

Original research article**Determination of sex of adult human clavicle by morphometry parameters****¹Dr. Syeda Ishrat Fatima, ²Dr. Syeda Tasneem Kauser, ³Dr. Md Althaf**^{1,2} Assistant Professor, Department of Anatomy, Malla Reddy Institute of Medical Sciences, Suraram, Hyderabad, Telangana, India² Associate Professor, Department of Biochemistry, Mallareddy Medical College for Women, Suraram, Hyderabad, Telangana, India**Corresponding Author:**

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Abstract

Background: When human skeletal remains are discovered, one of the most pressing concerns that must be answered is the identity of the person who died. Hence, not only do anatomists, but also anthropologists and forensic professionals, find interest in researching sexual dimorphism of bones in the human population.

Material and Methods: At the Anatomy Department of Kakatiya Medical College, Warangal, Telangana, India, we collected one hundred dried clavicles from adults of both sexes. This project is generating literature on metrical data of the clavicle by measuring various morphological data of adult humans of known sex at the Department of Anatomy, Kakatiya Medical College, Warangal, Telangana between August 2013 to September 2014.

Results: The present study measured the length, mid-shaft circumference, weight, length and breadth of the rhomboid fossa, and angles of curvature of one hundred dried and cleaned adult human clavicles of known sexes. There are a total of 100 clavicles; 50 belong to males (25 on each side), and the other 50 belong to females (25 are of right side and 25 are of left side). Sex determination of clavicles would be challenging at best due to the large overlap between the hypomusculine and hypermuscular ranges of male clavicles and the hypofeminine and hyperfeminine ranges of female bones.

Conclusion: All the characteristics and indices do, however, show a sex overlap. This could be related to hypomascularity in male clavicles and hypermasculinity in female clavicles, or it could be the result of individual differences in genetics, nutrition, and socioeconomic status.

Keywords: Parameters of morphometry, adult human clavicle, and sex determination

Introduction

Determination of sex of an unknown individual is one of the critical questions addressed when human skeletal remains are found, both in forensic investigation and archaeological studies.¹ Therefore the study of sexual dimorphism of bones in human population is a matter of interest not only for the anatomists but also for the anthropologists and forensic experts^[1].

The doctor, who is doing postmortem examination on highly decomposed body or on the skeletal remains of unknown person, plays an essential role in establishing the identity of a dead person. While establishing the identification, age, sex, stature and race of the person are the primary criteria's (big fours) of identification. Among them, determination of sex is statistically most important criteria, as it immediately excludes approximately half of the population, where as the age, stature and race each provides the points within a wide range of variables^[2,3].

Following the death, human body shows destructive effects of postmortem putrefaction and decomposition, but osseous skeleton is the only structure which resists this effect for longer time by maintaining its morphological features long after the soft tissues have been destroyed. Thus these persistent morphological features of the skeleton will help in establishing primary criterias of identification *viz.* age, sex, stature and race to a certain extent^[4].

As the obvious sex differences become apparent only after puberty, it is not a difficult task to determine the sex of an adult deceased when a complete or almost complete skeleton is available for examination. However, it becomes difficult to determine the sex of the deceased if a single bone or only few bones are available, as nature and completeness of a skeleton available for examination varies widely from well preserved full skeleton to a scanty material with few bones only. Thus the accuracy of assessment of sex of a skeleton is directly proportional to the amount of bones available^[5].

One of the most obvious sex differences in long bones is that the typical male bones are longer, heaviest and more massive than typical female bones. The male to female ratio for long bone length hovers around 100:90^[6].

According to most of the authors; female clavicle is shorter, thinner, less curved and smoother. The clavicle is thicker and more curved in manual workers and in males the ridges for muscular attachment are better marked^[7, 8]. These traditional, non- metrical methods including size, weight and muscular markings are not always helpful, as these methods depends on experts' ability and experience and shows subjective variations^[9].

The sexing of the clavicle by metrical methods had been attempted in Western countries by various workers who found that the midclavicular circumference was a good criterion for sexing the clavicle^[10, 11]. Similar studies have been done in India on clavicles using their midclavicular circumference, length and weight and found that the midclavicular circumference as a best criterion for identifying the sex^[12]. The standards of morphological and morphometric differences in the skeleton e.g. femur, humerus, clavicle, etc., may differ with the population samples involved. As a general rule, morphometric standards should be used with reference to the group from which they were drawn and upon which they are based. They are not ordinarily interchangeable as the populations vary significantly with respect to their physical and morphological characteristics. This aspect necessitates building contexts of references for any given population^[2].

Even though many workers studied the morphometric data of the clavicles extensively at various parts of the world, the available literature clearly shows that there is a paucity of metrical data on the clavicle in this geographical region^[9, 12].

Hence, the present study is undertaken to study sexual differences in adult human clavicle by measurement of certain parameters of the clavicles of known sex and their statistical analysis. This study is based on the measurement of certain morphological characteristics like length, mid-shaft circumference, weight, angles, nature of rhomboid fossa etc. of clavicles of the known sex from this region. Later comparing these values with clavicles of unknown individual can properly identify their sex and will help to build the context of reference values for the population of this geographical region. The present morphometric study on the clavicle will also give the common values of dimensions of the clavicle of this region. The knowledge regarding this will help the orthopedic surgeon to decide correct size and shapes of plates and nails for the treatment of clavicular fractures by open reduction method.

Aims and Objectives

I have undertaken the present study at department of Anatomy, Department of Anatomy, Kakatiya Medical College, Warangal, Telangana. With the following objectives:

1. To study the sex related differences in the adult human clavicle.
2. To study the utility and limitations of the various clavicular parameters and indices in sex differentiation.
3. To find out „demarking points“ of sex differentiation for the parameters like length, mid- shaft circumference and weight of clavicles.
4. To study the incidence, nature and dimensions of rhomboid fossa in the clavicles of male and female.
5. To analyze and compare the present data with previous studies.

The present study is aimed to determine whether sexing of unknown clavicles can be done by applying values of morphometric parameters and formulae generated by present study on clavicles of known sex and to find out the best parameters for sex determination.

Material and Methods

The total 100 dried clavicles of adult human bodies of known sexes (50 male and 50 female) were obtained from the Department of Anatomy, Kakatiya Medical College, Warangal, Telangana, India between August 2013 to September 2014, by measuring various morphological data of adult human clavicle of known sex to generate literature on metrical data of the clavicle.

Inclusion criteria

Clavicles of adult human of both sex with complete ossification and fusion, without any deformity

Exclusion criteria:

1. The clavicles which were incomplete in ossification and fusion and those showing deformities and degradation
2. Bones showing any pathology like fracture, tumors, etc.

Out of 50 male clavicles (25 right and 25 left) and out 50 female clavicles (25 right and 25 left) were taken. Before taking measurements, clavicles were cleaned and dried. The metrical data after the measurement and observation of each clavicle were noted in the following manner.

Length of clavicle: The maximum length of each clavicle is measured in millimeters (mm) from sternal

end to acromial end with the help of Vernier caliper ^[21].

Mid-shaft circumference of clavicle: While measuring the length of the clavicle, a mark was done with pencil at the middle of distance between two ends of clavicle. At this midpoint, circumference was measured in millimeters (mm) with the help of calibrated narrow strip of graph paper or a thread ^[24]. (fig no.7, 8)

Robustness index (RI): It (Length: Circumference index) is calculated using following formula. ¹²

$$RI = \frac{\text{Mid shaft circumference}}{\text{Maximum length of clavicle}} \times 100$$

Weight of clavicle: The weight of each clavicle in grams (gm) is measured with the help of physical balance. ¹² (fig no. 9)

Rhomboid fossa:

Its Presence/ Absence, nature, length and breadth

The presence or absence of rhomboid fossa was noted. If present, its length and breadth were measured in millimeters (mm) with the help of Vernier calliper or thread or scale. ^{18, 20} (fig no.10, 11)

The nature of rhomboid fossa was noted as follows: ²⁰

- a) Whether the fossa is flat
- b) Whether the fossa is depressed below the surface
- c) Whether the fossa is raised above the surface.

Index of Rhomboid fossa (IRF): It is calculated using following formula.

$$IRF = \frac{\text{Breadth of rhomboid fossa}}{\text{Length of rhomboid fossa}} \times 100$$

Measurements of angles (Medial, Lateral and Total Angles)

The angles (inner angle and outer angle) of clavicles were measured in degrees with the help of protractor. To measure the angles / curves of the clavicle, the method described by Parson FG was followed ^[15].

