CHAPTER-3

REVIEW OF LITERATURE

Historical Background of Forensic Anthropology

The seeds of forensic anthropology were sown in France in 1755, when Jean Joseph Sue published the measurements of cadavers of various ages from fetus to young adults, which marked the emergence of a nascent science specifically aimed at skeletal analysis. Broca (1824-1880) recognized the need and importance of understanding human variations and put forth the skeletal interpretation on a more specific footing by developing new osteometric instruments for quantification of skeletal measurements and thus initiated the discussions in comparative skeletal anatomy (Spencer, 1997). Rollet (1889) compared the long bone lengths with the cadaver lengths and his data was presented and published in a widely utilized form by Manouvrier (1893). Pearson (1899) presented Rollet's data in the form of regression equations which started a new era for future development of forensic anthropology statistically. The term “forensic anthropology” was first of all used by Schwidetzky (1954) who emphasized the importance of anthropological analysis in forensic cases.

Wyman (1814-1874) was the first to explore the application of osteological knowledge in legal context for better dispension of justice (Stewart, 1979). Dwight (1881, 1890a,b, 1894a,b, 1905), popularly known as “father of forensic anthropology”, became the first American anatomist to engage in research issues relating to forensic anthropology and to publish a number of scientific papers on medicolegal identification of human skeleton and estimation of sex, age-at-death and stature. Hrdlicka was a prodigious researcher of forensic anthropology (Ubelkar, 1999). Krogman (1986) presented detailed information on techniques of skeletal analysis to enhance the applications of physical anthropology to forensic issues. Trotter's (1970) work on improving the stature estimation methods and McKern and Stewart's (1957) classic monograph on skeletal age changes in young American males, documented and generated new research trends, and thus helped in recognition of the importance of techniques of forensic anthropology in identification of skeletal remains. Since then a number of studies
There have been conducted in forensic anthropology by different workers to figure out
the biological profile of an individual or populations.

It is a widely known fact that degree of sexual dimorphism and presence of
age indicators vary among populations and the standards derived from one
population differ from the others. A number of bones of human skeleton have
been studied in forensic anthropology in attempts to establish population specific
methods of age and sex determination based on the examination of bones.
However, osteometrically, the clavicle and the sternum are still the least studied
bones. Most anatomists and physical anthropologists who studied the
contemporary skeletons or skeletal materials of prehistoric excavations in
profiling an individual, usually neglected these bones. Some attempts have been
made in Western countries as well as in India to estimate age and sex from
clavicle and sternum from various metric and non-metric features with varying
degrees of reliability, and a review of these studies is presented here separately
for both, clavicle and sternum.

Clavicle

The maximum clavicular length and mid-clavicular circumference were
measured, weight and volume were taken, various indices and ratios were
calculated and bilateral asymmetry in clavicles was noticed by the previous
workers on variable number of bone specimens/radiographs/tomographs to
estimate age and sex from the clavicle (Parsons, 1916; Ray, 1959; Jit and
Singh, 1966; Singh and Gangrade, 1968a, b; Jit and Sahni, 1983; Yadav and
Aggarwal, 1983; Kaur, 1989; Sharif, 1989; McCormick et al., 1991; Sayee et al.,
1992; Singh and Jit, 1996; Rogers and McCormick, 1997; Kaur et al., 1997; Singh
and Jit, 1999; Kaur et al., 2002; Katzmozyk, 2002; Frutos, 2002; Patel and Shah,
2004; Rios et al., 2008; Auerbach and Raxter, 2006).

