Research Article

Morphometric analysis and sex determination of adult human clavicles in Maharashtra region

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Abstract

Introduction: Determining the sex of deceased is easy when a complete skeleton is available for examination. On the whole, the bones are heavier, larger and markings of muscular attachment are more pronounced in the males than in females. Clavicle has been selected to study the sexual differences and to find out some measurable characters for the determination of the sex of an individual from this bone alone. **Materials and Methods:** One hundred fifty two dry macerated adult human clavicles of known sex (101 males and 51females) were obtained from Government Medical College, Aurangabad with the kind permission of the concerned authorities, for this study. Parameters were taken specifically in relation to acromial breadth, acromial height, acromial surface area and index of outer end. **Result:** As a part of univariate analysis, Demarking Point (D.P.) was obtained for each parameter. The percentage of bones identified beyond D.P. was found for each of them. Mean of all parameters in concern to above mentioned values stands statistically significant. **Conclusion:** For different populations based on geographic areas different anthropometric criteria should be applied which could be specific to that particular population. It can be concluded that to identify the sex of clavicle with 100% accuracy, single parameter was not sufficient. Hence it requires multiple parameters and indices to reach at the most accurate result.

Keywords: clavicles, demarking point, acromial breadth, height, surface area, outer end index.

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INTRODUCTION

Morphometric measurements of skeleton or its isolated parts help to determine the age, sex, and stature of an individual. These measurements have helped the different specialties like Anthropology, Archaeology, Forensic Medicine and Anatomy. Besides providing important and useful data for anthropological purposes, identification of sex of an individual from the remains of skeleton has great medico- legal significance. Clavicle is the less studied element of the shoulder girdle. It is an important bone for human evolution and it permits all movements outside the para sagittal plane (J.L. Voisin, 2006).[1] The observations of Dwight (1905) indicate that, important sex differences are in the size of the articular surfaces of long bones. In males these surfaces are distinctly larger than females. These observations are of considerable assistance in sex determination of a skeleton.[2] Howells (1941) stated that where two observers examine the same series, there is generally a disagreement between them as to sex of 10 to 15% of individuals.[3] The acromial end has a smooth oval articular facet which articulates with the medial aspect of acromion at acromioclavicular joint. Choudhary D. S. (1976) stated, the index of outer end in male and female is statistically not significant.[4] Padeyappanavar (2012) and Patil A.B. (1996) observed that acromial height, acromial breadth and acromial surface area are statistically significant.[5,6] As India is a vast country with intermixing of races, the comparison and verification of findings from different parts and regions of country are essential. Though many workers have studied the morphometric data for the clavicle in both sexes and statistical assessment of this metrical study for its usefulness in sexing clavicles is available

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from other regions of country there is paucity of the population specific data from the Maharashtra region. Thus the present study was planned to study the sex differences of different parameters of clavicles of known sex is prepared tabulated, statistically analyzed and compared with the data of other workers.

MATERIALS AND METHODS

The study was cross –sectional, observational and descriptive in nature, approved by IEC. One hundred fifty two dry macerated adult human clavicles of known sex (101 males and 51 females) were obtained from Government Medical College, Aurangabad with the kind permission of the concerned authorities. Amongst, 51 clavicles of female sex, 25 were of right side and 26 were of left side. Out of 101 male clavicles 54 were of right side and 47 were of left side. In order to avoid observer's error, all the parameters were measured and recorded single handedly. For each of the parameters, three readings were taken and then their mean was taken as final reading. The fallowing parameters were recorded in mm by Digital Vernier caliper with accuracy of 0.1mm.

1. **Acromial breadth of clavicle: (photograph no. 1)**
   The maximum width of acromial end of clavicle measured in mm.
2. **Acromial height of clavicle: (photograph no.2)**
   The maximum height of acromial end of clavicle measured in mm.
3. **Acromial surface area**
   This was measured with the help of graph paper. The acromial end was kept on the graph paper and was traced on it and then squares were counted.
4. **Index of outer end**
   Index of outer end = Acromial height + Acromial breadth.

Statistical Methods

The data was analyzed into range, mean, standard deviation etc. by a standard computerized program. Comparison of each study factor was done by applying,

1. 'Z' Test and obtaining 'P' value
2. Calculation of Demarking Point (D.P.)

OBSERVATIONS AND RESULT

In the present study, 152 dried adult human clavicles of known sex were studied by measuring above mentioned parameters. The values of the range and mean of the parameters of male clavicles were higher and compared to female clavicles, even though there was consider overlap of the values between male and female clavicles. The sexing was also attempted by using the demarking point. By this method, the chances of misclassification of sex were minimal.