A tracing of the contour of the bone was made from its superior aspect. Care being taken to ensure the same orientation in all the bones. The midpoint of the sternal and acromial ends have been located and connected by a straight line (fig no.12). The mid axis of the tracing was laid in. The two (medial and lateral) angles have been constructed to fit the curves of the mid axis at its greatest convexities and at the points of intersection of mid axis and straight line. The angles are measured with a compass or protractor. The total angle or index of curvature is the sum of medial and lateral angles of clavicle. ^[10, 15, 21]

Results

In the present study, total of 100 dried and cleaned adult human clavicles of known sexes have been studied by measuring their various morphometric parameters like length, mid-shaft circumference, weight, length and breadth of rhomboid fossa and angles of curvature. Out of these 100 clavicles, 50 are of male sex (25 are of right side and 25 are of left side) and remaining 50 clavicles are of female sex (25 are of right side and 25 are of left side). The male clavicles range from hypomusculine to hypermuscularity while the female bones have a range of hypofemininity to hyperfemininity with a considerable overlapping portion between both sexes, which would thus cause difficulty or even impossibility in sex determination of clavicles.

In univariate discriminate functional analysis using single parameter, range, mean, standard deviation (SD), p value, mean \pm 3SD were calculated applying statistical analysis. The values of range and mean of most of the parameter of male clavicles are higher compared to female clavicles. Even then there is considerable overlap of the value between male and female clavicles.

The clavicle having the measurement of its parameter more than that of the upper limit of range of same parameter of female clavicles is identified as male clavicles. While the clavicle having measurement of parameter smaller than the lower limit of range of male clavicles is identified as of female. The sexing is also attempted by using the „demarking point“ calculated for parameters like length, mid-shaft circumference, robustness index and weight. By this method chance of miscalculation of sex is very minimal. The demarking point is calculated by a formula DP = mean \pm 3SD. By finding this point, we can statistically fix a measurement above which no female clavicle can be found and another measurement below which no male clavicle can be seen. Any single demarking point for any one parameter, if crossed

would definitely identify the unknown sex of the clavicle with 100% accuracy. As the clavicle is one bone which shows side related asymmetry, it is planned to analyze sex differences of each parameter of right and left side clavicles separately.

Based on univariate analysis using single parameter and by finding its demarking point and identification point, the utility and limitations of different measurement and indices of the clavicles in determination of sex are presented as follows.

Table 1: Descriptive statistics of various parameters of Adult Human Clavicles of Male & Female

| Sr. no. | Parameters | Male | | | | | | Female | | | | | |
|---------|-----------------------------|---------|-------|---------|-------|------------|-------|---------|-------|---------|-------|------------|-------|
| | | Rt (25) | | Lt (25) | | Total=(50) | | Rt (25) | | Lt (25) | | Total=(50) | |
| | | Mean | S.D | Mean | S.D. | Mean | S.D | Mean | S.D | Mean | S.D. | Mean | S.D |
| 1 | Length (mm) | 143.8 | 9.23 | 142.56 | 11.46 | 143.1 | 10.32 | 124 | 13.78 | 124.36 | 11.22 | 124.2 | 12.44 |
| 2 | MSC (mm) | 40 | 3.58 | 38.6 | 4.75 | 39.34 | 4.23 | 29.24 | 5 | 28.92 | 6 | 29 | 5.52 |
| 3 | Robustness Index (RI) | 27.95 | 3.22 | 27 | 3.39 | 27.52 | 3.30 | 24.1 | 4.38 | 23.28 | 4.89 | 23.69 | 4.61 |
| 4 | Weight (gm) | 17.77 | 4.97 | 18 | 3.75 | 17.89 | 4.36 | 10.44 | 2.36 | 11.82 | 2.81 | 11.13 | 2.66 |
| 5 | Rhomboid fossa-Length (mm) | 18.8 | 3.24 | 21.64 | 4.98 | 20.22 | 4.4 | 15.1 | 2.81 | 18.24 | 5.39 | 16.7 | 4.53 |
| 6 | Rhomboid fossa-Breadth (mm) | 12 | 3.76 | 9.64 | 1.7 | 10.86 | 3.14 | 9.4 | 2.27 | 8.4 | 1.6 | 8.91 | 2 |
| 7 | IRF | 64.29 | 15.56 | 45.73 | 9.24 | 55 | 15.76 | 63 | 14.14 | 49.97 | 18 | 56.5 | 17.3 |
| 8 | Medial angle | 153.28 | 4.24 | 153.12 | 6.13 | 153.2 | 5.22 | 152.72 | 8.80 | 150.3 | 7.59 | 151.52 | 8.22 |
| 9 | Lateral angle | 156.0 | 9.66 | 156.64 | 11.72 | 156.36 | 10.63 | 148.76 | 10.33 | 150.28 | 9.32 | 149.52 | 9.76 |
| 10 | Total Angle | 309.3 | 10.5 | 309.7 | 14.3 | 309.56 | 12.47 | 301.4 | 18.84 | 300.6 | 15.47 | 301.04 | 17.07 |

RF=Rhomboid Fossa, IRF=Index of Rhomboid Fossa, SD=Standard deviation, No=Number of clavicles.

Table 2: Comparison of various parameters of Male & Female clavicles of Rt. Side

| Sr. No. | Parameters | Male No=25 | Female No=25 | t Value | P Value |
|---------|----------------------------|------------|--------------|---------|---------|
| 1 | Length (mm) | 143.8 | 124 | 5.941 | <0.001 |
| 2 | MSC (mm) | 40 | 29.24 | 8.733 | <0.001 |
| 3 | Robustness Index (RI) | 27.95 | 24.1 | 3.532 | <0.001 |
| 4 | Weight (gm) | 17.77 | 10.44 | 6.659 | <0.001 |
| 5 | Rhomboid fossa-Length (mm) | 18.8 | 15.1 | 4.216 | <0.001 |
| 6 | Rhomboid fossa-readth (mm) | 12 | 9.4 | 3.026 | <0.05 |
| 7 | IRF | 64.29 | 63 | 0.30 | >0.05 |
| 8 | Medial angle | 153.2 | 152.72 | 0.286 | >0.05 |
| 9 | Lateral angle | 156 | 148.76 | 2.587 | <0.05 |
| 10 | Total Angle | 309.3 | 301.4 | 1.825 | <0.05 |

RF=Rhomboid Fossa, MSC=Mid-shaft circumference, IRF=Index of Rhomboid Fossa, HS=Highly significant, NS=Not significant, S=Significant, No=Number of clavicles.

Table 3: Comparison of various parameters of Male & Female clavicles of Lt. Side

| S. No. | Parameters | Male No=25 | Female No=25 | t Value | P Value |
|--------|------------------------------|------------|--------------|---------|---------|
| 1 | Length (mm) | 142.56 | 124.36 | 5.673 | <0.001 |
| 2 | Mid Shaft Circumference (mm) | 38.6 | 28.92 | 6.297 | <0.001 |
| 3 | Robustness Index (RI) | 27 | 23.28 | 3.197 | <0.05 |
| 4 | Weight (gm) | 18 | 11.82 | 6.596 | <0.001 |
| 5 | Rhomboid fossa-Length (mm) | 21.64 | 18.24 | 2.315 | <0.05 |
| 6 | Rhomboid fossa-Breadth (mm) | 9.64 | 8.4 | 2.646 | <0.05 |
| 7 | Index of rhomboid fossa | 45.73 | 49.97 | 1.047 | >0.05 |
| 8 | Medial angle | 153.12 | 150.3 | 1.433 | >0.05 |
| 9 | Lateral angle | 156.64 | 150.28 | 2.123 | <0.05 |
| 10 | Total Angle | 309.7 | 300.6 | 2.166 | <0.05 |

RF=Rhomboid Fossa, MSC=Mid-shaft circumference, IRF=Index of Rhomboid Fossa, HS=Highly significant, NS=Not significant, S=Significant, No=Number of clavicles

Length

Table 4: Discriminant analysis of length (mm) of male & female clavicles

| Sr. No | Details of Measurement | Right | | Left | |
|--------|------------------------------|---------------------|--------------|---------------------|-----------|
| | | Males | Females | Males | Females |
| 1. | No. of Clavicles | 25 | 25 | 25 | 25 |
| 2. | Range | 126-163 | 107-147 | 120-164 | 105-147 |
| 3. | Mean | 143.8 | 124 | 142.56 | 124.36 |
| 4. | S.D. | 9.238 | 13.78 | 11.46 | 11.221 |
| 5. | P value | <i>p</i> <0.001(HS) | | <i>p</i> <0.001(HS) | |
| 6. | T value | 5.941 | | 5.673 | |
| 7. | Identification point | >147 | <126 | >147 | <120 |
| 8. | % of identified bones | 32% | 60% | 32% | 36% |
| 9. | Calculated range (mean ±3SD) | 116-171.5 | 82.71-165.44 | 108.6-176.95 | 90.69-158 |
| 10. | Demarking pt (D.P) | >165.44 | <116.08 | >158 | <108.6 |
| 11. | % clavicles beyond D.P | 0% | 44% | 8% | 4% |

Right clavicle

The length of male right clavicles(No=25) varies from 126 to 163mm with a mean value of length being 143.8mm and SD of ±9.238(~143.8±9.238mm),where as that of the female right clavicles(No=25) ranges from 107 to 147mm with mean length of 124mm and SD of 13.78(~124±13.78mm). Thus right male clavicle is longer than female right clavicle. The sex differentiation by comparing the length of male and female clavicles of right side is statistically highly significant (*p*<0.001). As maximum length of right female clavicle is 147mm, right clavicle having its length more than 147mm is identified as of male sex. Similarly, as the minimum length of right male clavicle is 126mm, the right clavicle having its length less than this is identified as of female sex. Accordingly, 60% of right female clavicles are identified as of female sex, i.e. 32% of male and 60% female right clavicles do not overlap in their measurements of length.