Similarly, a number of non-metric traits like rhomboid fossa (Pendergrass
and Hordes, 1937; Chawla and Mukarjee, 1970, Goldenberg and Bogdon, 1970;
Aggarwal and Khatri, 1974; Srivastava et al., 1977; Jit and Kaur, 1986 and
Rogers et al., 2000), nutrient foramina (Mays et al., 1999), coraco-clavicular joint
(Lewis, 1959; Kaur and Jit, 1991; Nalla and Asvat, 1995; Cho and Kang, 1998;
Gumina et al., 2002), epiphyseal union degrees (McKern and Stewart, 1957; Jit...
and Kulkarni, 1976; Szilvassy, 1980; Webb and Suchey, 1985; McLaughlin, 1990
c.f. Scheuer, 2002; Black and Scheuer, 1996; Ji et al., 1994; Kreitner et al., 1998;
Schultz et al., 2005 and 2006, Mühler et al., 2006), shapes of inner and outer
ends (Ray, 1959), conoid and deltoid tubercles (Ray, 1959) etc., of clavicle have
been studied in relation to aging and sexing of this bone.

Parsons (1916) found that in both sexes the length of left clavicle, on
average, was a little more than the right (in spite of the fact that the right arm is
used more frequently than the left arm consequently causing an increase in
curvature of left clavicle bringing the two ends nearer). The nutrient foramina,
perforations, rhomboid pit, conoid facet and trapezoid tubercles were noticed in a
negligible number of bones. Ray (1959), by metric and non-metric examinations,
found the clavicles of Australian aborigines to be comparatively smaller in all
measurements with greater thickness index than other races and well marked by
attachments mainly in males.

Some workers found mid-clavicular circumference alone as an extremely
useful and valuable measurement to correctly sex the clavicles (Jit and Singh,
1966; Singh and Gangrade, 1968a,b; McCormick et al., 1991; Rogers and
McCormick, 1997 and Kaur et al., 1997), whereas, others found both weight and
mid-clavicular circumference (Singh and Gangrade, 1968b; Jit and Sahni, 1983;
Kaur et al., 1997), and still others found length and weight jointly (Sayee et al.,
1992) to be better sex indicative. Robustness index was found to be a very poor
indicator of sex (McCormick et al., 1991; Rogers and McCormick, 1997, Frutos
2002).

Different workers have established the demarking points of metric
parameters of clavicle separately for different zones of India to estimate sex i.e.,
for Amritsar zone (Jit and Singh, 1966), Varanasi zone (Singh and Gangrade,
1968b), Chandigarh zone (Jit and Sahni, 1983, Singh and Jit, 1996; Singh and
Jit, 1999), Gujarat zone (Patel and Shah, 2004), Bangalore zone (Sayee et al.,
1997) Hyderabad zone (Sharif, 1989), Patiala Zone (Kaur et al., 2002) etc., and a
great difference was found in the demarking points and the percentage of
clavicles identified by them in these zones. Clavicles from Varanasi zone were
found to be shorter in length, smaller in mid-clavicular circumference and heavier
in weight than the clavicles from Amritsar zone (Singh and Gangrade, 1968b),
whereas Gujarat zone clavicles were shorter in length, broader in mid-clavicular
circumference and average in weight as compared to Varanasi and Amritsar zone clavicles (Patel and Shah, 2004), but Singh and Jit (1999) found that all the three measurements of Chandigarh zone clavicles were slightly greater than those of other zones of India possibly due to the reason that population of Chandigarh zone, in general, is better nourished and well built than those of other zones of India.

Multivariate analysis on all the parameters give best results of sex estimation than on one or two parameters (Singh and Jit, 1999 Sayee et al., 1992), but Jit and Sahni (1983) found that when length was included in multivariate analysis of weight and mid-clavicular circumference, the estimation of sex decreased, both in males and females.

McCormick et al., (1991) found that length and circumference of clavicles, and particularly their product index, were useful in sexing the American adult clavicles. The ratio of body length to mid-clavicular circumference was found to have a fair sex-predictive capability and to be a more useful indicator of maleness than the body length to the clavicular length ratio in the studied clavicles and the two ratios, on average, were greater in women than in men. The body length to the clavicular length ratio was noticed to be greater in left clavicles than the right ones, whereas, the ratio of body length to clavicular circumference was found to be greater in right clavicles than their left counterparts. The male/female body length to the clavicular length ratio differences, though statistically significant, were not found to be useful for sexing the studied clavicles.

