more than the Males.

The mean of the width of hyoid (BC) was 44.45mm in males and 37.89mm in females with standard deviation of 3.99mm and 2.70mm respectively. Maximum width of hyoid was 54.43mm in males and 42.40mm in females and minimum width of hyoid was 34.50mm in males and 33.20mm in females.

Mean of the length of the hyoid (AP) was 39.68mm in males and 32.27mm in females with standard deviation of 4.36mm and 1.93mm respectively. The maximum length of hyoid was 49.70mm in males and 37.6mm in females and minimum was 30.20mm in males and 29.23 in females.

The mean length of the cornu (CR) was 32.91mm in males and 27.95mm in females with standard deviation of 2.93mm and 3.71mm respectively. Maximum length of cornu was 43.6mm in males and 39.65mm in females and minimum length was 26.9mm in male and 22.1mm in female.

The mean of the width of hyoid body (AW) was 11.46mm in males and 10.96mm in females with standard deviation of 0.78mm in male and 0.71mm in females. The maximum width was 12.61mm in males and 12.63 in females and minimum was 9.52mm in male and 9.63mm in females.

The mean distance between two lesser horns (DR) was 21.67mm in males and 17.64mm in females with standard deviation of 1.50mm and 1.00mm respectively. The maximum distance was 24.67mm in males and 20.39mm in females and minimum was 18.44mm in males and 15.83mm in females.

Unpaired T-test (Table 1) was done which showed that all the five measurements are statistically significant between males and females.

Tests of Equality of Group Means (Table 2) were calculated for development of Discriminant function analysis.

A discriminant function analysis was performed using all the five variables as the predictors of sex. All the variables were entered together. The unstandardized canonical discriminant function was estimated using five variables (Table 3). The cut score was –1.980 which was calculated from the group centroid by obtaining the arithmetic mean of the values (Table 4). Those cases where the DF score was less than –1.980 were Female, and those cases above –1.980 were Male.

Discriminant function(DF) = 0.084 (BC) + 0.081 (AP) +0.045(CR) + 0.252 (AW) +0.611 (DR) - 22.584

Table 1: Unpaired T- test

	t Value	df	P Value	Std Error Deviation
Width of hyoid	**-10.3655**	**114**	**<.0001**	**0.633**
Anteroposterior length	**-11.8375**	**114**	**<.0001**	**0.626**
Length of cornu	**-7.9685**	**114**	**<.0001**	**0.622**
Width of the hyoid body at its midpoint	**-3.5621**	**114**	**0.0005**	**0.140**
Distance between the distal ends of the two lesser horn	**-16.9713**	**114**	**<.0001**	**0.237**

Table 2: Tests of Equality of Group Means

	Wilks' Lambda	F	df1	df2	Sig.
BC	.515	107.444	1	114	< 0.001
AP	.449	140.126	1	114	< 0.001
CR	.642	63.497	1	114	< 0.001
AW	.900	12.688	1	114	< 0.001
DR	.284	288.025	1	114	< 0.001

Table 3: Canonical discriminant Function Coeffcicients

	Function
	1
BC	.084
AP	.081
CR	.045
AW	.252
DR	.611
(Constant)	-22.584

Table 4: Functions at group Centroid

Gender	Function
	1
1	1.980
2	-1.980

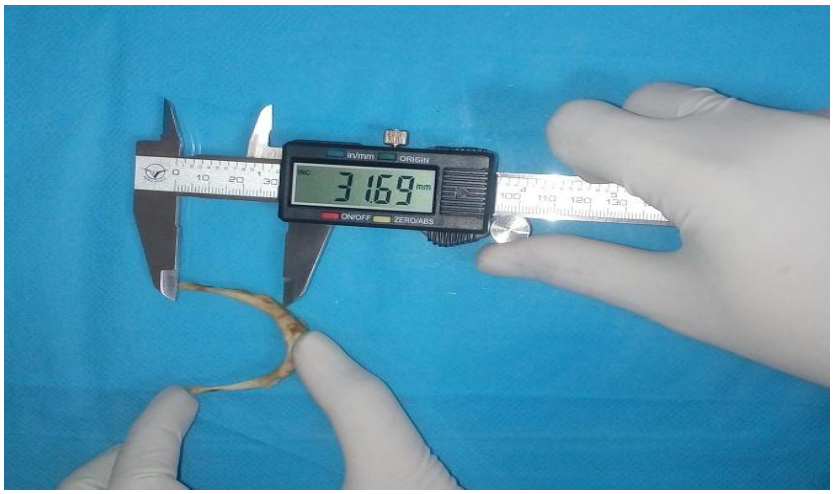
Picture - 1

Measuring the Width of hyoid (BC): Distance between the distal ends of greater horns