Demarking point

When nearly 100% accuracy of sexing of clavicle is required, it is advisable to calculate the maximum and minimum limits of the measurements by adding ±3SD to the mean of each measurement for males and female separately. This calculated range would cover 99.75% the samples. Such limiting points are known on demarking points. On application of demarking point to length of right clavicle, a clavicle having its length more than 165.44mm is definitely of male sex and one having its length less than 116.08 mm is definitely of female sex. By this method, the percentage of right clavicles that are accurately sexed is 0% in males and 44% in female.

Left clavicle

The length of left male clavicles (No=25) ranges from 120 to 164mm with a mean of 142.56mm and SD of ±11.46 (~142.56 ±11.46mm). While length of left female clavicles (No=25) ranges from 105 to 147mm with a mean of 124.36mm and SD of ±11.22 (~124.36±11.22mm). Thus, left male clavicle measures its mean length more than female clavicle. It is statistically significant for sex differentiation of left side clavicles (*p*<0.001).

The maximum length of female left clavicle is 147mm and minimum length of male left clavicle is 120mm. Hence, the left clavicle having its length more than 147mm is identified as of male and that with less than 120mm is identified as of female. Accordingly, only 32% of male and 36% of female left clavicles are identified as of male and female respectively.

On applying demarking point, calculated range for male left clavicle is 108.6 to 176.9mm and for female left clavicle is 90.69 to 158mm. Thus the demarking point for male left clavicle is >158mm and female left clavicle is <108.6mm. The left clavicle with its length more than 158mm is definitely identified as of male and that with its length <108.6mm is definitely identified as of female sex. Accordingly, only 8% of male and 4% of female clavicles of left side could be correctly sexed as of male and female respectively.

Mid Shaft Circumference

Table 5: Discriminated analysis of mid shaft circumference (mm) of male & female clavicles

| Sr. No | Details of Measurement | Right | | Left | |
|--------|-----------------------------------|---------------|------------|---------------|------------|
| | | Male | Female | Male | Female |
| 1. | No. of Clavicles | 25 | 25 | 25 | 25 |
| 2. | Range | 34-46 | 20-38 | 30-46 | 20-38 |
| 3. | Mean | 40.08 | 29.24 | 38.6 | 28.92 |
| 4. | S.D. | 3.58 | 5.0 | 4.75 | 6.0 |
| 5. | p value | $P<0.001(HS)$ | | $P<0.001(HS)$ | |
| 6. | T value | 8.733 | | 6.297 | |
| 7. | Identification Point | >38 | <34 | >38 | <30 |
| 8. | % of identified bones | 64% | 80% | 56% | 52% |
| 9. | Calculated range (mean \pm 3SD) | 29.33-50.82 | 14.0-44.44 | 24.3-52.85 | 10.79-47.0 |
| 10. | Demarking pt (D.P) | >44.4 | <29.33 | >47.0 | <24.34 |
| 11. | % of clavicles beyond D.P | 8% | 44% | 0 | 36% |

Right side

The mid-shaft circumference of right side male clavicles ranges from 34 to 46mm with a mean of 40.08mm and SD of \pm 3.58, while that of female clavicles ranges from 20 to 38mm with a mean of 29.24mm and SD of \pm 5.0. Thus the mean mid-shaft circumference of male right clavicle is more than that of female right clavicle. It is statistically highly significant for sex differentiation ($p<0.001$). The clavicles which don't show any overlaps in their mid-shaft circumference value with that of opposite sex are correctly identified as of particular sex. Accordingly, 64% of right male clavicles measuring their mid-shaft circumference more than 38 are identified as of male, while 80% of female right side clavicles measuring their mid-shaft circumference less than 34mm are identified as of female. On applying demarking point calculation, calculated range of mid-shaft circumference for right male clavicle is 29.33 to 50.82mm and that for right female clavicle is 14.0 to 44.44 mm. Thus the demarking point for mid-shaft circumference of male right clavicle is >44.4mm and that for female clavicle is <29.33mm. The right clavicles having their mid-shaft circumference beyond these demarking points could be sexed accurately. Accordingly, 8% of male and 44% of female right side clavicles are sexed correctly as male and female respectively.

Left clavicle

The mid-shaft circumference of left male clavicles ranges from 30 to 46mm with a mean of 38.6mm and SD of \pm 4.75, while that of female left clavicles ranges from 20 to 38mm with the mean of 28.92mm and SD of \pm 6.0. Thus, mid-shaft circumference of left male clavicle is greater than left female clavicle. This is statistically significant for sex differentiation ($p<0.001$). The left clavicles measuring their mid-shaft circumference >38mm are identified as male (56% of left male clavicles) and that having their mid-shaft circumference <30mm are identified as female bones (52% of left female clavicles), i.e. 56% of male and 52% of female left sided clavicles don't show any overlapping in their mid shaft circumference.

Demarking point

The calculated range for left male clavicle is 24.3 to 52.8mm and that for left female clavicle is 10.79mm to 47mm. Thus the demarking point for left clavicle in male is >47mm and in females is <24.3mm. Accordingly, 0% of male and 36% of female right sided clavicles are sexed correctly as male and female respectively.

Weight

Table 6: Discriminant analysis of Weight (gm) of male & female clavicles

| Sr. No | Details of Measurement | Right | | Left | |
|--------|------------------------|--------|--------|-------|--------|
| | | Male | Female | Male | Female |
| 1. | No. of Clavicles | 25 | 25 | 25 | 25 |
| 2. | Range | 9.5-26 | 7-15 | 12-24 | 7.5-17 |
| 3. | Mean | 17.77 | 10.44 | 18 | 11.82 |

| | | | | | |
|-----|-----------------------------------|---------------|------------|---------------|------------|
| 4. | S.D. | 4.977 | 2.360 | 3.75 | 2.81 |
| 5. | p value | $P<0.001(HS)$ | | $P<0.001(HS)$ | |
| 6. | T value | 6.659 | | 6.596 | |
| 7. | Identification Point | >15 | <9.5 | >17 | <12 |
| 8. | % of identified bones | 68% | 36% | 60% | 52% |
| 9. | Calculated range (mean \pm 3SD) | 2.84-32.7 | 3.36-17.52 | 6.74-29.2 | 3.39-20.25 |
| 10. | Demarking pt (D.P) | >17.52 | <2.84 | >20.25 | <6.74 |
| 11. | % of clavicles beyond D.P | 56% | 0 | 32% | 0 |

Right clavicle

The weight of right male clavicle ranges from 9.5 to 26gm with a mean of 17.77gm and SD of +4.97. While that of female right clavicle ranges from 7 to 15gm with a mean of 10.44gm and SD of +2.36. Thus, the mean weight of right male clavicle is greater than the right female clavicle. This is statistically highly significant for sex differentiation ($p<0.001$).

The right clavicle having its weight >15gm is identified as male and that with <9.5gm is identified as female bone. Accordingly, 68% male and 36% of female right clavicles could be identified as of male and female sex respectively. By applying demarking points, which is >17.52gm for male clavicle and <2.84gm for female right clavicles, only 56% of male and 0% of female right clavicles are identified as of male and female sex respectively.

Left clavicle

The weight of male clavicles ranges from 12 to 24gm and that of female clavicles ranges from 7.5 to 17gm. The mean weight of male left clavicles is 18gm and SD of \pm 3.75 and that of female clavicles is 11.82gm and SD of \pm 2.81. Thus, mean weight of male left clavicle is more than that of female left clavicle. This is statistically highly significant ($p<0.001$).

