ESTIMATION OF STATURE OF AN INDIVIDUAL USING ULNAR LENGTH AMONG CHENNAI POPULATION

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BONAFIDE CERTIFICATE

This is to certify that this dissertation titled **"ESTIMATION OF STATURE OF AN INDIVIDUAL USING ULNAR LENGTH AMONG CHENNAI POPULATION"** bonafied original work done by **Dr. S. SIVAKUMAR,** Postgraduatein Department of Forensic Medicine Govt. Kilpauk Medical College, Chennai, in partial fulfillment of the regulations of The Tamil Nadu Dr. MGR University for the Award of M.D. Degreein Forensic Medicine (BranchXIV).

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CERTIFICATE

This is to certify that this dissertation titled **"ESTIMATION OF STATURE OF AN INDIVIDUAL USING ULNAR LENGTH AMONG CHENNAI POPULATION"** submitted by **Dr. S. SIVA KUMAR,** is an original worked one in the Department of Forensic Medicine, Government Kilpauk Medical College and Hospital, Chennai in partial fulfillment of regulations of The Tamil Nadu Dr. M.G.R. Medical University, for the award of degree of M.D. (FORENSIC MEDICINE) Branch–XIV, under my supervision during the academic period 2015-2018.

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DECLARATION

I, **Dr. S. SIVA KUMAR,** solemnly declare that the dissertation on **"ESTIMATION OF STATURE OF AN INDIVIDUAL USING ULNAR LENGTH AMONG CHENNAI POPULATION."** is a bona- fide work done by me during the period of **October 2016** to **February 2017** at Government Kilpauk Medical College and Hospital, under the expert Supervision of **Dr. R. SELVAKUMAR, M.D,** Professor and Head of Department of Forensic Medicine, Government Kilpauk Medical College, Chennai. This thesis is submitted to The Tamil Nadu Dr .M.G.R. Medical University towards partial fulfillment of the rules and regulations for the M.D. degree examinations in Forensic Medicine to be held in April 2018.

Dr. S. SIVA KUMAR

Place: Chennai-10

Date:

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INSTITUTIONAL ETHICS COMMITTEE
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Protocol ID. No.06/2016 Meeting held on 14/12/2016
CERTIFICATE OF APPROVAL

The Institutional Ethical Committee of Govt. Kilpauk Medical College, Chennai reviewed and discussed the application for approval **"ESTIMATION OF STATURE OF AN INDIVIDUAL BY ULNA LENGTH AMONG CHENNAI POPULATION"** submitted by Dr.S.Sivakumar., Post Graduate in Forensic Medicine, Govt. Kilpauk Medical College, Chennai.

The Proposal is APPROVED.

The Institutional Ethical Committee expects to be informed about the progress of the study any Adverse Drug Reaction Occurring in the Course of the study any change in the protocol and patient information /informed consent and asks to be provided a copy of the final report.

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Urkund Analysis Result

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INTRODUCTION

Estimation of stature has a significant importance in the field of forensic medicine and anthropometry. Anthropometry is a series of systematized measuring techniques that express quantitatively the dimensions of human body and skeleton.[(1)]The ultimate aim of using anthropometry is to help the law enforcement agencies in achieving ‘‘personal identity’’ in case of unknown human remains.[(2)]

Establishing the identity of an individual from mutilated, decomposed, and amputated body fragments has become important in recent times, due to natural disasters (such as earthquakes, tsunamis, cyclones, and floods) and man-made disasters (such as terror attacks, bomb blasts, wars, and plane crashes).

Fig. 1 - BOTH BONE FRACTURE OF LEFT FOREARM

Fig. 2 - DISMEMBERED RIGHT LIMB IN TRAIN TRAFFIC ACCIDENT

It is important for both legal and humanitarian reasons[3]. The ulna is a long bone on medial side of forearm. Proximally it has an olecranon process, and at its distal end isa styloid process. The whole length of subcutaneous border of ulna is palpable down up to the styloid process.

The length of ulna has been shown to be a reliable and precise means in predicting stature of an individual. In 1952, Trotter and Gleser published a definitive study on stature calculation for American whites and blacks. Data used were from the cadavers of World War II and the Terry Collection[4]. All six long bones were measured for maximum length along with maximum length of the femur, and tibial length between upper and lower articulating surfaces.

Different equations for the estimation of stature were established for whites and blacks, and for males and females.[(5)]The equations that were derived by Trotter and Gleser in the early 1950 for Americans were being continuously revised using data from different sources. In 1977, they proposed new equations using radius and ulnar length.

In 1961, Allbrook attempted to develop standards for the estimation of stature from a British sample using ulnar length, which was measured from ‘‘the tip of the olecranon process to the distal margin of the head” with forearm flexed and semipronated and hand in the natural position.

In 1964, Athawale [(7)]carried out a study on forearm bones. His study was based on 100 Maharashtrian male adults aged between 25 and 30 years. In 2005, Devi and Nat [8]formulated multiplication factors for stature estimation from upper extremity among male and female Tangkhul Nagas of Manipur. The purpose of this study was to analyze the anthropometric relationship between ulnar length and stature and to derive regression formulas to estimate stature.

Stature or body height is one most important and useful anthropometric parameter that determines the physical identity of an individual. In anthropometric research, prediction of stature occupies relatively a central position.

Fig. 3 - CRUSH INJURY OF RIGHT ELBOW JOINT

Estimation of stature of an individual from the skeletal remains or from the mutilated or amputated limbs or parts of limbs in the events of the murders, accidents or natural disasters like floods,tsunamis, earthquakes, plane crashes, train crashes, terrorist attacks usually requires the identification of victims which mainly concerns with the forensic identification analysis.[9].The most detailed description of stature estimation from skeletal remains was compiled by Krogman and Iscan.[10]

The first serious research on estimation of length of long bones of 50 male and 50 female corpses was conducted by Rolletin. Pearson estimated the stature fromlong bones by formulating the regression equations. **He also found that these formulae are population specific and should not be applied to individuals of different population groups**. Later Dupertuis and Hadden estimated stature in cases where the racial roots of the individual are unknown by formulating general equation. Further it was also noted that discrepancies might occur between right and left parts when using these formulae.[11]Studies on the estimation of stature from various body parts such as upper and lower extremities including hand and foot dimensions has been reported. The ulna is a long bone on the medial side of the forearm. Proximally the ulna has a bony process called the olecranon process which articulates with the humerus. Distally the ulna bears a styloid process. The olecranon is subcutaneous and easily palpable. The whole length of the subcutaneous border of the ulna is palpable down to the styloid process. The ulna has easily identifiable surface and marks making the measurements possible even in compromised postures Therefore, formulae based on the ulna length provide an alternative stature predictor under such circumstances. Determination of stature of an individual from fragmented remains is still a very demanding assignment despite numerous studies carried out as formula derived in a particular population does not fit worldwide because of genetic, ethnic, dietary and climatic differences. **Therefore regression formulae needs to formulated for each specific population.** [12]

AIM OF THE STUDY

The aim of the study is to find out the relationship between personal stature and length of ulna and to derive linear regression equation to calculate the height from length of ulna and vice-versa.

OBJECTIVES

1. To find out correlation between ulnar length with stature of an individual.

2. To derive linear regression formula to estimate stature from these dimensions obtained.

3. To evolve linear regression equation for male and female separately.

JUSTIFICATION

Estimation of stature is a key feature of personal identification which is of utmost importance to the Medico -Legal Experts.

Growth – the vital process is measured my measuring the height of a person, which itself is a sum of length of certain bones and appendages of the body represent certain relationship with form of proportion to the total stature. Assessment of height from different parts of body by anthropometric study of skeleton is an area of interest in medicine.

Anthropometric characteristics have direct relationship with sex, shape and form of an individual and these factors are intimately linked with each other and manifestation of internal structure and tissue components which in turn are influenced by genetic and environmental factors.

Personal identification is an integral part of investigation in case of mass disasters where disintegrated and amputated body segments are found very frequently. Estimation of stature from incomplete skeletal and decomposing human remains becomes most important for personal identification from the mutilated or amputated limbs or parts of limbs in events like murders, accidents or natural disasters like floods, tsunamis, earthquakes, plane crashes, train crashes, terrorist attacks. It requires the identification of victims which is mainly concerned with the forensic identification analysis.

NEED FOR THE STUDY

The population of the world is highly variable as far as biological variability is concerned. Indian population is no exception, rather Indian population compromises various ethnic and racial groups leading to even greater variability in biological characteristics.

Accuracy in stature estimation depends to some extent on the **specificity of the samples on which the estimation is based and formulae of one population should not be used in another population.**

The subjects taken for study purpose belongs to Medical and ParaMedical students who are born and broughtup in Chennai persuing their education in Goverrnment Kilpauk Medical College and Hospital, Chennai - 10. Age group between 18 to 22 years were only included in the study.

REVIEW OF LITERATURE

STATURE:

Stature means body height of a person. Estimation of stature in major forensic anthropological concern used in identification of unknown and commingled human remains. Approximate height can be calculated from one of the long bones. Gender and race will need to be taken into consideration in making estimate. The median age for attaining adult height in males is 21.2 years and in females is 17.3 years with growth continuing in (10%) of male until 23.5 years and in females until 21.1 years. In Dead body –the height of dead body differs from height of person during life either it may be longer or shorter though lengthening is more common.

The measured height may change with different period in postmortem state. Example:

The body may lengthen in primary phase of muscular relaxation by 2-3cm, whereas it may shorten in rigor mortis phase and again it increases during decomposition.(13)

Stature is more in:

1. Stature is maximum between 20-25 years of age of a person.
2. It is more during Morning hours.
3. It is more in recumbent position.
4. It is more in dead bodies in stage of primary relaxation.(13)

Stature is less in:

1. After the age of 25 years, stature decreases about (1mm) per year.

2. It is less in evening hours than morning hours because of decreased elasticity and increased tonicity of the vertebral muscles.

3. It is less in standing posture than recumbent position.

4. In dead bodies, stature is less during the stage of Rigor mortis.[13]

Stature is estimated from:

1. Body parts.
2. Skeleton or bones.[13]

Estimation of stature from Body parts:

1. When both upper limbs are overstretched in a straight line then distance between the tips of two middle fingers of both hands is approximately equal to the living stature of a person.

2. Twice the length from vertex to symphysis pubis is equal to the stature of a person or twice the length from symphysis pubis to heel is equal to the stature of a person.

3. Stature of a person is equal to the length of one upper limb(from tip of middle finger to the acromial process)×2+34cm. (34cm is taken as 30cm length of two clavicle+4cm for the breadth of manubrium.