Picture – 2

Measuring the Length (AP): Distance in the anteroposterior plane from the anterior middle of the body of hyoid to the point lying mid-way between the tips of the greater horns

Picture – 3



Measuring the Length of cornu (CR): distance from the junction of horn and Body to the tip of greater horn (left side)

Picture – 4

Measuring the distance between the distal ends of the two lesser horn (DR)

Picture -5

Measuring the Width of the Body of Hyoid (DR)

Discussion

Earlier works have shown that the hyoid bone is sexually dimorphic and Metric analysis of the hyoid bone is a helpful technique in the sex determination of a skeleton[4]. Identification is the task that an investigator does when an unknown dead body is found with an allegation of crime or in cases of gross mutilation of the body. Identification is often a difficult task in many of the criminal cases due to the onset of decomposition by the time the dead body has been noticed. Because of the inability for facial recognition and the loss of soft tissues in a putrefied body, sex determination will have to be done with skeletal remains[9].

The mean of the distance between the distal ends of the greater cornu was less in the present study compared to the studies done by K.D.V. Santhi Priya[6], Seham A. Gad El.Hak et al[10], Dr. Amrutha Roopa Ramagalla[11]and Harjeet and Jit I[12]. The mean width of hyoid in a study conducted Partha Pratim Mukhopadhyay[4] was 35.58mm in Females and it was 42.86mmin Males which were slightly less compared to the present study. In a study done by Deepak Herald D"Souza et al[13] the mean width in males was 4.37cm and in females width was 3.84cm the values were similar to the present study.

The mean of the distance between the distal ends of the greater cornu was more compared to the present study in studies done by Igor Leksan et al[14], Dr. Durga Venkata Santhi Priya Kothapalli et al[15].

The mean of Anteroposterior length in study conducted Partha Pratim Mukhopadhyay[4] was 37.42mm with SD 2.95mm in Males and in Females it was 31.92mm with SD 2.118mm which were slightly less than the present study.

The anteroposterior length was less compared to the present study in studies done by K.D.V. Santhi Priya[6], Partha Pratim Mukhopadhyay[16], Seham A. Gad El.Hak et al[10], J. Pollard et al[17].

The mean length of the greater horn of hyoid was comparable to the present study in studies conducted by Deog-Im Kim et al[18], Dr. Amrutha Roopa Ramagalla[11].

Mean length of greater cornua (left) were less compared to the present study in studies conducted by Partha Pratim Mukhopadhyay[4], Partha Pratim Mukhopadhyay[16]. The measurements were also less compared to the present study in study conducted by Seham A. Gad El.Hak et al[10] in which the measurements were taken after radio graphingthe hyoid bone.

The Mean Width of body of hyoid in a study conducted by Partha Pratim Mukhopadhyay[4] was 11.34mm in Males and 9.75mm in females with

SD 0.74mm& 1.22mm respectively which were similar to the present study. The average width of the body of hyoid was more in Males and slightly less in Females than the present study in study done by Kindschuh et al[19]. The present study values were similar to the study conducted by Petra Urbanova et al[20].

The mean of the measurement of the distance between lesser horns in study conducted by Partha Pratim Mukhopadhyay[4] was 26.97mm in Males & 23.42mm in females with SD 2.17mm& 1.93mm respectively which were more compared to the present study.

Minimum transverse distance between bases of lesser cornua was 21.71mmin Males with SD 3.18mm&in Females 18.24mm with SD 2.9mm in study conducted by K.D.V. Santhi Priya[6]. Compared to the present study the male measurements were almost equal and in Females the values were more. However the points considered were different than the present study.