Introna et al., (1994) measured six parameters of Italian clavicles obtained from a known contemporary skeletal population to study sex determination by discriminant function analysis. They observed that value of these parameters were more in males than in females. The mean values of maximum clavicular length, mid-clavicular circumference, sternal end width, acromial end width, robustness index and product index were more in males than in females. The multivariate statistical analysis revealed that product index, mid-clavicular circumference and maximum clavicular length were the parameters with high probability of sex discrimination, while, from the univariate discriminant analysis, only product index revealed a least but acceptable sex misclassification rate. Considering maximum clavicular length and the mid-clavicular circumference together the multivariate discriminant function analysis correctly classified sex of
90% of the studied bones. As the mid-clavicular circumference is related with the breadths of proximal (sternal) and the distal (acromial) ends, respectively, the sex in case of fractured clavicles can be estimated from the measurement of width of the two ends.

Both the diameters, at the acromial/outer/distal end and at the sternal/inner/proximal end of the clavicle, were found to be greater in males than in females, and within each sex more prominent in right than left clavicles (Terry, 1932; Ray, 1959; Kaur, 1989; Introna et al., 1994; Kaur et al., 2002).

The robustness index as well as product index of male clavicles were found to be significantly greater than that of female clavicles and, the right clavicles of both the sexes were found to have greater values of these parameters than those of left clavicles (Terry, 1932; Oliver, 1951; Ray, 1959; Jit and Singh, 1966; Kaur, 1989; McCormick et al., 1991; Introna et al., 1994; Kaur et al., 2002).

Rogers and McCormick (1997) used the published cut-off values of McCormick et al., (1991) to sex independent modern and archaeological samples and confirmed that sex in unknown individuals can be assigned correctly from the product index (of length and circumference measurement) of clavicle than from measures of robustness. Frutos (2002) stressed the need for population specific standards for metric determination of sex in a Guatemalan forensic sample and found that genetic and environment factors of growth and development were responsible for morphologic differences observed between the two sexes. Katzomzyk (2002) confirmed that in Srilankan clavicles also, the left clavicle was longer than the right one in both the sexes.

Rios et al., (2007) comparatively studied 60 pairs of adult clavicles (48 males, 12 females) taken from Hamann-Todd Osteologic Collection and 19 fresh anatomic clavicles. The mean total length and distance from the edge of the clavicle to the medial edge of conoid tubercle of dry osteologic clavicles were more than the fresh anatomic clavicles, and within each sample the averages in male being more than in the female clavicles. On the contrary, in dry bones, the mean distance from the edge of the clavicle to the centre of trapezoid was less as compared to that of the fresh bones. When only dry clavicles were considered, the anterior-posterior clavicle thickness was more in males than in females.
Comparing the samples according to race, no significant differences in clavicular measurements were noticed.

Studying right-left asymmetry in clavicular length most workers found that the left clavicle was longer than the right one (Ljunggren, 1979; Mays et al., 1999; Steel and Mays, 1995; Auerbach and Raxter, 2007). It was presumed that the left clavicle was longer than the right one either due to presence and free expansion of heart, arch of aorta, longer left sub-clavian artery on the left side of the thorax (Sharif, 1989) or due to greater use of right handedness and hence greater curve of right clavicle (Kaur et al., 2002) or due to increased comprehensive forces in the shoulder girdle on the dominant side, thus making the right clavicle more robust and short (Mays et al., 1999).

Auerbach and Raxter (2007) studied patterns of bilateral directional asymmetry in 509 clavicles (259 males and 250 females) of diverse human groups of pre-industrial indigenous populations of North America. They found a left-biased clavicular length asymmetry and right-biased clavicular diaphyseal asymmetry. No sexual dimorphism was evident in directional asymmetries of other dimensions of the clavicles but it was found that diaphyseal breadth (mid-clavicular circumference) was more sensitive to mechanical loading than the clavicular length. Activity differences play a major role in amounts of asymmetries mainly in diaphyseal breadths than the lengths of long bones. As different human groups had different patterns of activity and loading behaviors, they had different observable patterns of asymmetry.