4. Stature=Length from sternal notch to symphysis pubis x 3.3[13].

5. Stature = Length of forearm (length from tip of finger to tip of olecranon) x 3.7
6. Stature=Length of head (from top of head to tip of chin as vertical length) x 7.
7. From hand – stature had been estimated from the length and breadth of hand by Bhatnagar et al (1984) and the regression equations are given as follows:

   Stature = 127.97+2.06×hand length.

   Stature = 141.67+3.13×hand breadth.
8. Stature = Length of vertebral column×35÷100.
9. From lower limb: stature = trochantric height×1.10+737.03 (trochantric height is measured from the lateral bulging of the greater trochantric protrusion to the heel.
10. Stature can be estimated from foot prints also.(13)

For estimation of stature long bones are widely preferred and are more reliable than flat or irregular bones.The length of bone is taken with the help of Hepburn osteometric board.When stature is estimated from a bone, an allowance of **2.5 to 4cm** is added to the calculated stature in order to compensate the loss of soft tissues. **(The total thickness of the soft tissues in between the bones at different joint from heel to vertex is about 2.5 to 4cm.**

Different formulae used to estimate stature:

1. Karl Pearson
2. Trotter and Glesser
3. Dupertuis and Haden
4. Pan
5. Nat
6. Shah and Siddiqui[(13)]

Formulae used to estimate Stature from Fragmented bones:

1. Muller
2. Steele
3. Steele and Mc Kern[(13)]

Multiplication Factors:

Length of bone	Bengal, Bihar and Orissa		Uttar Pradesh Punjab	
	Male	Female	Male	Female
Humerus	5.31	5.31	5.30	4.97
Radius	6.78	6.70	6.90	6.43
Ulna	6.00	6.00	6.30	5.93
Femur	3.82	3.80	3.70	3.57
Tibia	4.49	4.46	4.48	4.18
Fibula	4.46	4.43	4.48	4.35

HOW TALL ARE YOU, REALLY? Giles and Hutchinson (1991) have reviewed the major sources of extraneous variation in attempting to determine a “true” stature. These include average variations of nearly an inch attributable to the time of day; gravity pulls down on the vertically oriented during the course of a normal day. The measurement technique and variation among measurers introduce inaccuracies from half a centimeter to several centimeters—the greater errors usually attributable to medical, police, or correctional personnel untrained in Fundamentals of Forensic Anthropology.[14]

Trained measurers using freestanding anthropometers on shoe-less subjects achieve the greatest accuracy and reproducibility in measurements, and even then small variations persist. Noticeable inaccuracies in recorded heights of the living can result from systematic biases to random errors to simple over-optimism. Willey and Falsetti (1991) in a study of over 500 primarily young adults discovered statistically significant over estimation of driver’s license stature compared with measured stature. They also saw a tendency in males to round up to even inches on driver’s licenses. Driver’s license data are often used as a source of ante mortem descriptions. Analysing a very large U.S. Army database (6669 males and 1330 females) for young adults, Giles and Hutchinson (1991) compared self reported and uniformly measured stature. They found that over the entire range of height males, on average, overestimated their stature by about 2.5 cm (1 inch), and women over reported by an average of about 1 cm (3 8 inch).

Shorter men tended to over-report to a somewhat greater extent than taller men, but on average all over-reported their stature to some degree; no height categories under-reported. These two studies are consonant in reporting the tendency of young adults to overestimate their height, men on average to a greater extent than women. Can this phenomenon be simply attributed to an over-exuberance of youth that becomes more restrained and realistic as maturity progresses[14]

The loss of stature that attends adult aging becomes quite noticeable in the elderly, but begins earlier. Age-related bias exacerbates the inaccuracy of self-reported stature. Giles and Hutchinson (1991) found that men 45– 54 years of age over-reported their stature by an average of 0.25 cm (1 8 inch), in the following decade by 0.6 cm (1 4 inch), and between 65 and 74 by 1.25 cm (1 2 inch)—in addition to the overestimate expected of younger men[14]. The effect for women was an additional over-reporting of 0.5 cm (1 4 inch) between 45 and 54, 1.2 cm (1 2 inch) between 55 and 64, and 2.5 cm (1 inch) for those 65–74. These biases are important to consider in establishing an estimate of living stature and in the estimation of stature from long bone length. [14]

Stewart (1979) reviewed the historical highlights of stature estimation from post-mortem remains. Several efforts were preffered in the nineteenth century, but North American studies are a feature of the twentieth century.

Stature estimation a time when European methods and European population applications expanded, and numerous estimation equations for various Asian populations appeared in the literature (Krogman and Iscan, 1986)[14].

Regression formulae for circumscribed European or Asian populations can certainly be the method of choice in circumstances where the corresponding ethnicity of the deceased is known and appropriate to the chosen formula. However, here we will focus discussion on those methods most applicable to the general North American adult population. One of these methods was devised in Europe.[14]

The Fully Method In 1956 Georges Fully, a French physician, published a method for estimating stature from skeletal remains that improved upon the European methods of the day (Stewart, 1979b). Fully's "anatomical" method incorporated measurements of skeletal elements from head vertex to heel (Fully, 1956). The method is based on data from a very large sample of skeletons exhumed from a German concentration camp after World War II and for whom identity and measured height at arrival could be determined. The original article is rather hard to come by, but the method and measurements are described in Lundy (1988) and Stewart (1979). [14]

In brief, height ¼ basion-bregma height(þ) maximum heights of vertebral bodies C2 through S1(þ) lengths of femur (bicondylar) and tibia (maximum omitting spines)(þ) articulated height of talus and calcaneus (þ) soft tissue factor The correction factor for soft tissue was assigned by three categories: If calculated stature is 153:5cm (60:5 inches) or less, add 10cm (4 inches) If 153:6165:4cm (60:5 to 65:1 inches), add 10:5cm (4:1 inches) If 165cm (or 65 inches) or greater, add 11:5cm (4:5 inches) The correction factor can also be stroked somewhat to take age or vertebral pathology into account.

The method recommends articulating the spinal column beforehand in order to detect abnormal curvatures or other pathologies. If, for age or other reasons, there is kyphosis or scoliosis, then one measures minimum as well as maximum vertebral body height and takes the average of these measurements. Thus the technique accounts for a significant portion of aging stature loss. [14]

The simple summation of measurements does not generate a standard error of the estimate, but the specific individual errors of the estimate were astonishingly small. For the entire sample including 42 new cases, more than 80 percent of calculated statures differed from the known stature by less than 2 cm. There were no errors exceeding 3.5 cm. An obvious shortcoming of the anatomical method is that it requires a largely complete and undamaged skeleton. [14]

In 1960 Fully and Pineau published a second version that allowed calculation of stature when the skull and some vertebrae were missing (see also Stewart 1979a). This second study was based on the skeletons of (164)identified men between the ages of 18 and 65 years and between 151 and 188 cm tall. Two of the more useful regression equations follow.

Stature ¼ 2:09 (femur þ 5 lumbars) þ 42:67 + 2:35 cm Stature ¼ 2:32 (tibia þ 5 lumbars) þ 48:63 + 2:54 cm The standard errors of the estimate are generally smaller than for stature regression formulae based on long bones alone, which is not surprising considering that more measurements that contribute to height go into their estimates. Fully and Pineau remark that the two major components of stature, trunk length, and lower limb length are only weakly correlated to each other, and therefore elements of both components are prerequisites for good stature estimation. Beware, however, that Fully and Pineau's statement on error rate determination is incorrect. (14)

The standard error of the regression line is not the 68 % confidence interval, and twice this is not the 95 % confidence interval (see Reporting Stature Estimates, below). Stature Estimation From Long Bone Length Even casual observation reveals that limb length and stature are positively associated, as are limb bone length and stature. Plots of known statures vs lengths of a long bone show that association to be linear.(14)

As a consequence, stature can be predicted from long bone lengths by simple first-order regression equations. The regression equations are derived from a database of measured long bones taken from cadavers of measured or "known" stature. Because the magnitude of the contribution of limbs and particular limb segments to stature varies somewhat predictably on the bases of sex and ancestry, separate regression equations for sex and ancestry are needed. Since large databases on which to base regression equations for many populations do not exist, one does the best one can with what is 80 STATURE ESTIMATION which is available.

In many forensic situations, sex is known with a higher degree of assurance than ethnicity is known, so an extensive menu of closely defined subtle ethnic choices may be less utilitarian than is often supposed. Nevertheless, it is important to pick the equations that best fit the demographic description of the deceased and to have a large database sample size.(14)

Trotter and Gleser (1952, 1958, 1977; Trotter, 1970) produced a series of regression equations based on measured cadaver height and long bone length from the Terry Collection and measured long bone length from identified World War II and Korean War casualties with known living stature. (14)

For the Terry males living stature was derived from cadaveral height by subtracting 2.5 cm. Their female sample for American blacks and whites came exclusively from the Terry Collection. For American black and white males Trotter (1970) recommended equations from World War II data. The Korean War data produced equations for “Mexican” males (n ¼ 112) and “Mongoloid” males (n ¼ 92). The latter group was a heterogeneous mixture of Japanese, Hawaiians, Filipinos, Amerindians, and others, which detracts from its usefulness. A very important caution regarding the tibia length measurement for the Trotter and Gleser formulae has been presented by Jantz et al. (1995). They convincingly point out that the maximum length of the tibia measurement that Trotter and Gleser (1952) describes is, in fact, not the measurement that

Trotter used to produce the Terry Collection and World War II regression equations.(14)

Contrary to the stated direction of measuring from the lateral portion of the lateral condyle to the end of the medial malleolus, the measurement should not include the malleolus, but end at the talar surface. This measurement is, in practice, much easier to take if one does not have an osteometric board with a central groove cut into the vertical wall to accommodate the intercondylar eminence. For all of the 1952 formulae the tibial measurement should extend from the lateral condyle to the talar surface and not include the malleolus. Jantz and co-workers point out that the tibial measurement(s) for the Korean War dead are uncertain and recommend that these equations not be used.(14)

The standard operating procedure (SOP) for picking the best single regression equation is to select the one with the smallest standard error. If the bones of the leg are present in their entirety, they are inevitably better than the bones of the arm. For the Trotter and Gleser formulae, however, the uncertainties surrounding the measurement of the tibia may detract from its use, even when regressions using that measurement may sport the smallest standard error.

