

Determination of Sex and Age from Human Clavicles and its Radiographic Images

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Abstract

Introduction: The determination of sex and age of an individual is primary criteria of identification, but this is very difficult problem and becomes even more challenging when only a single bone like clavicle is available. The traditional methods of sexing bone are subjective and not of much help in medico legal cases where near 100% accuracy is needed. **Aims:** 1. Determination of sex and age of clavicle with the help of morphometric analysis. 2. Determination of age of clavicle with the help of digital X-rays. **Methodology:** This study was performed using 130 dry human clavicles with institutional ethical committee approval. Morphometric analysis of adult clavicles (108) was carried out using weighing machine, vernier calipers, scale, etc. Roentgenographic observations including adult (108) and young aged clavicles (22) were noted to estimate age with the help of visual seriation. **Results & Conclusion:** There was a significant difference in parameters like length, mid shaft circumference; weight and incidence of rhomboid fossa were observed between male and female clavicles. The present study emphasizes in the possibility of age estimation with the external appearance of medial end and X-ray observations of clavicle.

Keywords: Clavicle; Age Determination; Sex Determination; Medial End of Clavicle; Rhomboid Fossa; X-Rays.

Introduction

Clavicle is the only long bone which is placed horizontally and it possesses many gender and age specific metric and non-metric traits [1]. Estimation of age and sex of deceased is easy when a complete skeleton is available for examination. But, the determination of sex and age of an individual becomes challenging when a single bone like clavicle is available [2]. It presents a task of considerable importance from the view-point of the administration of justice [3].

Dimensions of clavicle like length, mid shaft circumference, weight were lesser in female than male, an amalgamation of these dimensions capitulate better results in identifying the sex of the individual [4].

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Estimation of age with the stage of ossification of the medial epiphysis among subjects below adolescent age is less complicated but the task becomes more crucial to assess age of an adult individual with a single clavicle bone. Radiography of clavicle is considered as one of the indices like teeth eruption, X-ray of left hand, orthopantomogram to estimate age of the subject [5].

The purpose of the present study is to determine the sex with morphometric analysis of dry human clavicles and to estimate the age with external appearance of medial end and visual seriation of radiographic pictures of clavicle.

Material and Methods

One hundred and thirty clavicles with predetermined sex were included in the study, all the bones were obtained from cadavers, being dissected in Department of Anatomy, Vinayaka Missions Kirupananda Variyaar Medical College, Salem. Tamil Nadu. The Institutional Ethical clearance was obtained to conduct the study. Out of which 108 adult clavicles (69 right and 61 left) and rest of them were

22 young aged clavicles (<23 years). Only adult clavicle were included in the study pertained to sex of the clavicle. Out of 108 adult clavicles 53 are male clavicles (29 right and 22 left), 55 are female clavicles (23 right and 32 left) and all 130 clavicles were included in determining age. Clavicles showing any pathology e.g. a healed fracture or mal-union, were excluded. Before analysis bones which were included in the study were boiled cleaned and dried.

Morphometric analysis of clavicle (A manual of biological anthropology) [6] – The maximum length of the clavicle (in mm) was measured with the help of digital vernier caliper was taken. Weight (in gm) was weighed with the help of digital weighing machine. Mid shaft circumference (MSC) was measured (in mm) while measuring the length of clavicle, a mark was done at the middle between two ends and circumference was measured with the help of thread and marked. The marked ends were measured with digital vernier caliper. The bones were visually examined for occurrence of rhomboid fossa and length and breadth were measured with digital vernier caliper and nature of rhomboid fossa noted whether it is flat, elevated or depressed [7] (Fig 1).

Formulas used to derive the Robustness Index (RI) and Index of Rhomboid Fossa (IRF) are

$$RI = MSC / \text{Maximum length of clavicle} \times 100$$

$$IRF = \text{Breadth of RF} / \text{Length of RF} \times 100$$

The methods reported here for age determination are from visual appearance of medial end of clavicle and from the radiographs.