Sankhayan (2005) noticed a considerable metric and non-metric bilateral variation noteworthy in the development of rhomboid fossa, deltoid and conoid tubercles and deltoid ridge etc. in the modern and fossilized clavicles of both sexes in Central Narmada valley region.

Clavicle displays the longest period of growth related activity than other long bones of human skeleton, thus rendering it useful for estimation of age at death in early years. Clavicle can be used as a reliable age indicator in early years of life at puberty as it retains its predictive value when other growth related indicators have become inactive and it remains a useful predictor of age at death until close to 30 years of age (Black and Scheuer, 1996). The slowly maturing, flake epiphysis at the medial end of the clavicle is a useful marker in the young adult age group. A clavicle with no evidence of a fused or fusing epiphysis is
most likely to have come from an individual less than 18 years of age. A well-defined fusing flake occurs in individuals between the ages of 16 and 21 years and one that covers most of the articular surface is typical between 24 and 29 years. Final fusion is unlikely before 22 years and is nearly complete by 30 years (Szilvassy, 1980; Webb and Suchey, 1985; Mc Laughlin, 1990 c.f. Scheuer, 2002; Black and Scheuer, 1996). Epiphyseal union is a reliable indicator of age at death in young adults and is of greatest discriminatory value.

Age estimation based on epiphyseal union degrees or ossification patterns of medial clavicle has been studied by many workers using bone specimens, radiographs; computed tomography, ultrasounds etc., and have found it a useful indicator of age in early years. (Mc Kern and Stewart, 1957; Jit and Kulkarni, 1976; Webb and Suchey, 1985; Ji et al., 1994; Kreitner et al., 1998; Schultz et al., 2005, 2006; Mühler et al., 2006.).

Mc Kern and Stewart (1957) estimated the age, of unidentified young American soldiers who died in ‘Operation Glory’ in North Korea, from the skeletal age changes in the clavicular epiphysis, and found that the epiphysis cap begin to unite to the billowed surface of the medial end of clavicle as early as 18 years but any time between 18 to 25 years. The epiphyseal union was found to begin at the centre and then spread to the superior margin, anteriorly or posteriorly and majority of cases were undergoing union from 25 to 30 years. The last site of union was located along the inferior border of medial end in the form of a fissure which obliterated at the age of 31 years, thus completing the epiphyseal union. They further categorized five stages (‘0’ to ‘4’) of epiphyseal union of medial clavicle and stated that 30th year is the latest age likely to show epiphyseal activity as the clavicles in some individuals are still actively fusing at this age.

Webb and Suchey (1985) found that epiphyseal union of medial clavicle in a modern American sample starts earlier in females than in males and the complete union occurs at 20+ years in females and at 21+ years in males. Female standards can vary 1-2 years from those of males but, in general, epiphyseal timing of both sexes is just similar. Ji et al., (1994) found that epiphyseal union proceeds faster in females than in males and comparatively more faster in Japanese males than in American males. Kreitner et al., (1998) tomographically studied the medial extremity of clavicle concluding that
ossification of clavicular epiphysis and its union lasts for several years and may be a useful adjunct in forensic age estimation in living individuals.

Schaefer and Black (2005) proposed that appropriate population specific standards of epiphyseal union of medial clavicle should be devised, as Bosnian clavicles start and attain complete union 1 to 3 years earlier than the American clavicles. Schulze et al., (2005) used the medial clavicle ossification pattern stages of Schmeling et al., (2004) and confirmed its earlier occurrence in females than in males. Schulze et al., (2006) proposed that computed tomographies of medial clavicle epiphysis will only be suitable for age estimation around the age of 21 years in living persons.