Genoves (1967) has offered tables and formulae for stature of a largely indigenous population from Central Mexico. Both male and female formulae are given, but the sample size is small:(22) for males and(15) for females. For many years the conventional wisdom advocated grouping Native Americans with East Asians in most all forensic analyses. However, this may not be the best procedure.

Using Fully's (1956) method to estimate living stature Sciulli and Giesen (1993) reported that, compared with East Asian populations, prehistoric Native Americans from the Ohio Valley area had relatively long legs and distal elements of the extremities. Therefore, stature estimation based on regression equations for East Asian populations will overestimate their stature. To what extent this holds true for all or most Native Americans is unknown, and there are no sets of formulae for male and female contemporary Native Americans. For the time being at least, it is probably wisest to apply Caucasian formulae. Regression formulae for American blacks and whites, male and female, based on data submitted from modern forensic cases can be supplied by the Forensic Data Bank at the University of Tennessee, Knoxville. (14)

Sample sizes and standard errors of the regression change from time to time as new measurements are submitted, so be sure to ask for these data as well. Comparison of Methods, if one compares the most widely used published methods for estimating stature from skeletal remains, it is easy to see that the Fully and Pineau regression equations (above) based on five lumbar vertebrae and either the femur or the tibia have decidedly smaller standard errors than the Trotter and Gleser equations, which are based on long bones alone.This is not surprising given the added input into the French formulations. Therefore, so long as one is dealing with males of European descent. (14)

Preferred Equations and Summary Data from Trotter and Gleser, 1952 Equation Standard Error N Mean Variance White males 2.38 fem(þ) 61.41 +3.27 714 47.32 5.59 2.68 fib(þ) 71.78 +3.29 580 38.15 4.39 Black males 2.11 fem(þ) 70.35 +3.94 80 48.24 5.04 2.19 fib(þ) 85.65 +4.08 68 39.80 4.92 White females 2.47 fem(þ) 54.10 +3.72 63 42.96 6.41 2.93 fib(þ) 59.61 +3.57 63 34.34 4.59 Black females 2.28 fem(þ) 59.76 +3.41 177 43.71 5.72 2.49 fib (þ) 70.90 +3.80 177 35.55 4.41 82 STATURE ESTIMATION advisable to use the Fully and Pineau method. However, it is important to follow the methodology correctly, including measurements and cautions. For the Fully anatomical method (1956) there is no regression equation given, and, therefore, no standard error**. However, in their 1960 publication Fully and Pineau do present a prediction formula Stature ¼ skeletal height þ 10:8 + 2:05 cm This standard error of 2.05 cm is a good proxy for the estimate of precision of the Fully anatomical method.**

It is decidedly smaller than any regressions based on long bones. In 1988 Lundy reported a comparison of Fully’s anatomical method with Trotter and Gleser’s regression equations for three military cases with recorded antemortem stature. The Fully estimate was closer to recorded stature than the Trotter–Gleser central tendency estimate in two of these cases. In one case the recorded stature lay outside the +1 standard error of the Trotter–Gleser estimate, but was within +2 standard errors.

Reporting Stature Estimates It is hard to overstate the importance of regularly reporting 95 % confidence intervals for stature estimates. These range from a minimum of nearly 5 inches up to more than 8 inches. In the ideal circumstance where the unknown individual is representative of an ethnic group for which there is a regression equation based on a large sample, the 95% interval will encompass the living stature 19 out of 20 times in the long run. In other words, one can use these large intervals and still miss the stature about one in 20 times. This is if all factors, such as age corrections if appropriate, have been applied. There is no way around this 5 % error ratio. You can do worse, but not better without increasing to, say, 99 % confidence intervals that are far too large to have practical use. In one case I had, the reported stature for a young man was only 1 8 inch inside the calculated lower 95 % confidence limit, which drew the attention of an attorney. It happens. It also happens that stated interval and reported stature do not coincide. You may have some statistical explaining to do.

To make matters worse, 95 % confident is often really overconfident. Perhaps the ethnicity is unknown or not represented by reliable and appropriate regression equations, an increasingly common situation as more immigrants of non-European and non-African descent, sometimes from impoverished backgrounds, join the North American population. It is a situation that requires a judgment call based on circumstances. Increasing the size of the 95 % confidence interval by some degree to compensate for uncertainties is not out of the question.

If the long bone being used for the stature estimate is reasonably close to the mean of the sample used to produce the regression equation, then doubling the standard error interval is a decent approximation of the 95 % confidence.

However, for those one-third that are more than one standard deviation from the database mean, the 95 % confidence interval should be calculated (see Giles and Klepinger, 1988; Klepinger and Giles, 1998 for discussion and details). The calculation for the predicted stature Yx for bone length X is Yx + tsyx½1 þ 1=N þ (X X) 2 =(N 1)s 2 x 1=2 where syx ¼ sample standard error of the estimate for the regression of Y on X, X ¼ known long bone length, X ¼ mean of the sample database values of X, sx 2 ¼ variance of the sample values of X, N ¼ sample size, and t ¼ distribution value at the desired level (0.975) with N 2 2 degrees of freedom. Because the standard errors of the estimate increase as the unknown measurement or stature deviates from the sample mean, doubling the standard error to approximate the 95 % confidence interval becomes correspondingly increasingly inaccurate.

Correcting Stature Estimates for Older Adults "Asked in her mid-80s how tall she was, [Babe Ruth's sister] Mamie smiled and said, 'Four feet eight, I used to be four feet ten, but I shrunk.'" — (Robert Creamer, "Rutholatry, or why everyone loves the Babe." Smithsonian, February 1995, pp. 68 – 79.) Stature loss accompanying advancing age stems from changes and/or loss in both bone and soft tissues.

Since the vertebral column is the structure responsible for the major portion of loss of standing height, stature estimates deriving from long bone measurements (wholly or in part) will overestimate stature if not corrected.

Trotter and Gleser's (1951) correction, subtracting 0.06 cm for each year over 30, viewed stature loss as linearly progressive, beginning in fairly early adulthood. This assumption was challenged (Hertzog et al., 1969) by a study of stature and radiogrammetric tibia length that separated male and female analyses and recognized nonlinearity of the age effect. However, the study did not offer a readily usable methodology for stature estimation. Galloway (1988) compared measured and reported statures of 550 living Caucasians aged 50 – 92. Her study pointed to a roughly linear loss from reported maximum stature for both men and women, probably beginning at the age of 45 years. Even her recommended correction factor was to subtract from calculated stature estimates 0.16 cm for each year over 45.

In 1991 Giles utilized data from two large (over 1200 men and over 1000 women) longitudinal studies of stature change over 10 years for men and over at least 5 years for women. The longitudinal study design eliminated the confounding secular trend that affects cross-sectional studies. This study also found no stature loss before age 45. The modest difference between the sexes was characterized by earlier and more pronounced stature loss among men until around age 75, when women's stature loss became permanently greater. Stature loss did accelerate with age, so a simple correction factor applicable over the 40 – 85 year age range is not appropriate.

To abbreviate the table in Giles (1991), one can safely ignore correction before age 50. From then on the age-appropriate centimeters should be subtracted from the maximum stature calculation. The differences between the three major methods published specifically for application to forensic stature estimation are not trivial. For example, female stature loss by age 85 calculated by the three methods gives: Trotter and Gleser (1951) 3:3 cm (1:3 inches) Galloway (1988) 6:4 cm (2:5 inches) Giles (1991) 4:9 cm (1:9 inches) Because of the sample sizes and longitudinal design, the data analyzed by Giles yield the currently best correction factors.[14]

Except for the Trotter and Gleser (1951) study using partial correlations of Terry Collection data, all of the studies rely on data from Caucasian groups only.Moreover Galloway (1988) advised that both maximum stature and age-corrected stature estimates be included in forensic reports because older people often ignore or do not recognize the extent of their height shrinkage when reporting their stature[14]

Age corrections are at best crude approximations. Individual pathologies, like vertebral collapse, can result in extensive stature loss, but these can usually be readily observed and accounted for. A more subtle source of error is that estimates of age in older adults encompass very large ranges, so picking a mean age estimate for subsequently estimating stature loss is an approximation that may be off by ten years or more. In other words, anthropologists often ignore or do not recognize the extent of their uncertainty. Secular Trend Over the past two decades a great deal of discussion has centered about the forensic import of the secular trend towards increased stature.[14]

For these issues see Jantz (1992, 1993), Giles (1993), Meadows and Jantz (1995), Ousley (1995), Ousley and Jantz (1998), Klepinger (2001). All of this attention may be more than the topic deserves. It is certainly true that mean stature has increased over the past century or two, but there have always been short and tall people who need to be accounted for.

The 95 percent confidence interval will include their ante-mortem stature 95 % of the time. The advantage of having regression formulae based on samples more representative of modern statures is that the 95 % confidence intervals will be somewhat smaller than those for formulae based on shorter people.

The Forensic Databank comprises measurements and reported statures sent in by forensic caseworkers around the county**. However, should it necessarily replace the Trotter and Gleser formulae? That is debatable. The Trotter and Gleser formulae also have some advantages.** The formulae and statistics are published, allowing a worker to customize confidence levels, check the statistics, and even catch errors, such as the tibia measurement. They also have the advantage of using consistently measured cadaveral stature, rather than necessarily relying on many different measurers and, as we have seen, reported stature estimates of dubious accuracy. However, the Trotter and Gleser sample sizes for females could definitely be larger.

It may take some time to acquire sufficient data to produce reliable equations for the new ethnic migrants, but herein lies a really valuable potential contribution of the Forensic Database. Stature Estimates from Fragmentary Long Bones Situations arise in which no complete long bone can be found or accurately reconstructed. [(14)]

In 1970 Steele (see also Steele and Bramblett, 1988) presented regression formulae for the complete long bone from various measured long bone segments. It even included are formulae for the direct estimation of stature from fragmentary long bones when only one or both ends are missing.

The equations are based on measurements from the Terry Collection for humerus,tibia and femur. Either procedure, one regression equation or two consecutive regressions, results in standard errors that are larger than those for complete bones. The 95 % confidence intervals are correspondingly enlarged to 8 or 10 inches. Nevertheless, such an estimate does narrow the field somewhat and may even provide an identification exclusion.