The left clavicle having its weight >17gm is identified as male bone and that with its weight <12 gm is identified as female bone. Thus, 60% of left male and 52% of left female clavicles which do not show any overlaps could be identified as male and female clavicles respectively.

On applying demarking points, left clavicle with its weight >20.25gm is definitely of male and that with its weight <6.74gm is definitely of female sex. Thus, only 32% of male and none (0%) of female left side clavicles could definitely be sexed as of male and female respectively.

Robustness Index

The robustness index of each clavicle is calculated using values of its length and mid- shaft circumference with the help of following formula.

$$RI = \frac{\text{Mid shaft circumference}}{\text{Length of clavicle}} \times 100$$

The values of RI thus generated are tabulated and analyzed in the following manner.

Table 7: Discriminated analyses of Robustness Indices of clavicles male & female clavicles

| Sl. No | Details of Measurement | Right | | Left | |
|--------|-----------------------------------|---------------|-------------|-------------|-----------|
| | | Male | Female | Male | Female |
| 1. | No. of Clavicles | 25 | 25 | 25 | 25 |
| 2. | Range | 22.6-33.3 | 15.4-33.3 | 22.5-36.6 | 15-33 |
| 3. | Mean | 27.95 | 24.1 | 27.0 | 23.28 |
| 4. | S.D. | 3.22 | 4.385 | 3.39 | 4.89 |
| 5. | p value | $P<0.001(HS)$ | | $P<0.05(S)$ | |
| 6. | T value | 3.532 | | 3.197 | |
| 7. | Identification Point | >33.3 | <22.6 | >33 | <22.5 |
| 8. | % of identified bones | 0 | 44% | 4% | 52% |
| 9. | Calculated range (mean \pm 3SD) | 18.28-37.6 | 10.95-37.26 | 16.9-37.28 | 8.61-37.9 |
| 10. | Demarking pt (D.P) | >37.26 | <18.28 | >37.9 | <16.9 |
| 11. | % of clavicles beyond D.P | 0 | 8% | 0 | 12% |

Right clavicle

The robustness index of male right clavicles ranges from 22.6 to 33.3mm with a mean of 27.95mm and SD of \pm 3.22 and that of female right clavicle ranges from 15.4 to 33.3mm with a mean of 24.1mm and SD of \pm 4.38. Thus, mean RI of male clavicles greater than that of female. The sex determination of right clavicle by comparing RI is statistically highly significant ($p<0.001$).

In the present study, right clavicle with its RI >33.3 is identified as male bone and that with RI <22.6 is

identified as female bone. Accordingly, none of the male (0%) and only 44% of female right clavicles could be identified as of male and female bones respectively.

Left clavicle

The RI of male left clavicles ranges from 22.5 to 36.6mm with mean of 27.0mm and SD of +3.39, while that of left female clavicles ranges from 15 to 33mm with a mean of 23.28mm and SD of +4.89. Thus the mean RI is greater for male clavicles. This is statistically significant for sex differentiation ($p < 0.05$). The left clavicle having its RI > 33 mm is identified as of male and that with its RI < 22.5 mm is identified as of female. Accordingly, only 4% male and 52% female left clavicles could be identified as male and female bones respectively. On application of demarking point, 8% of right and 12% of left female clavicles could be sexed correctly but not even single male clavicle identified as such.

Rhomboid Fossa of Clavicle

On inferior surface of medial two third of the clavicle near its sternal end, at the attachment site of costoclavicular ligament produces a skeletal trait that may be a tubercle, roughened impression, shallow groove like fosse, deep fosse, or leave no trace. A pit or depression at this site is often called as a “rhomboid fossa”.

Incidence of Rhomboid Fossa

In the present study, all the clavicles show the presence of rhomboid fossa.

Nature of rhomboid fossa

Table 8: Incidence & Nature of Rhomboid fossa of male and female clavicles

| Sex | Side | No. of Bones | Incidence | Flat | | Depressed | | Elevated | |
|--------|-------|--------------|-----------|------|-----|-----------|-----|----------|-----|
| | | | | No | % | No | % | No | % |
| Male | Right | 25 | Present | 9 | 36% | 10 | 40% | 6 | 24% |
| | Left | 25 | | 9 | 36% | 7 | 28% | 9 | 36% |
| | Total | 50 | | 18 | 72% | 17 | 68% | 15 | 60% |
| Female | Right | 25 | Present | 9 | 36% | 9 | 36% | 7 | 28% |
| | Left | 25 | | 7 | 28% | 8 | 32% | 10 | 40% |
| | Total | 50 | | 16 | 64% | 17 | 68% | 17 | 68% |

In the present study, the nature of rhomboid fossa is classified in to three type based on its appearance, viz., flat, depressed and elevated. Out of 50 male clavicles showing presence of rhomboid fossa, it is flat in 18(72%) of clavicles, depressed in 17(68%) of clavicles and elevated in 15(60%) of clavicles. Whereas in females, out of 50 clavicles showing presence of rhomboid fossa, it is flat in 16(64%) of clavicles, depressed in 17(68%) of clavicles and elevated in 17(68%) of clavicles. Thus, elevated rhomboid fossa is more frequent in both sexes, followed by depressed nature and then flat nature. Sex differentiation of clavicle by the expression of different nature of rhomboid fossa is statistically not significant ($p > 0.05$).

Length of rhomboid fossa

Table 9: Discriminant analysis of length (mm) of Rhomboid fossa of male & female clavicles

| Sl. No | Details of Measurement | Right | | Left | |
|--------|-----------------------------------|------------------|-----------|----------------|----------|
| | | Male | Female | Male | Female |
| 1. | No. of Clavicles | 25 | 25 | 25 | 25 |
| 2. | Range | 14-26 | 10-20 | 15-33 | 10-28 |
| 3. | Mean | 18.8 | 15.18 | 21.64 | 18.24 |
| 4. | S.D. | 3.24 | 2.81 | 4.98 | 5.39 |
| 5. | P Value | $P < 0.001$ (HS) | | $P < 0.05$ (S) | |
| 6. | T value | 4.216 | | 2.315 | |
| 7. | Identification point | > 20 | < 14 | > 28 | < 15 |
| 8. | % of identified bones | 24% | 28% | 12% | 32% |
| 9. | Calculated range (mean \pm 3SD) | 9.0-28.5 | 6.72-23.6 | 6.69-36.58 | 2.0-34.4 |

Right side

The length of the rhomboid fossa of male right clavicles ranges from 14 to 26mm with the mean of 18.8mm and SD of ± 3.24 and that in female ranges from 10 to 20mm with a mean length of 15.18mm and SD of ± 2.81 . Thus, mean length of rhomboid fossa of right male clavicle is more that of female right clavicle. This statistically highly significant in sex differentiation ($p < 0.001$).The right clavicles with length of rhomboid fossa > 20 mm (24% of the sample) are identified as of males and that with < 14 mm

(28% of female right clavicles) are identified as of females.

Left side

The length of the rhomboid fossa of male left clavicles ranges from 15 to 33mm with a mean of 21.64mm and SD of ±4.98 and that of female left clavicles ranges 10 to 28mm with mean of 18.24mm and SD of ±5.39. Thus, length of RF of left male clavicle is more than that of left female clavicle. This is statistically significant in sex determination (*p*<0.05). A left clavicle with the length of rhomboid fossa >28mm is identified as male and that with <15mm is identified as female bone. Accordingly, only 12% male left and 32% of female left clavicles could be sexed correctly, as their values do not overlap with opposite sex.

Breadth of Rhomboid Fossa

Table 10: Discriminant analysis of Breadth (mm) of Rhomboid fossa of male & female clavicles

| Sl. No | Details of Measurement | Right | | Left | |
|--------|------------------------------|-------------------|-----------|-------------------|------------|
| | | Male | Female | Male | Female |
| 1. | No. of Clavicles | 25 | 25 | 25 | 25 |
| 2. | Range | 6-20 | 6-15 | 7-13 | 5-11 |
| 3. | Mean | 12.08 | 9.42 | 9.64 | 8.4 |
| 4. | S.D. | 3.76 | 2.27 | 1.7 | 1.6 |
| 5. | p value | <i>P</i> <0.05(S) | | <i>P</i> <0.05(S) | |
| 6. | T value | 3.026 | | 2.646 | |
| 7. | Identification point | >15 | <6 | >11 | <7 |
| 8. | % of identified bones | 20% | 0 | 20% | 16% |
| 9. | Calculated range (mean ±3SD) | 0.79-23.36 | 2.6-16.23 | 4.52-14.75 | 3.57-13.22 |

Right clavicle

The breadth of rhomboid fossa of male right clavicles ranges from 6 to 20 mm with the mean of 12.08mm (SD of ±3.76), whereas that in female right clavicles ranges from 6 to 15mm with mean of 9.42mm (SD of ±2.27). Thus, mean breadth of rhomboid fossa of male right clavicles is more than that of in female right clavicles. This is statistically significant in sex differentiation of right of clavicle(*p*<0.05). The right clavicle having breadth of rhomboid fossa >15mm is identified as male bone and that with <6mm is identified as female bone. Thus, 20% male but no (0%) female right clavicles are identified as male and female bones respectively.