In the present study The distance between the distal ends of greater horns was more in Males compared to the Females and it was statistically significant(p value <.0001)which was in accordance with the previous studies conducted by Partha Pratim Mukhopadhyay[4, 16],K.D.V. Santhi Priya[6], Kindschuh et al[19], Miller K et al[21], Petra Urbanova et al[20], Dr. Amrutha Roopa Ramagalla[11].

The data in the present study showed that the width measurement is greater than length of hyoid measurement in both males and females which was in accordance with the studies conducted by Partha Pratim Mukhopadhyay[4], Deepak Herald D"Souza[13], Seham A. Gad El.Haket al[10] and Deepak Herald D"Souza[13].

The present study agrees with the view of the previous study done by Ubelaker DH et al[22] who explained the lack of correlation between the magnitude of the length and breadth parameters of the hyoid bone may be because of independently coordinated growth of the hyoid bone in orthogonal dimensions.

In the present study distance between lesser horns was more in Males compared to the Females and it was statistically significant (p <0.001) which was in accordance with the previous studies conducted by Kyoichi ITO et al[23] and K.D.V. Santhi Priya[6].

In the present study the width of the hyoid body showed a statistically significant difference(p <0.001) between the Male and Female, which was similar to the previous studies done by Kyoichi ITO et al[23] and Petra Urbanova et al[20].

The discriminate function was developed using all the five parameters. The sample had 116 hyoid bones which included 58 Males and 58 Females. In males 91.4% and in Females 100% hyoids were correctly classified using the DF in the present study. Overall accuracy of the Discriminant function was 95.7% in the present study.

In study conducted by Partha Pratim Mukhopadhyay[4] using discriminate function analysis 100% of female and 86.8% of male hyoids were correctly classified which was similar to the present study in females and less in males. Overall accuracy was 90% which was less compared to the present study.

Kim et al. (2006)[18]used three measurements to produce a discriminant function that resulted in an overall accuracy of 88.2%. In study done by Miller KW et al[21] the accuracy of discriminant function using five measurements was 69.2% in males and 75.2% in females and overall accuracy was around 72%. In a study by Reesink et al[24], the accuracy of discriminant function using three measurements was 76%, these measurements were the maximal medial height of the body, anterior–posterior thickness of the body, and the maximal transverse diameter of the body.

All the above mentioned accuracies are less than the present study. This may be because of the use of different measurements in these studies compared to the present study to develop the discriminant function analysis.

We tried to compare the accuracy of discriminant function analysis between our study and that of others, but there were no common measurements

used as discriminant variables except for one study done by Partha Pratim Mukhopadhyay[4].

Partha Pratim Mukhopadhyay[4] pointed out that morphometry and sexual dimorphism in adult human hyoids is population-specific and Discriminant functions too are population-specific. We agree with the above point as the accuracy of discriminant functions in our study was almost similar to that of an Indian study and the accuracy varied significantly when compared to the accuracy of the other western studies though there were no common parameters.

For determining sex in hyoid bone, single parameter may not be sufficient to decide the sex and it is mandatory to view all the parameters before deciding the sex of an unknown hyoid bone. Sex can thus be determined from the hyoid bone, even in mutilated or grossly decomposed human remains.

Conclusion

Present study was able to establish the sexual dimorphism of the hyoid bone with respect to the five parameters measured which was similar to all the previous studies which showed sexual dimorphism in the hyoid bone. Some authors measured more parameters then our study. Most of the previous studies established the sexual dimorphism of the hyoid length, width and other parameters. The same conclusion was drawn in the present study. However there were no standard values which can be considered for determination of sex.

In the present study the discriminant function analysis developed using all the five variables showed 91.4% accuracy in classifying male hyoids correctly and 100% accuracy in classification of female hyoids. This standard function can be used for determination of sex of the recovered hyoid bone.

The distribution of sex in the present sample was homogeneous as we included equal number of hyoids from male & female which was done in only few previous studies. This study showed Male hyoids were larger than Female hyoids. All five measurements were statistically significant between males and females which conclude that the hyoids can be used for determination of the sex using lengths and width measurements. The measurements increase with the advancement of age. Width of the hyoid is more than the length of the hyoid in both sexes. In conclusion, the hyoid can be used for determination of sex as they show sexual dimorphism. Along with the other bones it will be more accurate to establish the sex.

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