Approach to the fragmented bone challenge has been done by Holland (1992), who devised regression equations for estimation of stature from measurements of the superior surface of the proximal tibia. Based on smallish sample data from the Hamann–Todd Collection, these regressions still sport hefty standard errors, but avoid the use of Trotter and Glesertibial length equations and the problems of measurement point uncertainties associated with the Steele method. [(14)]

Stature Estimation from Short Bone Length Sometimes complete metacarpals or metatarsals may be recovered when all long bones are incomplete. Meadows and Jantz (1992) have presented regression equations based on lengths of the metacarpals. This measurements vary from each race. Using measurements from the Terry Collection they produced versions for male and female, black and white. All of the standard errors are about 2 inches or more, which is comparable to those based on long bone fragments, depending on the specific metacarpal and specific long bone fragment. Byers et al. (1989) have presented a methodology based on metatarsal length. Footwear may protect and preserve the feet when the rest of the corpse has been badly damaged.(14)

ULNA:

The ulna is medial to the radius in the supinated forearm. Its proximal end is a massive hook which is concave forwards. The lateral border of the shaft is a sharp interosseous crest. The bone diminishes progressively from its proximal mass throughout almost its whole length, but at its distal end expands into a small rounded head and styloid process. The shaft is triangular in section but has no appreciable double curve. In its whole length it is slightly convex posteriorly. Mediolaterally, its profile is sinuous. The proximal half has a slight laterally concave curvature, and the distal half a medially concave curvature.(15)

Fig. 4 - LEFT ULNA

Fig. 5 - RIGHT ULNA

PROXIMAL END

The proximal end has olecranon and coronoid processes and trochlear and radial notches which articulate with the humerus and radius. More proximal is the olecranon and is bent forwards at its summit like a beak. It enters the humeral olecranon fossa in extension. Its posterior surface is smooth, triangular and subcutaneous, and its proximal border contains the 'point' of the elbow. In extension it can be felt near a line which joins the humeral epicondyles, but in flexion it descends, so that the three osseous points form an isosceles triangle. Its anterior, articular surface forms the proximal area of the trochlear notch. Its base is slightly constricted where it joins the shaft and is the narrowest part of the proximal ulna. The coronoid process projects anteriorly distal to the olecranon. [15]

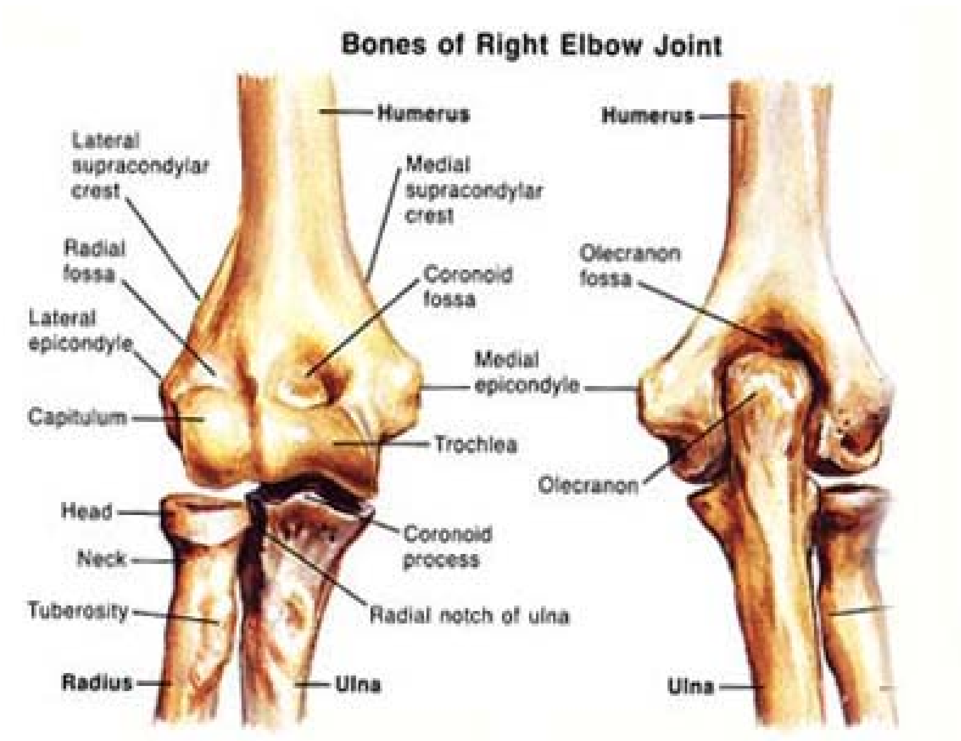


Fig. 6 - RIGHT ELBOW JOINT

Its proximal aspect forms the distal part of the trochlear notch. On the lateral surface, distal to the trochlear notch, there is a shallow, smooth, oval radial notch which articulates with the radial head. Distal to the radial notch the surface is hollow to accommodate the radial tuberosity during pronation and supination. The anterior surface of the coronoid is triangular. Its distal part is the tuberosity of the ulna. Its medial border is sharp and bears a small tubercle proximally.[15]

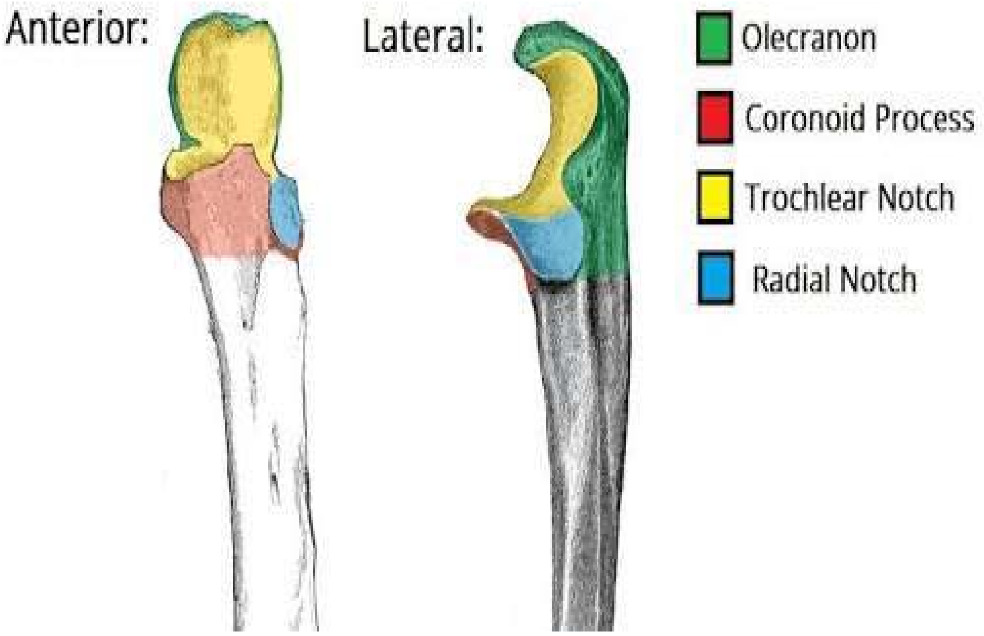


Fig. 7 - PROXIMAL END OF ULNA

The trochlear notch articulates with the trochlea of the humerus.. A smooth ridge, adapted to the groove on the humeral trochlea, divides the notch into medial and lateral parts. The medial fits into the trochlear flange. The radial notch, an oval or oblong proximal depression on the lateral aspect of the coronoid process, articulates with the periphery of the radial head, and is separated from the trochlear notch by a smooth ridge.[15]

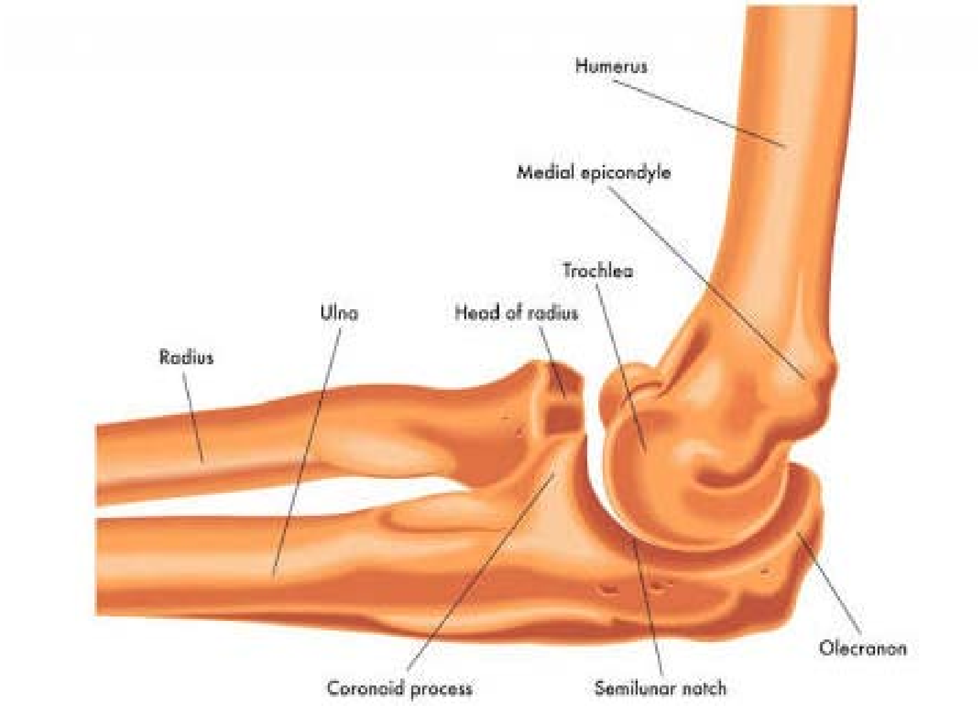


Fig. 8 - LATERAL VIEW OF ELBOW JOINT

SHAFT

The shaft is triangular in section in its proximal three-fourths, but distally is almost cylindrical. It has anterior, posterior and medial surfaces and interosseous, posterior and anterior borders. The interosseous border is a conspicuous lateral crest in its middle two-fourths. Proximally it becomes the supinator crest, which is continuous with the posterior border of a depression distal to the radial notch. Distally, it disappears. The rounded anterior border starts medial to the ulnar tuberosity, descends backwards, and is usually traceable to the base of the styloid process. The posterior border, also rounded, descends from the apex of the posterior aspect of the olecranon, and curves laterally to reach the styloid process. It is palpable throughout its length in a longitudinal furrow which is most obvious when the elbow is fully flexed.(15)