Left clavicle

The breadth of Rhomboid fossa of left clavicles in male ranges from 7 to 13mm with mean breadth of 9.64mm (SD of ±1.7). Whereas that of female left clavicle ranges from 5 to 11mm with mean breadth of 8.4mm (SD of ±1.6). Thus, male left clavicle has mean breadth of RF more than that of female left clavicle. This is statistically significant for sex differentiation of clavicle (*p*<0.05). A left clavicle having the breadth of its rhomboid fossa more than 11mm is identified as male and that with <7mm as female bone. Thus, 20% male and 16% female left clavicles which do not show any overlapping can be identified as male and female bones respectively.

Index of Rhomboid Fossa (IRF)

This metrical parameter of the clavicle (IRF) is calculated by using the measurements of length and breadth of rhomboid fossa by following equation.

$$IRF = \frac{\text{Breadth of rhomboid fossa}}{\text{Length of rhomboid fossa}} \times 100$$

The resulting values are tabulated in master chart and analyzed for sex differentiation as follows.

Table 11: Discriminate analysis of Index of Rhomboid fossa of male & female clavicles

| Sl. No | Details of Measurement | Right | | Left | |
|--------|------------------------|--------------------|---------|--------------------|--------|
| | | Male | Female | Male | Female |
| 1. | No. of Clavicles | 25 | 25 | 25 | 25 |
| 2. | Range | 31.5-86.9 | 41.1-90 | 30.4-70.5 | 30-90 |
| 3. | Mean | 64.2 | 63 | 45.73 | 49.97 |
| 4. | S.D. | 15.56 | 14.14 | 9.24 | 18.0 |
| 5. | p value | <i>P</i> >0.05(NS) | | <i>P</i> >0.05(NS) | |
| 6. | T value | 0.30 | | 1.047 | |

| | | | | | |
|----|------------------------------|------------|------------|-------------|----------|
| 7 | Identification point | >90 | < 31.5 | >90 | <30.4 |
| 8. | % of identified bones | 0 | 0 | 0 | 4% |
| 9. | Calculated range (mean ±3SD) | 17.6-110.9 | 20.5-105.4 | 17.99-73.47 | 4.11-104 |

Right clavicle

In the present study, IRF of male right clavicle ranges from 31.5 to 86.9mm with mean of 64.2mm(SD ±15.56), whereas that of female right clavicle ranges from 41.1 to 90mm with a mean of 63mm(SD±14.14). Thus, mean IRF of right male clavicle is bit more than that of right female clavicle. This is statistically not significant for sex differentiation ($p>0.05$). The right clavicle with its IRF >90% is identified correctly as of male and that having <31.5 is identified as female bones. Thus, percentage of right clavicles that are accurately sexed is 0% in both males and females, as no male right clavicle has IRF>90 and no female right clavicle has IRF less than31.5mm.

Left clavicle

The index of rhomboid fossa of left male clavicle ranges from 30.4 to 70.5mm with mean of 45.73mm (SD ±9.24) and that of left female clavicle ranges from 30.0 to 90.0mm with mean of 49.97mm (SD ±18.0).Thus, mean IRF of left male clavicle is less than that of left female clavicle. This is statistically not significant ($P>0.05$). The left clavicle with its IRF measuring >90mm is identified as male and that with IRF<30.4mm is identified as female. Thus 0% of male and 4% of female left clavicles which do not show overlapping are identified correctly as male and female clavicles.

Angles of clavicles

Medial angle

Table 12: Discriminate analysis of Medial Angle of male & female Clavicles

| Sl. No | Details of Measurement | Right | | Left | |
|--------|------------------------------|------------|-------------|-------------|-------------|
| | | Male | Female | Male | Female |
| 1. | No. of Clavicles | 25 | 25 | 25 | 25 |
| 2. | Range | 140-159 | 133-168 | 140-161 | 132-165 |
| 3. | Mean | 153.28 | 152.72 | 153.12 | 150.3 |
| 4. | S.D. | 4.24 | 8.80 | 6.13 | 7.59 |
| 5. | p value | p>0.05(NS) | | P>0.05(NS) | |
| 6. | T value | 0.286 | | 1.433 | |
| 7. | Identification point | >168 | <140 | >165 | <140 |
| 8. | % of identified bones | 0 | 8% | 0 | 4% |
| 9. | Calculated range (mean ±3SD) | 140.5-160 | 126.3-179.1 | 134.7-171.5 | 127.5-173.0 |

Right clavicle

The medial angle of right side male clavicles ranges from 140° to 159° with the mean of 153.28°(SD of ±4.24) and that of female clavicles ranges from 133° to 168° with mean of 152.72°(SD of ±8.80). Thus, mean medial angle of right male clavicle is more than that of female clavicle i.e. right male clavicle is less angulated at its middle third than that of right female clavicle. These differences in medial angle between male and female clavicles are statistically not significant in sex determination ($p>0.05$). As mean of medial angle of right clavicle is more for male clavicles, the right clavicle having its medial angle >168° is identified as male bone and that <140° as female bone. Thus no (0%) male right clavicles and only 8% of female right clavicles which do not show overlapping are identified as male and female bones respectively.

Left clavicle

The medial angle of left male clavicle ranges from 140° to 161° with a mean of 153.12° (SD of ±6.13) and that for female left clavicle ranges from 132° to 165° with a mean of 150.3° (SD of ±7.59). Thus, mean medial angle of left male clavicle is slightly more than that of female clavicle. These differences are statistically insignificant for sex differentiation ($p>0.05$). The left clavicle having its medial angle >165° is identified as male and that with <140° is identified as female. 0% of the male left clavicles and 4% of female left clavicles could be correctly sexed by medial angle measurements alone.

Lateral Angle

Table 13: Discriminant analysis of Lateral Angle of male & female clavicles

| Sl. No | Details of Measurement | Right | | Left | |
|--------|------------------------|---------|---------|---------|---------|
| | | Male | Female | Male | Female |
| 1. | No. of Clavicles | 25 | 25 | 25 | 25 |
| 2. | Range | 120-168 | 125-169 | 125-170 | 130-171 |

| | | | | | |
|----|-----------------------------------|-------------|-------------|--------------|-------------|
| 3. | Mean | 156.08 | 148.76 | 156.64 | 150.28 |
| 4. | S.D. | 9.66 | 10.33 | 11.72 | 9.32 |
| 5. | p value | $p<0.05(S)$ | | $P<0.05(S)$ | |
| 6. | T value | 2.587 | | 2.123 | |
| 7. | Identification point | >169 | <120 | >171 | <125 |
| 8. | % of identified bones | 0 | 0 | 0 | 0 |
| 9. | Calculated range (mean \pm 3SD) | 127.0-184.9 | 117.7-179.7 | 121.48-191.8 | 122.3-178.2 |

Right clavicle

The lateral angle of right male clavicle ranges from 120° to 168° with mean of 156.08° and SD of \pm 9.66. Whereas, lateral angle for female right clavicle ranges from 125° to 169° with mean of 148.76 and SD of \pm 10.33. Thus, mean lateral angle of male right clavicle is greater than that of female right clavicle. These differences are statistically significant for sex determination ($p<0.05$). The right clavicles measuring their lateral angle >169° (0% of samples) are identified as male bones and that measuring <120° (0% samples) are identified as female bones.

Left clavicle

The lateral angle of male left clavicle ranges from 125° to 170° a mean of 156.64° and SD of \pm 11.72 and that of female left clavicle ranges from 130° to 171° with a mean of 150.28° and SD of \pm 9.32. Thus, lateral angle of male left clavicle is greater (less curved) than that of female left clavicle. This is statistically significant for sex differentiation of left clavicle ($p<0.05$). The left clavicles measuring their lateral angle >171° (0% of samples) are identified as male bones and that measuring <125° (0% samples) are identified as female bones.

Total Angle

The total angle of the clavicle (angle of curvature) is calculated as the sum of medial and lateral angle of the clavicle (i.e. angle of curvature = medial angle + lateral angle). The resulting values are tabulated in master chart and analysed for sex determination as follows.