Age Determination By the External Appearance of Medial Articular Surface

Based on McKern and Stewart's system [8] clavicles were classified into 5 phases as (Fig-2) (1) no-fusion or no-union: Coral like appearance of medial articular surface (10 – 13 years), (2) beginning union: Flake commencing fusion, less than 50% of medial articular surface covered by flake (14 -16 years), (3) active union: Greater than 50% of the medial articular surface is covered by flake (17 -18 years), (4) recent with a scar: Visible gap between epiphyseal flake and bone surface (nodule like)(19 -22 years) and (5) complete fusion: Smooth appearance of medial articular surface with no scar (>24 years).

Radiographs were made with a Hewlett-Packard Faxitron series 4305N cabinet X-ray system at 50kvp and 1.8 minutes exposure time. Film- tube distance was 60 cm was used. All plates were developed in the same automatic processor.

Age Determination by Visual Seriation of Radiographs

The age was assigned on the basis of individual rank in sequence based on the trabecular involution method [9] the radiographs were seriated with visual inspection on the basis of relative radiolucency. A final age is assigned to each radiograph. The bones were categorised based on the radiographic standards developed by Walker and Owen (1985)[9] into following eight stages.

Stage 1 (18 – 24 years)

Major part of the posterior cortex is thick and finegrained. Complete medullary cavity is filled with dense trabeculae which are aligned in the form of parallel plate in the vein of layers. The medial and lateral metaphyses are filled with fine-grained trabeculae.

Stage 2 (25 – 29 years)

Posterior cortex shows coarsening trabeculae in medullary cavity, minor disintegration of metaphyses with fewer trabeculae which are moderately grained. Anterior cortex exhibits increased trabecularization.

Stage 3 (30 – 34 years)

Increased evacuation of epiphyses with moderately grained and fewer trabeculae. Minor thinning of posterior cortex without scalloping. Medullary cavity is filled with trabeculae but the parallel plate arrangement of trabeculae is lost.

Stage 4 (35 – 39 years)

Prominent reduction of posterior cortex is seen, including medial and lateral ends. Trabecular fibres exhibit more coarsening with constant evacuation of metaphysic with increased transparency.

Stage 5 (40 – 44 years)

Increased lumen of medullary cavity. Trabecularization is more evident with coarse trabecular fibres at sternal and lateral ends. Significant thinning of anterior and posterior cortex is demonstrated.

Stage 6 (45 – 49 years)

Gradual bone loss with generalized increased translucency.

Stage 7 (50 – 54 years)

The characteristic feature of this phase is the

trabeculae are thicker and coarse. There is demonstrable bone loss but with no evacuation of medullary cavity.

Stage 8 (>55 years)

Seriation is analogous with stage 7 with more trabecularization and translucency with reduced cortex and trabeculae nearing to cortical shell condition. No evidence of trabeculae at medial and lateral ends.

Statistical Analysis

The obtained measurements of parameters were tabulated and subjected to statistical analysis using SPSS 16 version. The resultant values were analyzed using student's paired t test and chi-square analysis appropriately.

Results

The mean difference of length of the right clavicles between male and female was 10.38mm and of the left clavicles was 13.13mm. The mean difference of mid shaft circumference (MSC) between male and female clavicles on the right side was 3.9mm and on the left side was 5.8mm. The difference in mean of Robustness Index (RI) among male and female clavicles was 0.88 on right side and 1.74 on left side. The mean difference of weight of the bones on right and left side was 4.23gm and 5.44gm.