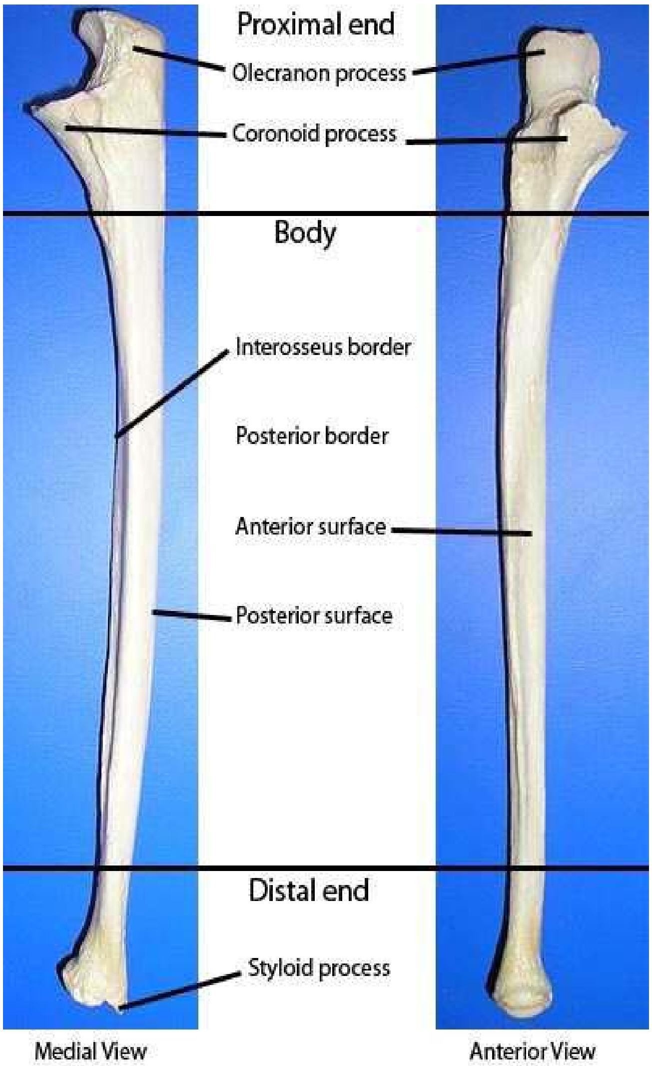


Fig. 9 - SURFACE AND BORDERS OF RIGHT ULNA

The anterior surface, between the interosseous and anterior borders, is longitudinally grooved, sometimes deeply. Proximal to its midpoint there is a nutrient foramen, which is directed proximally and contains a branch of the anterior interosseous artery. Distally, it is crossed obliquely by a rough, variable prominence, descending from the interosseous to the anterior border. The medial surface, between the anterior and posterior borders, is transversely convex and smooth. The posterior surface, between the posterior and interosseous borders, is divided into three areas. The most proximal is limited by a sometimes faint oblique line ascending laterally from the junction of the middle and upper thirds of the posterior border to the posterior end of the radial notch. The region distal to this line is divided into a larger medial and narrower lateral strip by a vertical ridge, usually distinct only in its proximal three-fourths.(15)

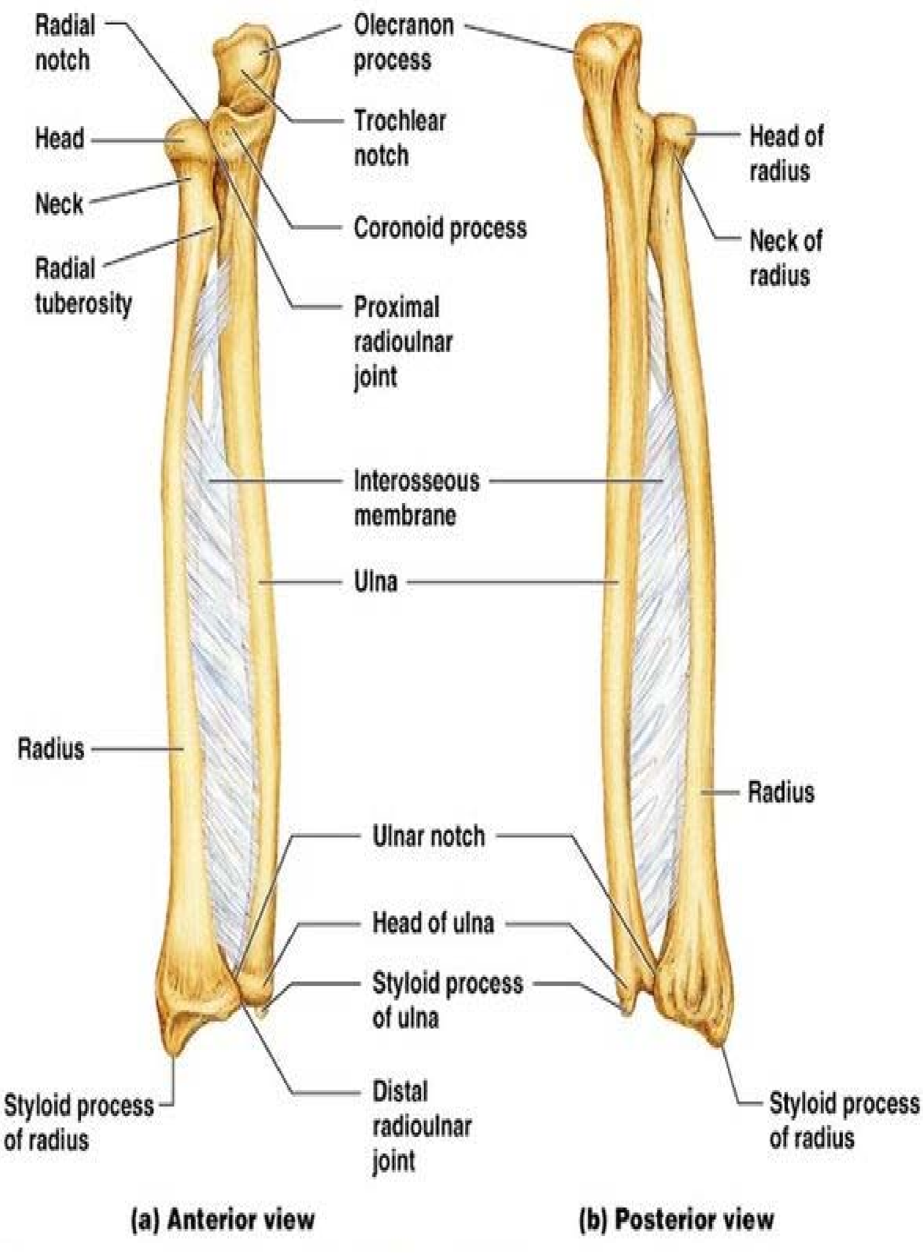


Fig. 10 - INTEROSSEOUS MEMBRANE

DISTAL END

The distal end is slightly expanded and has a head and styloid process. The head is visible in pronation on the posteromedial carpal aspect, and can be gripped when the supinated hand is flexed. Its lateral convex articular surface fits the radial ulnar notch. Its smooth distal surface is separated from the carpus by an articular disc, the apex of which is attached to a rough area between the articular surface and styloid process. The latter, a short, round, posterolateral projection of the distal end of the ulna, is palpable (most readily in supination) about 1 cm proximal to the plane of the radial styloid. A posterior vertical groove is present between the head and styloid process.[15]

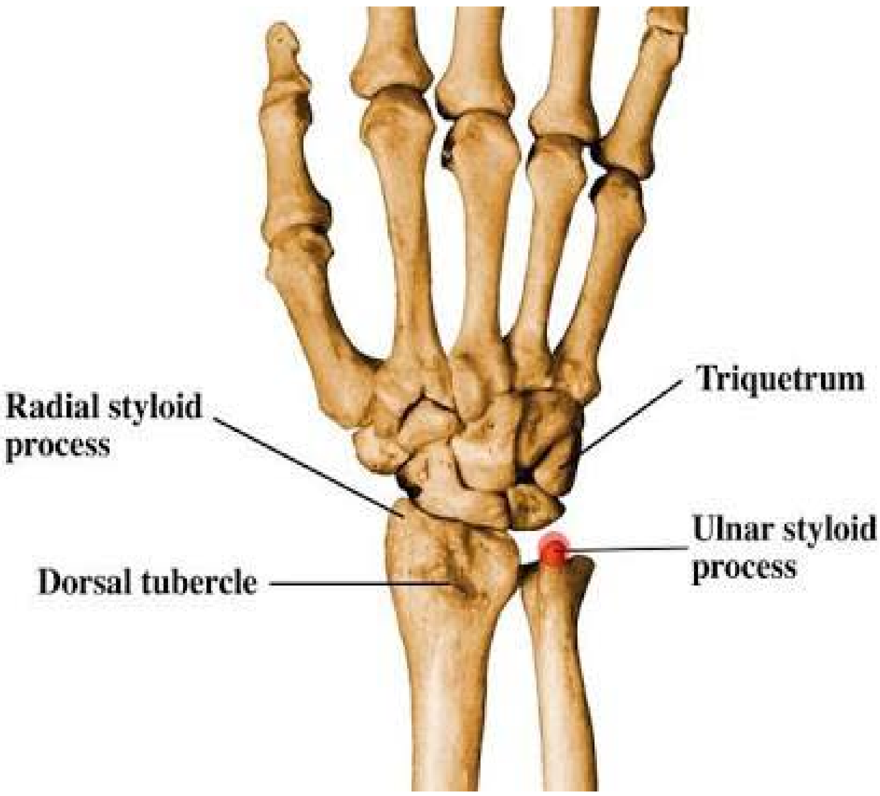


Fig. 11 - DISTAL RADIO ULNAR JOINT

Muscle, ligament and articular attachments

Anteriorly, the capsule of the elbow joint is attached to the proximal olecranon surface. The tendon of triceps is attached to its rough posterior two-thirds: the capsule and tendon can be separated by a bursa. The medial surface of the olecranon is marked proximally by the attachment of the posterior and oblique bands of the ulnar collateral ligament and the ulnar part of flexor carpi ulnaris. The smooth area distal to this is the most proximal attachment of flexor digitorumprofundus. Anconeus is attached to the lateral olecranon surface and the adjoining posterior surface of the ulnar shaft as far as its oblique line. The posterior surface of the ulna is separated from the skin by a subcutaneous bursa.(15)