Table 14: Discriminant analysis of Total Angle of male & female clavicles

| Sl. No | Details of Measurement | Right | | Left | |
|--------|-----------------------------------|-------------|-------------|-------------|-------------|
| | | Male | Female | Male | Female |
| 1. | No. of Clavicles | 25 | 25 | 25 | 25 |
| 2. | Range | 277-326 | 263-337 | 270-330 | 272-327 |
| 3. | Mean | 309.36 | 301.48 | 309.76 | 300.6 |
| 4. | S.D. | 10.5 | 18.84 | 14.3 | 15.47 |
| 5. | p value | $p<0.05(S)$ | | $P<0.05(S)$ | |
| 6. | T value | 1.825 | | 2.166 | |
| 7. | Identification point | >337 | <277 | >327 | <270 |
| 8. | % of identified bones | 0 | 8% | 4% | 0 |
| 9. | Calculated range (mean \pm 3SD) | 277.8-340.8 | 246.2-356.6 | 266.8-352.6 | 254.4-346.8 |

Right clavicle

The total angle (angle of curvature) of male right clavicle ranges from 277° to 326° with a mean curvature of 309.36° and SD of \pm 10.5 whereas that of female right clavicle ranges from 263° to 337°, with a mean of 301.48° and SD of \pm 18.84. Thus, total angle of male right clavicle is greater (less curved) than that of female right clavicle. i.e, male right clavicle is straighter than female right clavicle. These differences are statistically significant for sex determination of right side clavicle ($p<0.05$).The right clavicle with total angle more than 337° is identified as male bone and that with <277° is identified as female bone. Thus, no (0%) male and only 8% of female right clavicles are identified as of male and female bones respectively.

Left clavicle

The total angle of male left clavicle ranges from 270° to 330° with a mean of 309.76° and SD of \pm 14.3 and that of female left clavicle ranges from 272° to 327° with mean of 300.6° and SD of \pm 15.47. Thus, total curvature of male left clavicle is greater than that of female left clavicle i.e. male left clavicle is less angulated than that of female left clavicle. These differences between male and female left clavicle are statistically significant for sex determination ($p<0.05$).The left clavicle with total angle >327° is identified as male bone and that with <270° is identified as female bone. Thus, 4% of male left and 0% of female left clavicles are correctly sexed as male and female bones respectively.

Discussion

The morphometric data of the clavicle of present study is compared with the similar studies in the past. However, all parameters used in this study were not studied by all the workers, eg: metrical study of rhomboid fossa, angle of clavicle etc. which have been studied by only few workers. When many studies are available on same data, comparison is done by representing the findings in tabular format.

Length of Clavicle

Table No: 15 shows comparison of length of clavicles by different authors. In the present study, mean length of male clavicle is significantly higher than that of female clavicle. Thus, it is clear from table that, similar to studies of Jit I and Singh S,^[12] Jit I and Sahni D,^[9] and J.P. Patel *et al*,^[24] the present study observed statistically significant difference between length of male and female clavicles ($p < 0.001$).

Right clavicle

In the present study, in case of male, the mean length of clavicle (143.8mm) is comparable with the study of Singh S and Gangrade KC^[17] (141.19mm), J.P Patel *et al*,^[24] (141.8mm) and Shobha *et al*,^[30] (141.1mm). These values are higher in the studies of Parsons F.G^[15] (151mm), Terry R.J^[10] (153.3mm), Oliver G^[11] (154.2mm) Jit I and Singh S^[12] (145.58mm), Jit I and Sahni D^[9] (148.0mm), Yashoda Rani *et al*,^[27] (146.18mm), Kaur K *et al*,^[19] (146.89mm). In case of females, mean length of clavicle (124.0mm) is comparable with results of Singh S and Gangrade KC^[17] (125.78), J.P Patel *et al*^[24] (125.9mm) but much higher compared to Yashoda Rani *et al*,^[27] (115.6mm) and less compared to Parsons F.G^[15] (138mm), Terry R.J^[10] (140.98mm), Oliver G^[11] (137.9mm), Jit I and Singh S^[12] (130.36mm), Jit I and Sahni D^[9] (132.4mm), Kaur K *et al*^[19] (132.62mm) and Shobha *et al*,^[30] (131.7mm).

Left clavicle

In the present study, mean length of male clavicle (142.5mm) is comparable with the studies of Singh and Gangrade KC^[17] (144.18mm), J.P Patel *et al*,^[24] (142.3mm) and Shobha *et al*,^[30] (143.8mm). but it is lower than the studies of Jit and Singh^[12] (147.59mm), Jit I and Sahni D^[9] (149.8mm), Terry RJ^[10] for USA Negroes (155.86mm), Parsons F.G^[15] (153mm), Oliver G^[11] (155mm), Yashoda Rani *et al*,^[27] (149.74mm), Kaur K *et al*^[19] (148.27mm). The mean length of left female clavicle in present study (124.36mm) is comparable with J.P Patel *et al*,^[24] (126.8mm) but it is much higher compared to Yashoda Rani *et al*,^[27] (118.4mm) and less compared to Parsons F.G^[15] (138mm), TerryR.J^[10] (141.78mm), Oliver G^[11] (138.7mm), Jit I and Singh S^[12] (129.8mm), Singh and Gangrade KC^[17] (127.77mm), Jit I and Sahni D^[9] (134mm), Kaur K *et al*,^[19] (133.98mm) and Shobha *et al*,^[30] (132.7mm).

Table 15: Comparison of length of male and female clavicles by different authors

| Sr. No | Year | Author | Region | Side | Male | | Female | | P Value |
|--------|------|---------------------------|----------------------|------|--------|--------------|--------|-------------|---------|
| | | | | | Mean | Range | Mean | Range | |
| 1 | 1916 | Parsons F.G | English | Rt | 151.00 | - | 138 | - | - |
| | | | | Lt | 153.00 | - | 138 | - | |
| 2 | 1932 | Terry RJ | USA Negroes | Rt | 153.30 | - | 140.98 | - | - |
| | | | | Lt | 155.86 | - | 141.78 | - | |
| 3 | 1951 | Oliver G | France | Rt | 154.20 | - | 137.9 | - | - |
| | | | | Lt | 155.00 | - | 138.7 | - | |
| 4 | 1966 | Jit I & Singh S | Amritsar Zone | Rt | 145.58 | 119.8-171.4 | 130.36 | 103.0-157.7 | <0.001 |
| | | | | Lt | 147.59 | 119.84-175.3 | 129.8 | 103.5-151.1 | |
| 5 | 1968 | Singh S & Gangrade KC | Varanasi Zone | Rt | 141.19 | 116.8-166.2 | 125.78 | 103.3-148.3 | - |
| | | | | Lt | 144.18 | 120.2-168.2 | 127.77 | 103.5-146.4 | |
| 6 | 1983 | Jit I & Sahni D | Chandigarh Zone | Rt | 148.00 | 127-175 | 132.4 | 16-160 | <0.001 |
| | | | | Lt | 149.80 | 127-176 | 134 | 117-149 | |
| 7 | 1997 | Kaur k <i>et al</i> | Patiala Zone | Rt | 146.89 | - | 132.62 | - | <0.001 |
| | | | | Lt | 148.27 | - | 133.98 | - | |
| 8 | 2009 | J.P Patel <i>et al</i> | Gujarat Zone | Rt | 141.8 | 118-160 | 125.9 | 112.5-142 | <0.001 |
| | | | | Lt | 142.3 | 125.5-160.5 | 126.8 | 108-142 | |
| 9 | 2011 | Yashoda Rani <i>et al</i> | - | Rt | 146.18 | 137.98-165.7 | 115.6 | 138.7-161.2 | - |
| | | | | Lt | 149.74 | 104.2-135.2 | 118.4 | 106-137.6 | |
| 10 | 2014 | Shobha | North Karnataka Zone | Rt | 141.1 | 123-167 | 131.7 | 115-150 | <0.001 |
| | | | | Lt | 143.8 | 120-162 | 132.7 | 114.5-151 | |

| | | | | | | | | | |
|----|------|---------------|------------------|----|-------|---------|--------|---------|--------|
| 11 | 2014 | Present study | Telangana region | Rt | 143.8 | 126-163 | 124 | 107-147 | <0.001 |
| | | | | Lt | 142.5 | 120-164 | 124.36 | 105-147 | |

Mid Shaft Circumference

The mid-shaft circumference of the clavicle had been calculated in several races by different workers and this is the most popular clavicular parameter used for sex identification. Table No. 16 shows the comparison of mid-shaft circumference of clavicles as estimated by different authors. It is clear from the table that, mid-shaft circumference in the present study is statistically highly significant ($p < 0.001$) in differentiating the sex of male and female clavicles, which is similar to the studies of Terry R.J^[10], Jit I and Singh S^[12], Jit I and Sahni D^[9], J.P Patel *et al*^[24]. However, most other studies have not quoted statistical significance.