Many workers used the presence and characteristics of rhomboid fossa of clavicles as an age and sex indicator (Pendergrass and Hordes 1937; Chawla and Mukarjee, 1970; Goldenberg and Bogdon, 1970; Aggarwal and Khatri, 1974; Srivastava et al., 1977; Jit and Kaur, 1986 and Rogers et al., 2000). A broader and larger fossa mainly on right clavicle was attributed to right-handedness by Srivastava et al., (1977). Jit and Kaur (1986) found the incidence of bilateral fossa more than the unilateral fossa in both sexes, and the latter was mainly on the right clavicles. Rogers et al., (2000) found rhomboid fossa as a reliable sex indicator in the absence of other skeletal indicators as they are more common in males and especially younger ones than in females and older ones. A fossa on left clavicle was better indicative of maleness and larger fossa was commonly found in 20-30 year old males. The number and size of nutrient foramen were found to be greater on left clavicles than the right clavicles due to greater vascularisation of the former (Mays et al., 1999).

The coracoclavicular joint has been observed either radiologically (Moore and Renner, 1957), osteologically (Parsons, 1916; Nutter, 1941; Kaur and Jit, 1991) or dissectionally (Lewis, 1959). The frequency of this facet/joint obtained from osteological or actual dissections was higher than that obtained from radiological studies (Cho and Kang, 1998). Its prevalence was upto 10% as per osteological studies or dissectional studies (Ray, 1959; Pillay, 1967; Kaur and Jit, 1991; Gumina et al., 2002) and upto 21% as per radiological studies (Moore and Renner, 1957; Cho and Kang, 1998).

Nutter (1941) stated that an articular facet on the inferior surface of the conoid tubercle of the clavicle superiorly, indicates the pre-existence of
coracoclavicular joint which was termed an uncommon osteological feature by Lewis (1959). It was found to be more commonly present in Asians than in Europeans or Africans by Abe (1964) and Cockshott (1979). Most of the workers found it to be more common in males than in females (Pillay, 1967; Kaur and Jit, 1991; Nalla and Asvat, 1995).

Kaur and Jit (1991) studied the dry bones of northwest Indians and found the occasional incidence of coracoclavicular joint to be more common in males than in females. They concluded that neither there exist any relation between the occurrence of this joint and a particular occupation nor it is a congenital anomaly. No significant difference was noticed between various measurements of clavicle with or without a coracoclavicular joint. Side and sexual differences were found to be statistically insignificant. They further noticed that the facet was oval or circular in shape, varying in size from 8 x6mm to 17x9mm.

Nalla and Asvat (1995) studied the incidence of the coracoclavicular facet on the conoid tubercle of the clavicle of South African populations and found that males (56.3%) presented a higher incidence of this facet than the females (43.5%). They further reported that in majority of cases, it was present bilaterally and sexual or racial differences were not found statistically significant. The larger scapulae, longer clavicles and longer first ribs were thought to restrict the associated movements of the scapulae and hence the development of this facet on the clavicles.

Cho and Kang (1998) found the occurrence of the articular facets of the coracoclavicular joint in 9.8% of the studied Koreans subjects. No significant difference in its occurrence between the clavicles of two sides or between the clavicles of two sexes was noticed. No relationship was found between various measurements of the clavicles and scapulae, rather its occurrence/prevalence increased with the increase in the age of the specimens which was also supported by Kaur and Jit (1991) who proposed that this facet occurs later in life, mainly after 40 years of age (Cho and Kang, 1998).