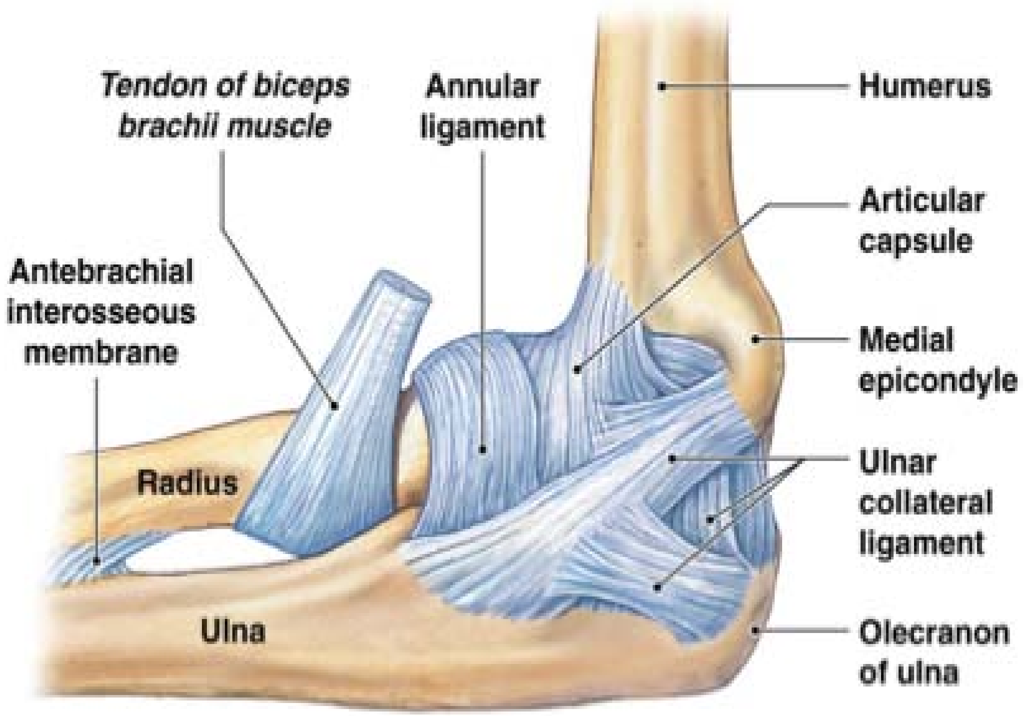


Fig. 12 - LIGAMENTS OF ELBOW JOINT

Brachialis is attached to the anterior surface of the coronoid process, including the ulnar tuberosity. The oblique and anterior bands of the ulnar collateral ligament and the distal part of the humero-ulnar slip of flexor digitorumsuperficialis are attached to a small tubercle at the proximal end of the medial border. Distal to this the margin provides attachment for the ulnar part of pronator teres. An ulnar part of flexor pollicislongus may be attached to the lateral or, more rarely, the medial border of the coronoid process. Fibres of flexor digitorumprofundus are attached to its medial surface. The annular ligament is attached to the anterior rim of the radial notch and posteriorly to a ridge at or just behind the posterior margin of the notch. The depressed area distal to the notch is limited behind by the supinator crest, and both provide attachment for supinator.[15]

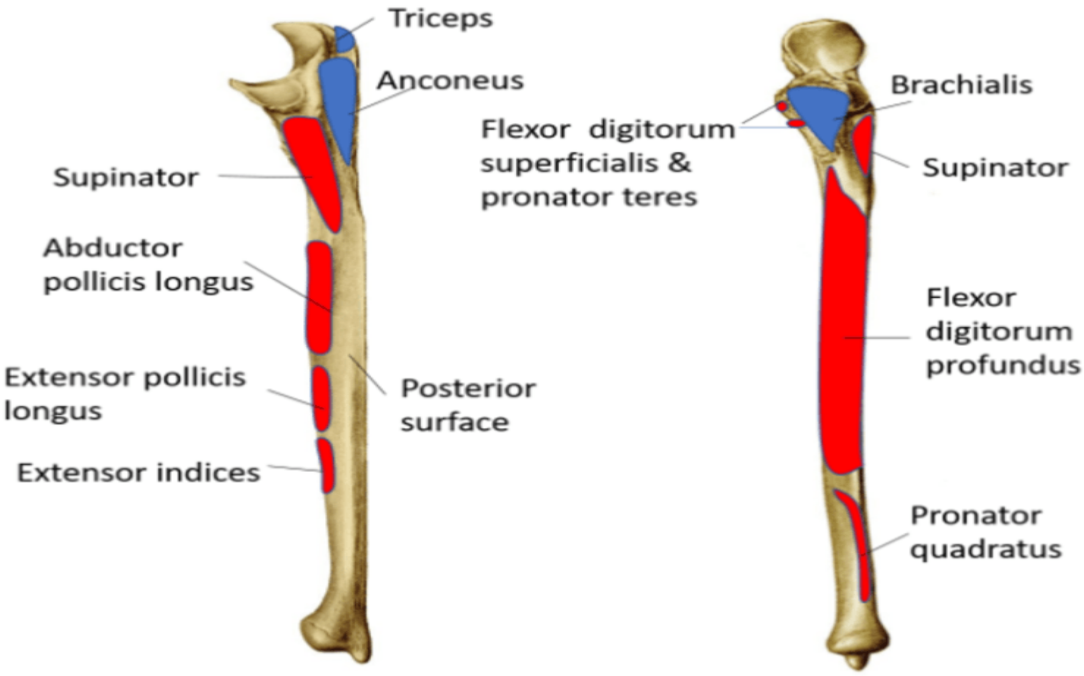


Fig. 13 - MUSCLE ATTACHMENTS OF ULNA

The olecranon area of the trochlear notch is usually divided into three areas. The most medial faces anteromedially, and is grooved to fit the medial flange of the humeral trochlea, with which it makes increasing contact during flexion. A flat intermediate area fits the lateral flange, and the most lateral area, a narrow strip, abuts the trochlea in extension. The articular surface is narrower than the base of the olecranon: non-articular parts are related to the synovial processes. The coronoid area of the trochlear notch is also divided, and its medial and lateral areas correspond to medial and intermediate areas of the olecranon. The medial is more hollow, and conforms to the convex medial trochlear flange. The medial and anterior parts of the capsular ligament are attached to its medial and anterior borders.(15)

The deep fascia of the forearm is attached to the subcutaneous posterior border. This border also provides an attachment for the aponeurosis of flexor digitorumprofundus in its proximal threequarters, for flexor carpi ulnaris in its proximal half, and for extensor carpi ulnaris in its middle third. These three muscles connect with the posterior border through a common blended aponeurosis. The interosseous membrane is attached to the interosseous border, except proximally.(15)

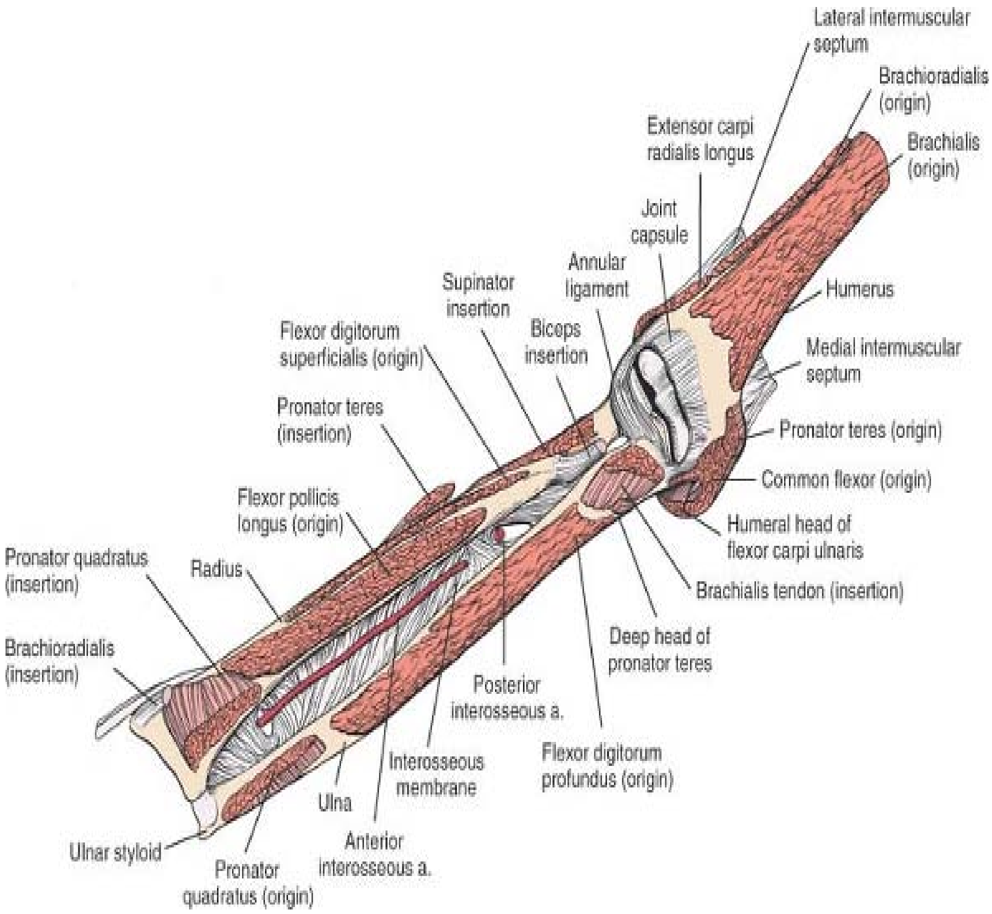


Fig. 14 - MUSCLE ATTACHMENTS AROUND ELBOW JOINT

Flexor digitorumprofundus is attached to the proximal three-fourths of the anterior border and medial surface, attaching medial to the coronoid process and olecranon. The rough strip across the distal fourth of the anterior surface provides part of the bony attachment for pronator quadratus. Anconeus is attached to the posterior surface proximal to the oblique line and lateral to the olecranon. The narrow strip between the interosseous border and vertical ridge gives rise to the attachment of three deep muscles: abductor pollicislongus arises from the proximal fourth, extensor pollicislongus arises from the succeeding fourth (sometimes a ridge is interposed between them), and extensor indicis is attached to the third quarter. The broad strip medial to the vertical ridge is covered by extensor carpi ulnaris, whose tendon grooves the posterior aspect of the distal end of the ulna. The ulnar collateral ligament is attached to the apex of the styloid process.[15]