Right clavicle

In the present study, mean mid shaft circumference of male (40mm) is comparable with Terry RJ^[10] (40.02mm) and Oliver G^[11] (38.4mm) but is not comparable with other studies. The mean mid-shaft circumference of females in the present study (29.24mm) is comparable with Jit I and Singh S^[12] (29.69mm), Singh and Gangrade KC^[17] (28.52mm) but is not comparable with other studies.

Left clavicle: The mean mid shaft circumference of male (38.6mm) is comparable with Terry RJ^[10] (38.58mm), Oliver G^[11] (38.4mm) but is not comparable with other studies. The mean mid shaft circumference of female (28.92mm) in present study is comparable with Jit and Singh S^[12] (29.51mm) and Singh and Gangrade KC^[17] (28.0mm) but is not comparable with other studies.

Table 16: Comparison of mid-shaft circumference of male and female clavicles by different authors

| Sl. No | Year | Author | Region | Side | Male | | Female | | P Value |
|--------|------|-------------------------|------------------|------|-------|-------------|--------|-------------|---------|
| | | | | | Mean | Range | Mean | Range | |
| 1 | 1932 | Terry RJ | USA Negros | Rt | 40.02 | | 35.26 | - | <0.001 |
| | | | | Lt | 38.58 | | 32.42 | - | |
| 2 | 1951 | Oliver J | French(France) | Rt | 38.4 | | 31.06 | - | - |
| | | | | Lt | 38.4 | | 31.6 | - | |
| 3 | 1966 | Jit I & Singh S | Amritsar Zone | Rt | 36.17 | 27.11-45.23 | 29.69 | 24.47-34.91 | <0.001 |
| | | | | Lt | 35.7 | 26.22-45.18 | 29.51 | 23.60-35.42 | |
| 4 | 1968 | Singh S and Gangrade KC | Varanasi Zone | Rt | 35.09 | 25-28 | 28.52 | 21-41 | |
| | | | | Lt | 34.64 | 25.12-44.16 | 28 | 21.32-34.68 | |
| 5 | 1983 | Jit I and Sahni D | Chandigarh Zone | Rt | 36.2 | 31-45 | 30.4 | 24-35 | <0.001 |
| | | | | Lt | 35.9 | 27.8-45 | 30 | 21.6-38 | |
| 6 | 1997 | Kaur K. <i>et al</i> | Patiala Zone | Rt | 36.97 | - | 30.8 | - | <0.001 |
| | | | | Lt | 36.91 | - | 30.6 | - | |
| 7 | 2009 | J.P. Patel <i>et al</i> | Gujarat Zone | Rt | 37.1 | 30-46 | 30.15 | 24-35 | <0.001 |
| | | | | Lt | 36.44 | 30-49 | 30.16 | 20.5-35 | |
| 8 | 2014 | Present Study | Telangana region | Rt | 40 | 34-46 | 29.24 | 20-38 | <0.001 |
| | | | | Lt | 38.6 | 30-46 | 28.92 | 20-38 | |

Weight

Table No: 17 shows the comparison of weight of clavicles as estimated by different authors. From the table it is clear that, studies including the present one, Jit I & Sahni D⁹ and others show that there is a statistical significance in differentiating sex of clavicle by its weight ($p < 0.001$).

Right clavicle

In the present study, mean weight of male clavicle (17.77gm) is comparable with the studies of Jit I and Singh S^[12] (18.89gm), J.P Patel *et al*^[24] (19.5gm) but less than the study results of Singh S and Gangrade KC^[17] (21.46gm) and Jit I and Sahni D^[9] (25.78gm), Kaur k *et al*(25.33gm). The mean mid shaft circumference of female clavicle (10.44gm) is comparable with the studies of Jit I and Singh S^[12] (12.47gm), J.P Patel *et al*^[24] (12.26gm) but less than the study results of Singh S and Gangrade KC^[17] (12.83gm) and Jit I and Sahni D^[9] (17.55gm), Kaur k *et al*,^[19] (16.56gm).

Left clavicle

The mean weight of male clavicle (18gm) is comparable with Jit I and Singh S^[12] (18.68gm) and J.P Patel *et al*^[24] (18.70gm) and not comparable with other studies. The mean weight of female clavicle(11.82gm) of present study is comparable Jit I and Singh S^[12] (12.03gm), J.P Patel *et al*,^[24] (11.73gm) and not comparable with other studies.

Table 17: Comparison of weight (gm) of male and female clavicles by different authors.

| Si. No | Year | Author | Region | Side | Male | | Female | | P Value |
|--------|------|-------------------------|------------------|------|-------|------------|--------|-------------|---------|
| | | | | | Mean | Range | Mean | Range | |
| 1 | 1966 | Jit I & Singh S | Amritsar Zone | Rt | 18.89 | 7.82-29.96 | 12.47 | 4.07-20.87 | <0.001 |
| | | | | Lt | 18.68 | 6.05-31.31 | 12.03 | 3.96-20.10 | |
| 2 | 1968 | Singh S and Gangrade KC | Varanasi Zone | Rt | 21.46 | 8.85-34.08 | 12.83 | 4.60-21.07 | <0.001 |
| | | | | Lt | 21.32 | 8.92-33.73 | 12.84 | 4.94-20.75 | |
| 3 | 1983 | Jit I & Singh D | Chandigarh Zone | Rt | 25.78 | 19-42 | 17.55 | 11.10-23.00 | <0.001 |
| | | | | Lt | 25.34 | 19-45.9 | 17.21 | 11.00-24.0 | |
| 4 | 1997 | Kaur K. <i>et al</i> | Amritsar Zone | Rt | 25.33 | 15-38 | 16.56 | 8.30-23.80 | <0.001 |
| | | | | Lt | 24.92 | 14.9-36.8 | 16.39 | 8.60-24 | |
| 5 | 2009 | J.P. Patel <i>et al</i> | Gujarat Zone | Rt | 19.5 | 12-31.9 | 12.26 | 8.0-18.0 | <0.001 |
| | | | | Lt | 18.7 | 12.0-29.0 | 11.73 | 6.0-18.0 | |
| 6 | 2014 | Present Study | Telangana region | Rt | 17.77 | 9.5-26 | 10.44 | 7.0-15.0 | <0.001 |
| | | | | Lt | 18 | 12.0-24.0 | 11.82 | 7.5-17 | |

Robustness Index

Table No: 18 shows comparison of robustness index (RI) of clavicles by different authors. In the present study, mean RI of male clavicle is more than that of female clavicle. This is in accordance with all other workers who agree that the RI is greater in males than in females. But their reliance to be put on this index as a parameter useful to identify the sex of clavicle has not been worked out. The figures in this study prove that this index is significantly greater in male compared to female and this difference is statistically significant ($p < 0.001$). This is similar to the studies of Jit I and Singh S^[12] (1966) and Kaur K. *et al*^[19] (1992) who also found that RI values are statistically significant for sex differentiation. In the present study, mean RI of male clavicle on the right (27.95) and on left (27) is not comparable with the studies where as mean RI of female clavicle on right (24.1) and on left (23.28) is comparable with Terry RJ,^[10] Oliver G,^[11] Jit I and Singh S,^[12] Kaur K *et al*.^[19]

Rhomboid Fossa

The attachment site of costoclavicular ligament at the inferior surface of clavicle near sternal end is called as rhomboid fossa. In the present study, role of rhomboid fossa in sex differentiation is studied by its incidence / occurrence, nature of its expression and if present, its length, breadth and IRF (breadth: length ratio).

Incidence of Rhomboid fossa

Rogers *et al*,^[20] found significant relationship between the presence of a rhomboid fossa and sex and concluded that the fossa expression is more common in males (36% left, 31% right) than in females (3% left, 8% right). According to their study, if fossa is found on right clavicle, indicates that the clavicle is of male with 81.7% probability and on the left clavicle, indicates that the clavicle is of a male with 92.2% probability.

In the present study, all the clavicles showed Rhomboid fossa and therefore the role of Rhomboid fossa in sex determination is studied by its nature of its expression and its length, breadth and index of Rhomboid fossa.