Gumina et al., (2002) studied the occurrence of coracoclavicular joint in European dry bones and found its occurrence only in 0.78% cases which was lower than that observed in Asians. Its incidence was related to aging and they noticed no significant difference between various measurements of clavicle with or without a coracoclavicular joint.
**Sternum**

Several workers, in India as well as in Western countries, have made numerous attempts to estimate gender and age from the morphology or dimensions and proportions, etc., of sternum, either from bone specimens or from x-rays. (Dwight, 1881, 1890; Hyrtl, 1889; Paterson, 1904; Ashley, 1951, 1953, 1956; Stewart, 1954; McKern and Stewart, 1957; Narayan and Varma, 1958; Riach, 1967; Rother et al., 1975; Jit et al., 1980; McCormick, 1981; Dokladal, 1981; Jit and Harjeet, 1982; Stewart and McCormick, 1983; Ullah and Singh, 1983; Jit and Bakshi, 1984, 1986; McCormick et al., 1985, 1998; Moore et al., 1988; Cooper et al., 1988; Jit and Kaur, 1989; Singh et al., 1993, 1994; Vella et al., 1994; Sun et al., 1995; Dahiphale et al., 2002; Gautam et al., 2003; Naranbabu et al., 2003; Singh et al., 2004; Torwalt and Hoppa, 2005; Selthofer et al., 2006; Queiroz et al., 2004; Fernandez et al., 2007; Atal et al., 2008; Hunnargi et al., 2008, 2009).

A few investigators have used the measurements of sternal area, i.e. length and breadth of manubrium and body, separately as well as both combined, as useful indicators of age and sex. Most of the workers were unanimous that combined length of manubrium and body was more in males than in females (Dwight, 1881, 1990; Hyrtl, 1893; Ashley, 1956; Jit et al., 1980; Gautam et al., 2003). In 1881 Dwight observed that breastbone was not trustworthy guide to estimate sex, but in 1890 he stated contrary to earlier statement that combined length of manubrium and body was more in males (164.1 mm) than in females (141.3 mm). According to Hyrtl (1893) the manubrium generally exceeds half the length of body in females, whereas, in males the body of sternum is twice as long as manubrium. Paterson (1904) found that a broader mesosternum in lower part was a feminine feature, though not uncommon in males. For sexing the European and African sterna on the basis of combined length of manubrium and body, Ashley (1956) formulated 'rule149' and 'rule136' as demarking points for males and females, respectively.

Riach (1967) examined relationship between appearance of centre of ossification in the sternum and the chronological age from the study of a small number of Birmingham sternums. No relation was found between the studied
parameters; it was suggested that appearance of ossification may help in assessing skeletal maturity in pathological or forensic situations.

Rother et al., (1975) suggested that discriminant function when applied on any two parameters from among length, breadth and thickness of sternum may be used in sex diagnosis in forensic osteology especially if more reliable criteria of pelvic measures are missing. Combined length (of manubrium and body) was found extremely useful in sexing North Indian sterna by Jit et al., (1980). Male sterna were longer than the female sterna and cent percent accuracy in sexing the sterna was possible when this combined length was 140 mm or more for males and 131 mm or less for females. Width of first and the third sternubrae, and their relative index were statistically insignificant in sexing the sternum. Manubrial length was found not to be a reliable criterion for sexing the sternum, however, length of mesosternum was a better criterion in this regard.

Jit and Kaur (1982) measured sternal angle in 272 male and 78 female north Indian adult sterna. Though the mean value of the angle was found to be more in males than in females, yet it was not a reliable parameter for sexing the studied sternums.

Stewart and McCormick (1983) determined the sex predictive value of sternal length and found it to be absolutely sex predictive in about one-fourth of the studied cases, the length being more in males than in females. Ullah and Singh (1983) examined the length and breadth of manubrium of 210 adult sterna (156 males and 54 females) of Jammu region and found that mean length of manubrium was significantly more in male than the female sternums, whereas, the breadth of manubrium was significantly more in female than the male sternums.

McCormick et al., (1985) studied adult chest plate roentgenograms for sternal length and ossification pattern, and found sternal length alone to be less sex predictive (67.2%) as compared to sternal length and the ossification pattern collectively (94%). Sternal growth continued for longer time in males and they had more robust sternum with greater sternal length than the females. They further opined that correct sexing was possible if length was in the range of 143-157 mm.