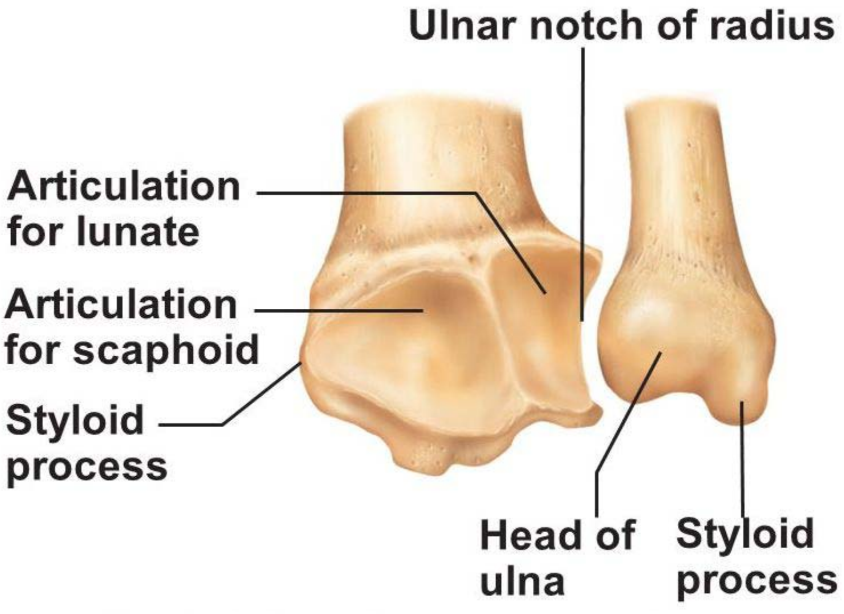


Fig. 15 - ARTICULATING SURFACE OF LOWER END OF ULNA

VASCULAR SUPPLY

Multiple metaphysial nutrient foramina transmit branches of the radial, ulnar, anterior and posterior interosseous arteries. These vessels give off a number of smaller segmental branches. Usually one, but occasionally two, major nutrient diaphysial foramina are located on the anterior surface of the bone, directed proximally toward the elbow. A network of small fascioperiosteal and musculoperiosteal branches given off from the compartmental vessels reaches the bone via septal and muscular attachments.[15]

RADIO ULNAR JOINT:

Articulating surfaces

The articulating surfaces are between the convex distal head of the ulna and the concave ulnar notch of the radius, and are connected by an articular disc.

Fibrous capsule

The fibrous capsule is thicker anteriorly and posteriorly, but the proximal part of the capsule is lax.[15]

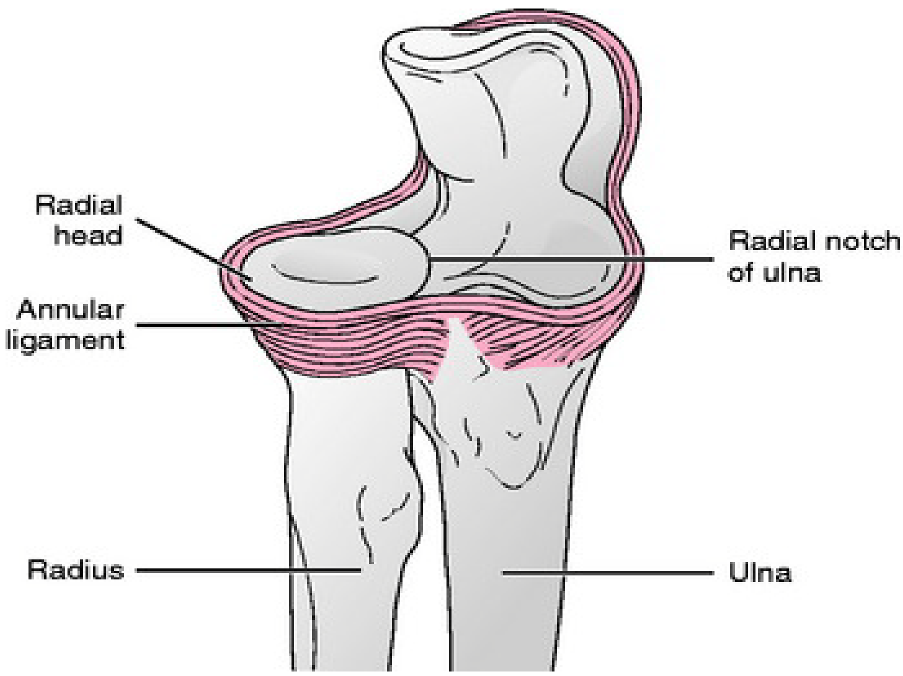


Fig. 16 - ANNULAR LIGAMENT

Articular disc

The articular disc is fibrocartilaginous (collagen with few elastic fibres in the young) and is triangular, binding the distal ends of the ulna and radius. Its periphery is thicker, its centre sometimes perforated. The disc is attached by a blunt, thick apex to a depression between the ulnar styloid process and distal articular surface, and by its wider thin base to the prominent edge between the ulnar notch and carpal articular surface of the radius. Its margins are united to adjacent carpal ligaments, its surfaces are smooth and concave: the proximal articulates with the ulnar head, the distal is part of the radiocarpaljoint, and articulates with the lunate and, when the hand is adducted, the triquetrum. The disc shows age-related degeneration, becoming thinned and ultimately perforated in about half the subjects over the age of 60.[15]

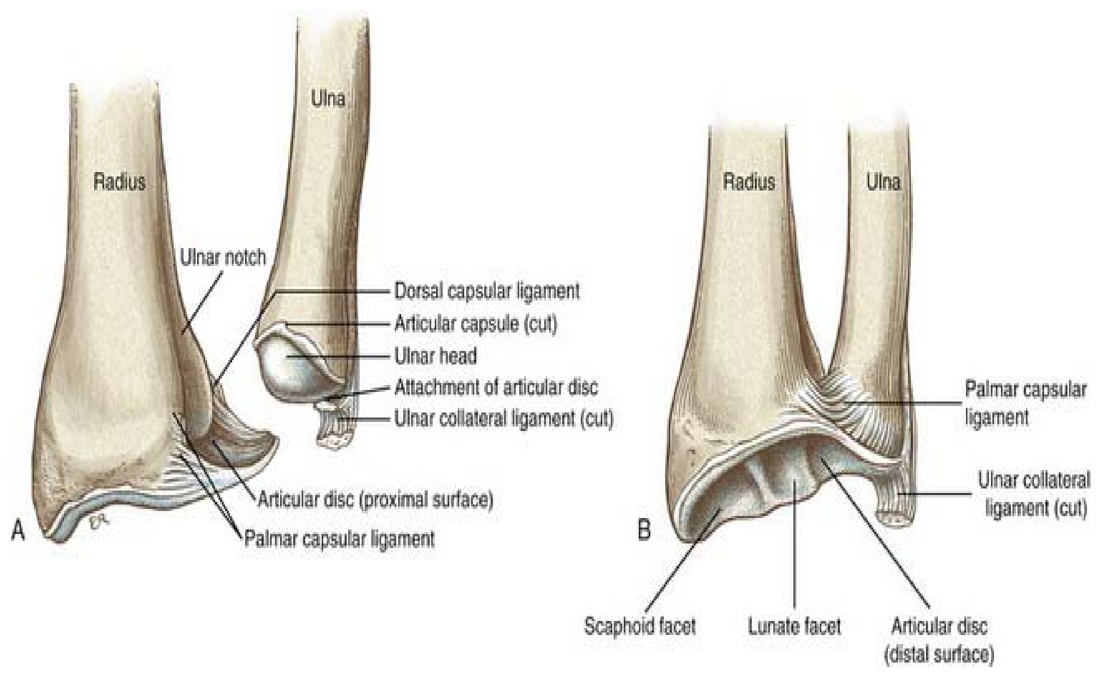


Fig. 17 - ARTICULAR DISC

Synovial membrane

The capsule is lined by synovial membrane which projects proximally between the radius and ulna as a recessus sacciformis in front of the distal part of the interosseous membrane.(15)

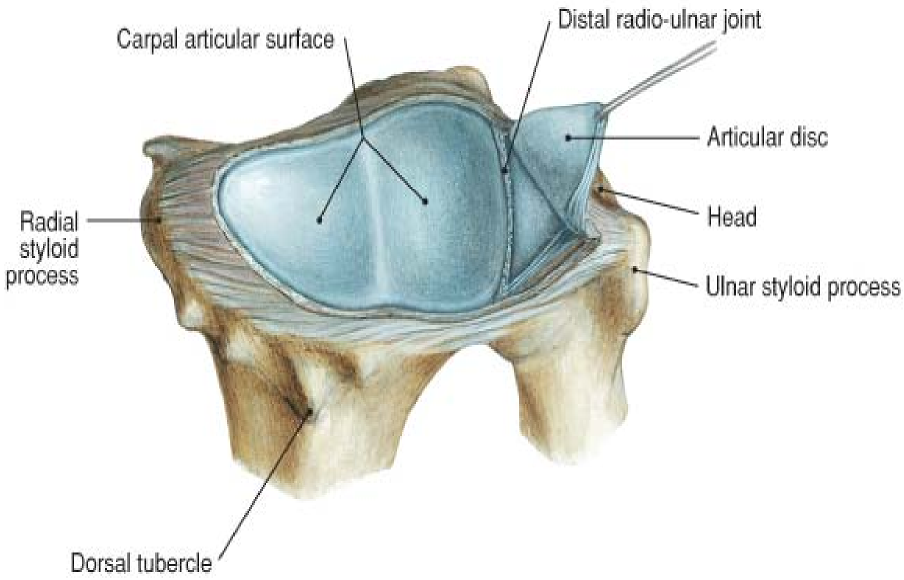


Fig. 18 - SYNOVIAL MEMBRANE

Vascular supply and lymphatic drainage

The arterial supply to the distal radio-ulnar joint and disc is mainly derived from the palmar and dorsal branches of the anterior interosseous artery, reinforced by the posterior interosseous and ulnar arteries.(15)

Innervation

The distal radio-ulnar joint is innervated by branches of the anterior and posterior interosseous nerves.(15)

Movements

Movements at the radio-ulnar joint includes pronate and supinate the hand. In pronation the radius, carrying the hand, turns anteromedially across the ulna, its proximal end remains lateral, its distal becomes medial. During this action the interosseous membrane becomes spiralled. In supination the radius returns to a position lateral and parallel to the ulna and the interosseous membrane becomes unspiralled. With the extended elbow the hand can be turned through 140–150°, this can be increased to nearly 360° by scapular movements and humeral rotation.. Power is greater in supination, a fact which has affected the design of nuts, bolts and screws, which are tightened by supination in right-handed subjects. Moreover, supination is an antigravity movement with a pendent upper arm and semiflexed forearm; in seizing objects for examination or manipulation, pronation is merely a preliminary and is aided by gravity.(15)