Nature of Rhomboid fossa

In the present study, the nature of rhomboid fossa is classified in to three type based on its appearance, viz., flat, depressed and elevated. Out of 50 male clavicles showing presence of rhomboid fossa, it is flat in 18(72%) of clavicles, depressed in 17(68%) of clavicles and elevated in 15(60%) of clavicles. Whereas in females, out of 50 clavicles showing presence of rhomboid fossa, it is flat in 16(64%) of clavicles, depressed in 17(68%) of clavicles and elevated in 17(68%) of clavicles. Thus, elevated rhomboid fossa is more frequent in both sexes, followed by depressed nature and then flat nature. Sex differentiation of clavicle by the expression of different nature of rhomboid fossa is statistically not significant ($p > 0.05$). According to Cave AJE¹⁶ findings, 60% of clavicles manifest a flat rhomboid area, 30% a depression and 10% an elevation of the bone site. The exact cause for different nature of

Rhomboid fossa expression is not clearly understood. However, many factors associated with sex like hormone levels, activity patterns, occupational stress, muscle build up, age and side related asymmetry are likely cause different morphological changes at Rhomboid area.

Length of the Rhomboid fossa

The results of present study on length and breadth of Rhomboid Fossa of clavicle are compared with findings of Jit I and Kaur H¹⁸ in Table No: 19 In present study, sex differentiation of clavicles by length of Rhomboid fossa has high statistical significance ($p<0.001$), but is statistically significant in Jit I and Kaur H study ($p<0.05$).

Right clavicle

In the present study, the mean length of rhomboid fossa of males(18.8mm) and that of females(15.1mm) are comparatively less than Jit and Kaur H^[18] study results.

Left clavicle

The mean length of Rhomboid fossa of males (21.64mm) and that of females (18.24mm) are comparatively less than Jit and Kaur H^[18] study results. As length of rhomboid fossa of clavicles show considerable overlapping between the both sexes, only 24% of right and 12% left male clavicles and 28% left female and 32% right female clavicles could be sexed correctly. Thus length of Rhomboid fossa of a clavicle alone as a single parameter can't establish the sex of each clavicle.

Breadth of the Rhomboid fossa

In present study, sex differentiation of clavicles by breadth of Rhomboid fossa has statistical significance ($p<0.05$) and this similar to Jit I and Kaur H¹⁸ study ($p<0.05$) as shown in Table No. 20

Right clavicle

In the present study, the mean breadth of Rhomboid fossa of males(12mm) was little more than that in Jit I & Kaur H¹⁸ study (9.77mm), but that of female (9.4mm)is comparable with Jit I and Kaur H¹⁸ study(8.69mm).

Left clavicle

The mean breadth of Rhomboid fossa of male (9.64mm) was comparable to that in Jit I and Kaur H¹⁸ study (9.42mm) while that of females (8.4mm) was also comparable with Jit I and Kaur H¹⁸ study (8.38 mm). Similar to the length of Rhomboid fossa, the breadth of Rhomboid fossa is not a single parameter which can help in identification of sex of each clavicle.

Index of Rhomboid fossa

This parameter (IRF / Breadth: length ratio of rhomboid fossa) has not been studied by any of previous workers who have worked extensively on sexing of clavicle. Hence no previous studies to compare this parameter with present study results. In the present study, the difference in the mean IRF is not statistically significant for sex differentiation ($p>0.05$).

As IRF is ratio of breadth and length of Rhomboid fossa, these two parameters are equally more in males and less in females. Hence the resulting ratio is frequently similar in male and female. Thus most of the clavicles show overlapping in values of IRF between both the sexes. The less number of clavicle that are not having overlapping in values of IRF could be sexed correctly i.e., 0% of left and right male clavicles, 0% of right female and only 4% left female clavicle could be identified as male and female respectively. Thus this parameter does not help in sex differentiation of the clavicles.

Angles of the clavicles

The different angles of clavicle viz., medial angle, lateral angle and total angle of clavicles in the present study are compared with other previous studies in Table no: 21

Medial angle

The observations made by Parsons FG¹⁵ on the English clavicle revealed that medial angle on both side was 153° in males and 155° in females. However, he did not subject his observations to a statistical analysis. He noted that the medial angle on both sides were greater in female clavicles than in males by 2°. Terry RJ¹⁰ found this difference to be 2.4° on the right side and 2° on the left side. This difference was statistically significant for gender differentiation. He noted that the medial angle was greater on right side in males, while it was greater on left side in females. Kaur H *et al*²¹ study shows that sexual difference in the mean medial angle was 1.85° on the right and 1.91° on the left where medial angle was greater in females than in males. This difference was statistically significant ($p<0.05$) for sex differentiation. The medial two-third of the male clavicle was more curved than the female clavicle. In

present study, side related differences are very less and sexual difference in mean medial angle of male is greater than female by 0.58° on right side and 2.82° on left side. This difference was found to be statistically insignificant for sex differentiation. As medial angle is greater in males than females, medial two-thirds of female clavicles is more curved than male clavicles. This observation is opposite to observations made by Parsons F.G¹⁵ and Kaur H *et al.*²¹

Lateral angle

In English clavicles, Parsons F.G¹⁵ recorded the difference between the mean lateral angle of the males and females about 2° - 3° , where the lateral angle was greater in the females than in the males⁴⁵. Terry RJ¹⁰ recorded this difference in the American Negroes as 5.64° on the right and 2.28° on the left side and found this to be statistically significant ($p < 0.05$) for sex differentiation. In French clavicles, Oliver G¹¹ also noted that sexual differences in the lateral angle between male and female clavicle to be 2.5° , where angle was greater in females as compared to males. Kaur H *et al.*²¹ study shows that the difference in mean lateral angle in two sexes was 1.38° on right and 0.53° on left side. This difference was statistically insignificant ($p > 0.05$) for sex differentiation⁵⁰. In the present study, similar to Kaur H *et al.* study, mean lateral angle is found to be greater on left side in both sexes i.e., right bones are more curved in their lateral two- third than left bones. The present observations show that the difference in mean lateral angle in two sexes is 7.24° on right and 6.36° on left side. This difference is statistically significant for sex differentiation ($p < 0.05$). It is also observed that the lateral angle is greater in males than in females. Thus the lateral two third of the female clavicles is more curved than male clavicles. The lateral angle of clavicles of both sides in the present study was greater than that found in American Negroes, French clavicles and North Indian clavicles.

Total angle

Parsons F.G¹⁵ calculated the sum of two angles (index of curvature) of the English clavicle and found that; English clavicle was more curved on right side than the left in both sexes with the difference being 1° . The difference between mean of total angle of males and females was 5° on both sides. He found this difference in the mean sum of angles to be statistically significant. Terry RJ¹⁰ found the sum of two clavicular angles was greater on left side than that of the right. He recorded that the difference between male and female was 1.88° on the right and 2.96° on the left side, where it is greater in female clavicles than males. This sexual difference in the mean sum of the angles of clavicles found to be statistically significant ($p < 0.05$). In the study by Kaur H *et al.*²¹ (2002), sum of angles was greater on left than right. The right bone was therefore more curved than the left. The angles were greater in females than males suggesting male bones are more curved than female bones and difference between mean sums of angles of male and female was 3.98° on right and 2.67° on left side. This difference was found to be statistically significant ($p < 0.05$).

In the present study, sum of angles was greater on right side than left side, thus left clavicle is more curved than right and female bones are more curved than the male bones. These two findings in the present study are contrary to all the previous studies including study of Kaur H *et al.*²¹. In the present study, the difference between the mean sum of angles of males and females was 7.9° on right side and 9.1° on left side. This sexual difference was found to be statistically significant ($p < 0.05$) similar to the findings of all previous authors.

Conclusion

For identification of sex of clavicle, 50 male and 50 female adult, fully ossified, dried clavicles are studied from department of Anatomy of Kakatiya Medical College, Warangal, Telangana, India. Its different measurements *viz.* Length, weight, midshaft circumference, length of Rhomboid fossa, breadth of Rhomboid fossa, index of Rhomboid fossa, medial, lateral and total angle of each clavicle are taken and by using them different indices are calculated for each clavicle. Univariate statistical tests are applied to the metrical data obtained to assess whether the differences between the mean of each parameter are statistically significant or not. The demarking points for identification of sex have been worked out for this population using a formula $\text{mean} \pm 3\text{S.D.}$ This will be useful in deciding the sex of unknown sample in future, which is an often-required in medico-legal case. The Rhomboid fossa of the clavicle is studied for variation of its nature along with the length and breadth of the fossa for sex difference. The clavicular parameters like length, mid-shaft circumference, robustness index and weight have been found to be statistically highly significant ($p < 0.001$). While rhomboid fossa length and breadths, clavicular angles (medial & lateral) were less significant ($p < 0.05$). The index of rhomboid fossa on both sides were insignificant ($p > 0.05$) in sex determination of clavicles. However, the sex overlap is observed in all the parameters and indices. This may be due to genetic, nutritional and socio-economic difference in the individuals or may be due to hypo masculinity in male clavicles and hyper masculinity in female clavicles.

Conflict of Interest: None

Finding: None

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