The percentage of occurrence of rhomboid fossa in male clavicles was 96% and in female clavicles was 76%. The mean difference in length and breadth of

rhomboid fossa on right side was 6.73mm and 2.93mm and on the left side was 6.17mm and 4.03mm respectively. The mean difference of Index of rhomboid fossa was 6.86 on the right side and 14.07 on the left side (Table 1&2). The result of comparison of occurrence and nature of rhomboid fossa (elevated, depressed, flat, absent) between male and female clavicles with the chi-square analysis was found to be highly significant with the p – value as 0.0001. (Table 3)

Estimation of age with the appearance of medial articular surface as: Coral (10-13years) [11.5%], Flake (<50%) (14-16 years) [5.38%], Flake (>50%)(17-18 years)[6.15%], Nodule (19-22 years) [7.69%], Smooth (above 25 years) [69.23%]. (Table 4)

Estimation of age of clavicle based on its observation of X-rays by visual seriation (Walker and Owen, 1985)⁹ was as follows – below 18 years (11.53%), 18-24 years (3.07%), 25-29 years (6.92%), 30-34 years (9.23%), 35-39 years (11.53%), 40-44 years (10.76%), 45-49 years (13.07%), 50-55 years (9.3%), above 55 years (24.61%) (Table-5).



Fig. 1: Rhomboid fossa–maximum length (red) and breadth (blue)

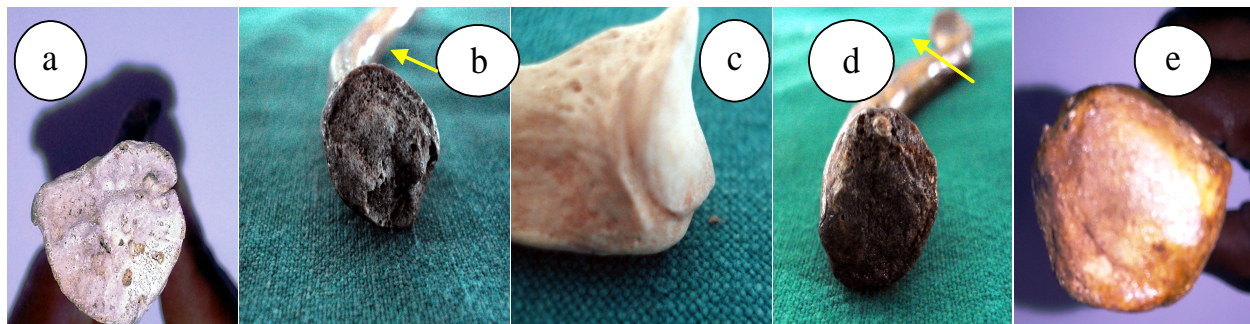


Fig. 2: External appearance of medial articulating surface to determine the age

- Coral like appearance (no-fusion or no-union)
- Flake commencing fusion (<50% of medial articular surface covered by flake)
- Active union (>50% of the medial articular surface is covered by flake)
- Recent union with a scar (nodule like)
- Complete fusion (Smooth appearance of medial articular surface with no scar)

Table 1: Comparison of various parameters of male and female clavicles of right side

SI.NO	Parameters	Male N=30	Female N=23	SD Male	SD Female	Mean Difference	t value	P value
1	Length(mm)	137.99	127.6	9.34	9.4	10.38	3.99	0.0002 HS
2	MSC(mm)	38.34	34.35	3.66	3.97	3.99	3.78	0.0004 HS
3	Robustness Index(RI)	27.84	26.96	3.09	2.72	0.88	1.09	0.2798 NS
4	Weight(gm)	16.45	12.22	4.28	3.419	4.237	3.884	0.0003 HS
5	RF Length(mm)	19.12	12.37	5.44	7.5	6.73	3.79	0.0004 HS
6	RF Breadth(mm)	9.26	6.12	2.95	3.94	2.93	3.098	0.003 HS
7	IRF	47.07	40.2	14.71	22.61	6.86	1.33	0.1874 NS

MSC- Mid shaft circumference
IRF- Index of Rhomboid fossa
HS-Highly significant
SD- Standard deviation
RF-Rhomboid fossa
NS- Not significant
S- Significant

Table 2: Comparison of various parameters of male and female clavicles of left side