Table 1: Breadth at acromial end of Clavicle in (mm)

Details of measurements	Right		Left	
	Male (M)	Female(F)	Male(M)	Female(F)
No. of bones	54	25	47	26
Range	10. 5-18.85	8.3-15.43	9.28-20.97	8.28-14.85
Mean	**14.57**	**11.70**	**14.82**	**12.21**
Median	14.76	11.25	14.96	12.27
Mode	12.08	10.33	15.23	10.38
Standard Deviation	2.14	2.08	2.66	1.75
Coefficient of variation (CV)	14.72	17.78	17.99	14.36
Identification Point	>15.43	<10.5	>14.85	<9.28
% of identified bones	38.88	36	53.19	7.69
Calculated range	8.13-21.01	5.46-17.95	6.82-22.82	6.95-14.47
Demarking point	**>17.95**	**<8.13**	**>14.47**	**<6.82**
% beyond demarking point	7.40	0	14.89	0
Z value	5.628697		5.518699	
P value	P<0.001		P<0.001	

Right Clavicle

The right clavicle having acromial breadth 17.95 mm or more was definitely a male clavicle and having acromial breadth 8.13 mm or less was definitely a female clavicle**.** Beyond demarking point, 7.40 % male clavicles and none of female clavicle could be identified with 100 % accuracy. The mean values of acromial breadth of right clavicles in both sexes were statistically highly significant.

Left Clavicle

The left clavicle having an acromial breadth 14.47 mm or more was definitely a male clavicle and having an acromial breadth 6.82 mm or less is definitely a female clavicle. Beyond demarking point, 14.89 % male clavicles and none of female clavicle could be identified with 100 % accuracy. The mean values of acromial breadth of left clavicles in both sexes were statistically highly significant.

Table 2: Height at acromial end of Clavicle in (mm)

Details of measurements	Right		Left	
	Male (M)	Female(F)	Male(M)	Female(F)
No. of bones	54	25	47	26
Range	6.23-14.75	5.59-10.81	5.84-13.81	4.42-9.78
Mean	**9.84**	**8.22**	**9.36**	**7.56**
Median	9.92	8.69	9.3	7.56
Mode	10.34	9.61	9.17	7.70
Standard Deviation	1.95	1.48	1.84	1.75
Coefficient of variation (CV)	19.85	18.05	19.66	20.25
Identification Point	>10.81	<6.23	>9.78	<5.84
% of identified bones	22.22	12	38.29	15.38
Calculated range	3.97-15.70	3.77-12.68	3.83-14.88	2.93-12.03
Demarking point	**>12.68**	**<3.97**	**>12.03**	**<3.83**
% beyond demarking point	9.25	0	8.51	0
Z value	4.044343		2.861377	
P value	P<0.001		P<0.01	

Right Clavicle

The right male clavicle having acromial height 12.68 mm or more was definitely male clavicle and having acromial height 3.97 mm or less was definitely female clavicle. Beyond demarking point, 9.25% male clavicles and none of the female clavicle could be identified with 100% accuracy. The mean values of acromial height of right clavicles in both sexes were statistically highly significant.

Left Clavicle

The left male clavicle having a acromial height 12.03 mm or more was definitely a male clavicle and having a acromial height 3.83 mm or less was a definitely female clavicle. Beyond demarking point, 8.51% male clavicles and none of female clavicle could be identified with 100 % accuracy. The mean values of acromial height of left clavicles in both sexes were statistically highly significant.

Table 3: Acromial surface area of clavicle in (mm^2)

Details of measurements	Right		Left	
	Male (M)	Female(F)	Male(M)	Female(F)
No. of bones	54	25	47	26
Range	52-187	35-130	53-193	40-123
Mean	**112.15**	**73.36**	**102.4**	**74.15**
Median	108	70	97	72.5
Mode	120	63.28	115	40
Standard Deviation	35	27.34	36.27	24.68
Coefficient of variation (CV)	31	37.26	35.42	34.68
Identification Point	>130	<52	>123	<53
% of identified bones	27.77	28	23.40	34.61
Calculated range	5.51-218	-8.61-155.38	-6.41-211.22	-2.8-145.2
Demarking point	**>155.3**	**<5.52**	**>145.2**	**<-6.41**
% beyond demarking point	18.51	0	12.76	0
Z value	5.349211		3.855714	
P value	P<0.05		P<0.001	

Right Clavicle

The right clavicle having an acromial surface area 155.3 mm^2 or more was definitely male clavicle and 5.52 mm^2 or less was definitely female clavicle. Beyond demarking point, 18.51% male clavicles and none of female clavicles could be identified with 100% accuracy. The mean values of acromial surface area of right clavicles in both sexes were statistically highly significant.