Vella et al., (1994) measured and analyzed seven sternal parameters of Southern Italian Apulian skeletal population and found that total sternal length,
length of manubrium, length of mesosternum were more in male sternums than in female sternums. The maximum manubrium width, maximum corpus or mesosternal width and thickness of manubrium were having greater values in male sterna than in female sterna. Thus female sterna were significantly smaller in dimensions than the male sternums. Both the results of descriptive statistical analysis of sternal measurements and the univariate discriminant function analysis found the total sternal height as the best significant parameter for sex determination in Italian sternums with lowest percentage of misclassification. They further revealed that in multivariate discriminant function analysis, the association of measurements taken only from manubrium, e.g., length, maximum width, thickness, jugular incisures width, etc., showed a correct rate of sex classification upto 90%, while association of sternal corpus parameters did not revealed useful results.

Dahiphale (2002) found sternal length best sex predictive than the combined length of manubrium and mesosternum and good number of sterna of both sexes were sexed correctly by applying discriminant function analysis. Singh et al., (2006) studied Manipuri subjects and found manubrial index, being comparatively larger in females than in males, as a significant tool in differentiation of sex. Type II sterna were found most common followed by type III and type I. Females mostly had type III sterna. Gautam et al., (2003) found that pattern of fusion of sternal elements had no relation with sex and set demarking points of length of body, manubrium and the combined length of manubrium and mesosternum of the sternum.

Singh et al., (2004) examined the degree of fusion of manubrio-sternal joint as an indicator of age in 160 Manipuri sterna (110 males and 50 females) and found that the earliest age at which fusion of this joint may start is 26 years in males and 31 years in females The complete fusion was not taking place before the age of 50 years in both sexes. Usually it occurred in very old age, and was found to occur by 2-3 years later in females than in males.

Torwalt and Hoppa (2005) metrically studied plastrons of Canadian individuals and concluded that 4th rib width and sternal area when used together were the best indicator of sex with accuracy rate of 95.8% for males and 90.3% for females. Selthofer et al., (2006) morphometrically analyzed that general sternum structure in the males and the females is equal and only a single
standard sternum shape was present in more than two-third of the analyzed sterna of both sexes.

For the purpose of gender determination, Queiroz et al., (2004) measured and weighed 100 adult Brazilian sternums (50 males and 50 females) and found that collective weight of manubrium and body was highly significant determinant of gender. The mean length of body of sternum and the mean total sternal length were more in the males than in the females, and the difference between the two sexes for these two measurements was found to be statistically significant.

Fernandez et al., (2007) studied 83 Spanish adult sterna (43 males and 40 females) to determine sex from their anatomical measures and found that only total sternal length and the mesosternal length were useful in sexing the studied sternums. The mean total sternal length was more in males than in females with a demarking point of 141mm. Similarly, the mean lengths of manubrium and mesosternum were also found to be more in males as compared to females. The demarking point for the mesosternal length was found to be 97mm which along with total sternal length allowed discrimination between two sexes with a probability of 90%. The mean width of first and the third sternubrium, and sternal index was found to be more in males than in females. The sternal index safely predicted sex in 66.16% studied cases. The difference in the means of total sternal length, length of manubrium, length of mesosternum and width of first sternubrium between the two sexes was found to be statistically highly significant.

Atal et al., (2008) morphometrically studied 100 sterna (56 males and 44 females) of Delhi region and found that combined length of manubrium and mesosternum the only best parameter in gender differentiation from sternum with its mean values being more in males than females. The demarking point for combined length of manubrium and mesosternum in males was calculated to be more than 133.30mm for males and less than 119.86mm in females. The length of the mesosternum was found to be the second best parameter in gender differentiation. The length of the manubrium and sternal index were found to be unreliable in sex determination. The mean values for length of manubrium, length of mesosternum and combined length were found to be greater in male specimens than in females. By using discriminant functions 92.9% male and 97.7% female were sexed correctly. Atal et al., (2008b) further postulated that width of first sternubrium could be used for gender determination from the
sternum but width of manubrium and width of third sternubrium were found to be unreliable in sex determination.