S. No	Parameters (mean)	Male N=23	Female N=32	SD Male	SD Female	Mean Difference	t value	p value
1	Length(mm)	142.21	129.19	9.99	11.119	13.019	4.46	0.0002 HS
2	MSC(mm)	39.48	33.68	3.66	3.24	5.799	6.194	0.0001 HS
3	Robustness Index(RI)	27.87	26.12	2.83	2.43	1.754	2.46	0.0171 S
4	Weight(gm)	16.2	10.75	4.294	3.326	5.44	5.298	0.0001 HS
5	RF Length(mm)	17.47	11.3	5.47	7.066	6.1711	3.498	0.001 HS
6	RF Breadth(mm)	9.14	5.15	3.179	3.138	4.0319	4.673	0.0001 HS
7	IRF	50.59	36.49	15.08	21.281	14.07	2.712	0.009 S

MSC- Mid shaft circumference
IRF- Index of Rhomboid fossa
HS-Highly significant
SD- Standard deviation
RF-Rhomboid fossa
NS- Not significant
S- Significant

Table 3: Comparison of nature of rhomboid fossa of male and female clavicles

S. No	Nature of RF	Male Total:52	Female Total:56	Chi-square value	P-value
1	Elevated	14	16	22.47	0.0001
2	Depressed	27	14		
3	Flat	9	13		
4	Absent	2	13		

RF- rhomboid fossa

Table 4: Mean length of clavicle in the two sexes in population with different ethnicity as compared to the present study

Population	No. of cases		Mean length (in mm) males		Mean length (in mm) females	
	Male	Female	Right	Left	Right	Left
English (Parsons, 1916)	50	50	152	154	138	139
French (Olivier, 1951)	110	60	154.2	155	137.9	138.7
USA whites (Singh, 1969)	230		151.40	153.37	133.68	134.84
USA Negroes (Singh, 1969)	80		155.72	157.32	137.60	140.80
North west Indians(Kaur, 2002)	748	252	149.40±8.91	151.14±8.72	134.53±9.68	136.21±9.64
Gujarat (Patel,2009)	107	109	141.85±9.5	142.3±9.98	125.9±7.4	126.88±8.86
Telangana region (Ashish, 2014)			138.71±8.66	137.83±7.99	-----	-----
Present study	53	55	137.99±9.34	142.21±9.99	127.6±9.4	129.19±11.11

Table 5: Occurrence of rhomboid fossa (RF) in both sexes of different regions

Origin/ Region	Occurrence of RF (%)		Reference
	Male	Female	
Northwest India	72	70	Kaur and Jit (2002)
North India	94	86	Jagmender and Dalbir (2009)
Australia	100	97	Ray(1959)
Brazil	63.6	2.9	Prado, et. al (2009)
America	33.5	5.5	Rogers, et. al (2000)
Present study	96	76	-----

Discussion

Length of the Clavicle

In present study the difference in length of male and female on both right and left side was found to be statistically highly significant (p value - 0.0002). The mean length of right and left sided clavicles in males were 137.99 ± 9.34 and 142.21 ± 9.99 and the mean length of female clavicles from right and left side were 127.6 ± 9.4 and 129.19 ± 11.11 correspondingly. This shows that the length of right clavicle was slightly less than that of the left clavicle among both the sexes (Table 1, 2). When we compared the values of mean length of clavicle in present study with the values of different ethnic group from different population, the values of the present study were less than the previous studies (Table 4) [10,11,12,13]. This proves that there is a morphological variation of length of clavicle in present study when compared with different population. But the values of present study (Tami Nadu population) were almost similar with Gujarat and Telangana population [14,15].

Mid Shaft Circumference (MSC)

Mid shaft circumference is considered as a reliable indicator in sexing human clavicles with the combination of other parameters [16]. In a study conducted in Karnataka the mean values of MSC of male clavicles was 43 mm; female clavicles was 30 mm⁷. In present study the difference in MSC measurements among male and female clavicles statistically highly significant on both sides having mean values in right male and female clavicles were 38.34 ± 3.66 mm; 34.35 ± 3.97 mm respectively. The mean MSC values on left male and female clavicles were 39.48 ± 3.66 mm; 33.68 ± 5.7 mm. There was no much difference was observed in mean values of mid shaft circumference among right and left clavicles in both the sexes.