Left Clavicle

The left clavicle having an acromial surface area 145.2 mm^2 or more was definitely male clavicle and having an acromial surface area - 6.41mm^2 or less was definitely female clavicle. Beyond demarking point, 12.76% male clavicles and none of female clavicles could be identified with 100% accuracy. The mean values of acromial surface area of left clavicles in both sexes were statistically highly significant.

Table 4: Index of outer end of clavicle (in mm)

Details of measurements	Right		Left	
	Male (M)	Female(F)	Male(M)	Female(F)
No. of bones	54	25	47	26
Range	17.85-33.28	14.6-24.26	15.85-32.39	12.7-24.26
Mean	**24.41**	**19.93**	**24.18**	**19.70**
Median	24.60	20.36	23.41	20.18
Mode	25.67	21.20	21.86	21.14
Standard Deviation	3.78	3.24	3.85	3.01
Coefficient of variation (CV)	15.51	16.27	15.9	15.30
Identification Point	>24.26	<17.85	>24.26	<15.44
% of identified bones	53.70	36	46.80	7.69
Calculated range	13.05-35.77	10.20-29.67	12.61-35.75	10.65-28.75
Demarking point	**>29.67**	**<13.05**	**>28.75**	**<12.61**
% beyond demarking point	5.55	0	12.76	0
Z value	5.400619		4.999035	
P value	P<0.001		P<0.001	

Right Clavicle

The right clavicle having an index of outer end 29.67 mm or more was definitely male clavicle and 13.05 mm or less was definitely female clavicle. Beyond demarking point, 5.55 % male clavicles and none of female clavicle could be identified with 100 % accuracy. The mean values of index of outer end of right clavicles in both sexes were statistically highly significant.

Left Clavicle

The left clavicle having index of outer end 28.75 mm or more was definitely male clavicle and 12.61mm or less was definitely female clavicle. Beyond demarking point, 12.76 % male clavicles and none of female clavicle could be identified with 100 % accuracy. The mean values of index of outer end of left clavicles in both sexes were statistically highly significant.

Figure 1: Measurement of acromial breadth

Figure 2: Measurement of acromial height

DISCUSSION

Williams and Warwick stated that the female bones are usually smaller and of less diameter than male bones.[7] The hips of adult women are broader than the shoulders and reverse in case of adult men. Since clavicle contributes to the breadth of shoulders. It is reasonable to predict that the clavicle in male will be longer and larger than in females.[8] Sex can be determined with a 73.3 %-88.3% accuracy by using dimensions of clavicle when only the clavicle bone is available due to explosion, plane crashes or in cases of mutilated bodies.[9] Most of the workers used length, weight and mid-shaft circumference for sex determination of clavicle. In the present study the parameters were measured like acromial height, acromial breadth, acromial surface area and index of outer end. All these parameters were statistically highly significant. The osteometric data of the clavicle of present study is compared with other similar studies.

Table 5a: Acromial breadth of clavicle (in mm) Right side

Investigators	Sample size		Mean		Range		S.D.		S.S.D.
	M	F	M	F	M	F	M	F	P value
Dongen R.V. (1963)[10]	50	50	21.5	17.5	-	-	2.28	2.22	<0.001
Patil A.B.(1996)[6]	76	62	13.97	10.59	3.34-24.60	3.10-18.08	3.54	2.49	<0.001

Padeyappanavar (2012)[5]	92	61	16.09	12.59	10-28	7-18	3.79	2.61	<0.001
Present study	**54**	**25**	**14.57**	**11.70**	**10.5-18.85**	**8.3-15.43**	**2.14**	**2.08**	**<0.001**

Right side: The mean values of acromial breadth of clavicles in both sexes were nearer to the values in the study done by Patil A.B.[5] These values were higher in the studies of Doengen.[12]

Table 5b: Acromial breadth of clavicle (in mm) Left side

Investigators	Sample size		Mean		Range		S.D.		S.S.D.
	M	F	M	F	M	F	M	F	P value
Dongen R. V. (1963)[10]	50	50	21.5	17.5	-	-	2.28	2.22	<0.001
Patil A.B. (1996)[6]	84	78	14.32	11.32	3.02-25.62	2.28-20.36	3.76	3.01	<0.001
Padeyappanavar (2012)[5]	104	76	14.88	13.3	9-25	8-20	3.05	2.77	<0.001
Present study	**47**	**26**	**14.82**	**12.21**	**9.28-20.97**	**8.28-14.85**	**2.66**	**1.75**	**<0.001**

Left side: The mean values of acromial breadth clavicles in both sexes were comparable with the values of Padeyappanavar[5].