Hunnargi et al., (2008) morphometrically studied 115 sterna (75 male and 40 female) of Maharashtra region of western India and found that the length of manubrium, length of mesosternum, and combined length of manubrium and mesosternum were significantly more in males than in females. The sexing potential of length of manubrium, length of mesosternum and combined length of manubrium and mesosternum was found to be higher when these measures are used together using multivariate discriminant function analyses, but is limited when each is used separately, as most of their values were found to lie in the overlapping zone. The identification points derived for various parameters distinguished 13.3% male and 27.5 female manubriums, 24% male and 22.5% female mesosternum and 46.6% male and 57.7% female sternums as a whole. The ‘rule 131’ derived for the combined length of manubrium and mesosternum correctly sexed 85.3% male bones and 77.5% female sternums. Using these criteria they found the combined length as the only most useful parameter in determining the sex of sternum in medicolegal skeletal examinations.

Hunnargi et al., (2009) reported that applicability of Hyrti’s law in sex determination is limited. Though sternal index is significantly higher in females (63.31) than in the males (59.21), it conclusively cannot be used for sex determination in sternums of Maharashtra region of western India and sternal index is different for different population groups.

McCormick (1981) found a prevalence of 7.7% sterna having oval to circular single foramina with diameter of 3-18 mm. and being twice more common in men (9.6%) than in women (4.3%) without having any clinical or functional significance. Jit and Bakshi (1984) studied a correlation between the sternal foramina and type of sterna concluding that majority of male bones showing foramina in the xiphoid process belonged to type II and comparative number to type I and III. Only a single female sternum showed foramina in xiphoid process which belonged to type I. A rare case of multiple mesosternal foramina was attributed to paired defects in cephalic-caudal line along with the midline of ossification by Cooper et al., (1988), whereas, a similar unusual case was noticed by McCormick et al., (1998) who emphasized that multiple mesosternal foramina can originate in more than one pattern. Moore et al., (1988) radio-graphically

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examined isolated plastrons of 2016 individuals and noticed that incidence of sternal foramina significantly discriminates race, without having any clinical significance or any relationship with sex prediction, but have a potential forensic value in individual identification.

Jit and Bakshi (1986) found that ossification of sternum does not help in establishing the age of an individual after the age of 18-20 years. Complete fusion of manubrium with body was seen at 21 years or above in both sexes. The xiphoid process did not fuse with body in males below 18 years and in females below 21 years. Jit and Kaur (1989) proposed that in a mesosternum, the sternubrae fuse one another from below upwards showing that complete fusion of all the sternubrae must be at over 16 years of age in a male and over 18 year in a female. Complete fusion of 3rd and 4th sternubrae was seen in the age group of 15-17 years in both sexes; of second and third sternubrae was seen in males over 25 years and in females over 30 years; and of 1st and 2nd sternubrae was seen in males over 60 years and in females over 30 years in all studied cases. Singh and Jit (1994) concluded that neither fusion of mesosternum with manubrium nor with the xiphoid process helps in determining the age of a subject above 18-20 years. Complete fusion was seen in the age group of 21-25 years and its incidence increased with the advancing age.

Garg (2005) conducted a radiological examination of 162 sterna of Patiala region for estimating age of fusion of sternal elements and found that the mean age of fusion of manubrium with the body of sternum was 54.4 years for males and 57 years for females. The earliest and latest age of fusion of manubrio-sternal joint was reported to be 37 years and 65 years in males and 35 years and 65 years in females, respectively. Similarly, the mean age of fusion of xiphio-sternum with the body of sternum was 50.04 years for males and 46.4 years for females. The earliest and latest age of fusion of xiphio-sternal joint was found to be 36 years and 59 years in males and 35 years and 56 years in females, respectively.

Sun et al., (1995) examined Chinese sterna for non-metric traits and found that quantification and stepwise regression analysis were reliable, simple, accurate and convenient method of age estimation for the female sternum, and was of high importance in forensic medicine and anthropology.