Robustness Index (RI)

In present study the mean values of Robustness Index also known as length circumference index was found to be not statistically significant among male and female clavicle.

Weight

Weight of the clavicle exhibited a statistical significance between male and female clavicles on both right and left side. In present study the mean weight of male and female right clavicle was

16.45 ± 4.28 gm and 12.22 ± 3.41 gm respectively. The mean weight of male and female left clavicle was 16.2 ± 4.29 gm and 10.75 ± 3.32 gm respectively. The mean weight of the clavicles in both males and females was low when compared with the previous studies by Jit and Sahani (1972) [17] and Singh and Gangrade (1968) [17] which were carried out in North part of India (Table 7). As the present study was conducted in Tamil Nadu the above observation proves that the Indians belong to South part of India has less weight clavicles than North Indians.

Rhomboid Fossa (RF)

Rhomboid fossa is a costal impression situated near sternal end and gives attachment to costo-clavicular ligament. It is considered as sex and age estimator of unknown individuals [19]. The present study was conducted to evaluate the occurrence, the nature and the dimensions of rhomboid fossa. In present study the incidence of RF in males was 96% and in females was 76% which shows the occurrence of RF in males is more common than in females. Based on the nature of RF the clavicles were categorised into four groups [20] (Table 3). The chi-square analysis results were found to be significant with the p value as 0.0001. The results were similar with the previous Indian studies (Table 5) which exhibited similar percentage of occurrence of RF. But, the occurrence of RF in Americans was very less that is 33.5% in males and 5.5% in females [19]. The dimensions of RF like length and breadth shown and significant difference between male and female values on both right and left clavicles (Table 1&2). But, Index of RF was statistically not significant different between male and female values.

Estimation of Age By External Appearance of Medial Articulating Surface

Clavicle is considered as one of the age indicator bone during adolescent age [23]. Based on the study of Mckern and Stewart in Americans the commencement of epiphyseal fusion of medial end of clavicle occurs at the age of 18 years [8]. Shirley and Richard in 2009 shown that the fusion of epiphysis begins at the age of 16 year old in European Americans [24]. In Japanese fusion begins at the age of 13 years [25]. In South-eastern Europeans (Bosnians) the clavicle starts its fusion one to three years earlier to Americans [26]. As there were no previous Indian studies for the assessment of age by the external appearance of articulating surface of medial end, based on the guidelines of previous studies in present study the medial end of clavicle starts union at the

age of 14 years and ossification gets completed by the age of 24 years.

Estimation of Age With Help of Visual Seriation of Radiographs (X-Rays)

Several previous studies were performed on estimation of age of an individual based on the stage of ossification of clavicle, but these studies limits up to the age of 25 years, as the ossification of clavicle gets completed by the age of 25 years. Determining age of an adult clavicle becomes a challenging task where the fusion of sternal end of clavicle is completed. In the present study, apart from the observation of stage of fusion [8], trabecular involution was also observed. The bones were categorised based on the Radiographic standards developed by Walker and Owen (1985) [9] into eight stages. Correlations of recorded age with the age obtained from observation of radiographs, the range of age was found to be similar.

Conclusion

Morphometric and non-metric analyses of clavicle plays an important role to identify the sex and age of an unidentified individual from their skeletal remains. Parameters like length, weight, mid shaft circumference, occurrence and dimensions of rhomboid fossa were found to be statistically significant between male and female. These parameters differ racially among different populations, so the values obtained from the present study can be used as reference for South Indian population. From the present study estimation of age both from the external appearance and radiographs are very helpful in identifying the age of an unknown individual and it can be concluded that from the external appearance of medial articulating surface, the sternal end of clavicle starts union at the age of 14 years and ossification gets completed by the age of 24 years and the observations are found to be similar in radiographs. Trabecular involution method by visual seriation of radiographs can be considered as a useful contrivance in determination of age of an adult clavicle.

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