Table 6a: Acromial height of clavicle (in mm) Right side

Investigators	Sample size		Mean		Range		S.D.		S.S.D.
	M	F	M	F	M	F	M	F	P value
Patil A.B.(1996)[6]	76	62	8.46	6.58	5-13	3-10	2.43	1.93	<0.001
Padeyappanavar (2012)[5]	92	61	11.84	9.37	7-20	4-15	3.25	2.1	<0.001
Present study	**54**	**25**	**9.84**	**8.22**	**6.23-14.75**	**5.59-10.81**	**1.95**	**1.48**	**<0.001**

Right side: The mean values of acromial height of male clavicles were nearer to the studies of Patil A.B.[13] and that of female clavicles were comparable with the study of Padeyappanavar.[5]

Table 6b: Acromial height of clavicle (in mm) Left side

Investigators	Sample size		Mean		Range		S.D.		S.S.D.
	M	F	M	F	M	F	M	F	P value
Patil A.B.(1996)[6]	84	78	8.44	5.92	5-13	3-10	2.29	1.90	<0.001
Padeyappanavar(2012)[5]	104	76	10.61	9.72	5-18	5-15	2.33	2.18	<0.001
Present study	**47**	**26**	**9.36**	**7.56**	**5.84-13.81**	**4.42-9.78**	**1.84**	**1.75**	**<0.001**

Left side: The mean values of acromial height of male clavicles were nearer to the studies of Patil A.B.[13] and that of female clavicle didn't match with the other workers.

Table 7a: Acromial surface area of Right clavicle (in mm^2)

Investigators	Sample size		Mean		Range		S.D.		S.S.D.
	M	F	M	F	M	F	M	F	P value
Patil A.B.(1996)[6]	76	62	99.25	74.40	50-192	30-125	29.05	24.37	<0.001
Padeyappanavar (2012)[5]	92	61	117	82.40	39-260	26-150	43.61	31.15	<0.001
Preset study	**54**	**25**	**112.15**	**73.36**	**52-187**	**35-130**	**35**	**27.34**	**<0.05**

Right side: The mean values of acromial surface area of male clavicles were didn't coincide with previous workers but for female clavicles were coinciding with the values of Patil A.B.[13]

Table 7b: Acromial surface area of Left clavicle (in mm^2)

Investigators	Sample size		Mean		Range		S.D.		S.S.D.
	M	F	M	F	M	F	M	F	P value
Patil A.B. (1996)[6]	84	78	96.25	72.17	40-190	32-120	29.85	23.15	<0.001
Padeyappanavar (2012)[5]	104	76	113.37	83	35-232	33-150	41	27.45	<0.001
Present study	**47**	**26**	**102.4**	**74.15**	**53-193**	**40-123**	**36.27**	**24.68**	**<0.001**

Left side: The mean values of acromial surface area of male clavicles were not coinciding with previous workers but female clavicles were coincide with the values of Patil A.B.[12]

Table 8a: Index of outer end of Right clavicle (in mm)

Investigators	Sample size		Mean		Range		S.D.		S.S.D.
	M	F	M	F	M	F	M	F	P value
Choudhary D.S. *et al* (1977)[4]	172	30	14.8	14.65	-	-	-	-	-
Patil A.B. (1996)[6]	76	62	22.39	17.17	12-33	9-26	5.74	4.20	<0.001
Present study	**54**	**25**	**24.41**	**19.93**	**17.85-33.28**	**14.6-24.26**	**3.78**	**3.24**	**<0.001**

Right side: The mean values of index of outer end of clavicles in both sexes were higher than previous workers.

Table 8b: Index of outer end of Left clavicle (in mm)

Investigators	Sample size		Mean		Range		S.D.		S.S.D.
	M	F	M	F	M	F	M	F	P value
Choudhary D.S. *et al* (1977)[4]	172	30	14.8	14.65	-	-	-	-	-
Patil A.B. (1996)[6]	84	78	22.76	17.26	12-35	9-28	5.74	4.48	<0.001
Present study	**47**	**26**	**24.18**	**19.70**	**15.85-32.39**	**12.7-24.26**	**3.85**	**3.01**	**<0.001**

Left side: The mean values of index of outer end of clavicles in both sexes were higher than previous workers. Univariate statistical tests were applied to the metrical data obtained to assess whether the differences between the mean values of each parameter are statistically significant or not. In present study, all parameters become statistically significant.

CONCLUSION

Demarking Point is a useful tool in deciding the sex of unknown sample in future which is an often required in medico- legal cases. However, the sex overlapping was observed in all parameters and indices. This may be due to genetic, nutritional and socio-economic differences in the individuals or may be due to hypo-masculinity in male clavicles and hyper-masculinity in female clavicles. Other factors like stress, strain, racial, hormonal factor also play important role in growth of bones. It can be concluded that to identify the sex of clavicles with 100% accuracy single parameter is not useful but number of parameters and indices are required. Such studies will also help to observe the changing trends in metric measurements, if any.

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