Forearm rotation occurs between the articulation of the head of the ulna and sigmoid notch distally, and the radial notch of the ulna and the head of the radius proximally. These distal and proximal radio-ulnar joints are pivot-type synovial joints: they act as a pair permitting stable rotary motion

pronation 61–66°, supination 70–77°). During rotation, the radius moves around the ulnar head. The axis for pronation and supination is often represented as a line through the centre of the radial head (proximal) and the ulnar attachment of the articular disc (distal). (15)

More correctly this is the axis of movement of the radius relative to the ulna and it does not remain stationary. The radial head rotates in the fibro-osseous ring: its distal lower end and articular disc swing round the ulnar head. During rotation of the radial head its proximal surface spins on the humeral capitulum. As the forearm moves from full pronation into supination the ulna translocates medially by 9–10 mm, such that the axis of rotation shifts but still passes through the ulnar head. In addition the sigmoid notch changes its contact position with the ulnar head, lying dorsal proximal in pronation and volar distal in supination. The distal end of the ulna is not stationary during these movements; it moves a variable amount along a curved course, posterolaterally in pronation, anteromedially in supination. (15)

The axis of movement, as defined above, is therefore displaced laterally in pronation, medially in supination. Hence the axis for supination and pronation of the whole forearm and hand passes between the bones at both the superior and distal radio-ulnar joints when ulnar movement is marked, but through the centres of the radial head and ulnar styloid when it is minimal. The axis may be prolonged through any digit, depending on the medial or lateral displacement of the distal end of the ulna. **The hand will rotate further than the forearm because of the sliding–rotatory movement** which occurs between the carpal bones and the bases of the metacarpals and, to a very minor degree, at the radiocarpal joint.(15)

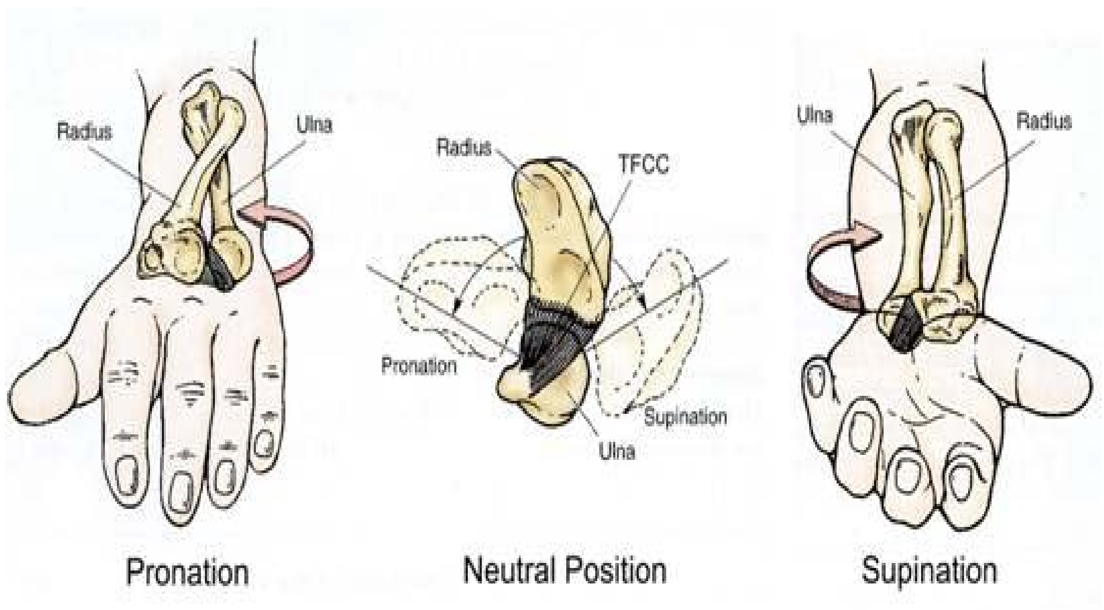


Fig. 19 - PRONATION AND SUPINATION OF WRIST JOINT

Accessory movements

Accessory movements include anterior and posterior translation of the radial head on the ulnar radial notch, and of the ulnar head likewise on the radial ulnar notch.(15)

Muscles producing movement

The muscles producing movements at the distal radio-ulnar joint are as follows.

Pronation

Pronator quadratus, aided in rapid movement and against resistance by pronator teres. Gravity also assists.(15)

Supination

Supinator, in slow unresisted movement and extension, assisted by biceps in fast movements in flexion, especially when resisted.

Electromyographic studies have not confirmed activity in brachioradialis during pronation and supination.

Ossification

The ulna ossifies from four main centres, one each in the shaft and distal end and two in the olecranon. Ossification begins in the midshaft about the eighth fetal week, and extends rapidly. In the fifth (females) and sixth (males) years, a centre appears in the distal end, and extends into the styloid process. The distal olecranon is ossified as an extension from the shaft, the remainder from two centres, one for the proximal trochlear surface, and the other for a thin scale-like proximal epiphysis on its summit. The latter appears in the ninth year in females, 11th in males. The whole proximal epiphysis has joined the shaft by the 14th year in females, sixteenth in males. The distal epiphysis unites with the shaft in the 17th year in females, 18th in males.[15]

Fig. 20 - X-RAY LATERAL VIEW OF RIGHT ELBOW JOINT

Fig. 21 - X-RAY AP VIEW LEFT HAND WITH WRIST JOINT

(OSSIFICATION CENTRES NOT FUSED)

Fig. 22 - X – RAY AP VIEW LEFT HAND WITH WRIST JOINT (OSSIFICATION CENTRES FUSED)

HISTORY:

Height estimation by measurement of various long bones has been attempted by several workers. There are indications that mobility in general has declined between European Mesolithic and late Neolithic, and that body size and shape may have become more variable throughout the continent following the Upper Paleolithic (The strange Horizon, a journal of Anthropology: 1996-1997). [16]

Dwight (1894) suggested two methods for estimation of stature from skeletal remains, i.e. Anatomical and Mathematical. The anatomical method involves in simply arranging the bones together, in reproducing the curves of the spine, in making respective allowance for the soft parts and measuring the total length. This method is workable when a complete skeleton is available. The mathematical method on the other hand is based on the relationship of individual long bone to the height of an individual and is workable even if a single long bone is available for examination. This method may be used either by **computing Multiplication Factor (M.F.) or by formulating regression formulae.**[16]

Due to the obvious disadvantage of using anatomical method where complete skeleton is required, Fully (1956) implemented certain modifications for its easy workability. He computed percentage(%) contribution of each vertebra to the total height of the column.

Thus using these values for missing vertebra and measuring the remaining, the height of the vertebral column is derived by a simple proportionality equation, besides this Fully employed methodology following cranial and other measurements are used for the purpose of stature estimation.

Estimation:

1. Basion - bregma height,
2. First sacral segment height,
3. Oblique length of femur,
4. Tibial length, and
5. Tarsal height.

After obtaining these measurements and adding the total height of the vertebral column one may obtain skeletal height, which can be used in the following regression equation to obtain living stature or ante mortem height.(16)

Living stature=0.98(total skeletal height) 14.63±2.05 cm

Further suggested addition of a correction factor (CF) to the fully stature thus obtained:

Estimated stature up to 153.5 cm add10 cm to the result,

Estimated stature between 153.6 and 165.4 cm add 10.5 cm to the result,

Estimated stature above 165.5 cm add 11.5 cm to the result.

The main advantage of Fully's method over the Dwight's is that one need not articulate the complete skeleton as described by Dwight. Secondly, this method is applicable universally to males and females of any population around the world.

Despite Fully's (1956) attempt to make the anatomical method workable even if a couple of vertebrae are missing as well as highlighting its universal applicability and greater accuracy in the predicted stature, the mathematical method gained more popularity with its obvious advantage that it is more convenient in use as it requires only length of the recovered long bone. The bone length may be entered into respective regression formulae or multiplied with the specific multiplication factor to obtain the estimated height. Somehow this method was in use even before Dwight could name it.

Beddoes (1887) made the first attempt to estimate stature from femoral length of ‘Older Races of England’ for either sex. Subsequently Rollet (1888) published the earliest formal tables for determining stature using all the six long bones of the upper and the lower limbs of 50 male and 50 female of French cadavers ranging in age from 24 to 99 years.[16]

Manouvrier (1892) re-examined Rollet’s data by excluding 26 males and 25 females above the age of 60 years and based on his prediction tables on 24 males and 25 females. He also suggested that the length of trunk declines by about 3 cm of their maximum stature due to the effect of old age. The major differences between the approaches of Rollet and Manouvrier are that the latter determined the average stature of individuals who possessed the same length of a given long bone while the former determined the average length of a given long bone from individuals with identical stature.

Manouvrier further suggested that while determining the stature from dried bones, 2mm should be added to the bone length for cartilage loss and subsequently 2 cm should be added to the corresponding stature to convert the cadaveric stature to the living stature[16].\

Pearson (1899), after Dwight had named the two methods of stature reconstruction, using Rollet’sdata. He developed regression equations for prediction of stature from long bone lengths. He restricted his study to four bones only, i.e. humerus, radius, femur and tibia. Stature prediction from measurement of long bones with the help of correlational calculus was first introduced by Professor Pearson.[17]

Pan (1924) worked on cadavers and derived relation between total ulnar length and total height of an individual. Since then many workers carried out work on cadavers as well as living and gave different formulae's for stature reconstruction from total length of different bones.

Telkka studied 115 male and 39 female dry skeletons. He took the maximum length of tibia for the purpose of finding out the stature of Finnish population; he opined about the need of a separate formula for the estimation of stature of different racial population.

Dupertius and Haddensummarized that long bones of lower extremity usually gives a closer estimate of stature than long bones of upper extremities.

Allbrookattempted to measure percutaneous tibial lengths from the medial condyle to the tip of medial malleolus with knee semi-flexed and foot partly everted and deduced the following formulae: 88.78 + 2.30 T (where, T=Tibial length).

Lundy concluded that length of the lower extremity provides the best estimate to measure stature of an individual.

Nineteenth century was nearing its end when anthropologists convened an international meeting in Geneva and promulgated the need of measuring oblique length of bones for correct estimation of stature.

Mohanty attempted to correlate percutaneous tibial lengths (from the medial condyle to the tip of medial malleolus) and stature of 1000 adult individuals belonging to the state of Orissa. [18]

METHODOLOGY

STUDY SETTING:

The present study was carried out in Government Kilpauk Medical College &Hospital (GKMC) Chennai.-10

STUDY DESIGN:

This study was a cross sectional one with both descriptive and analytical components. . The descriptive component to find out mean heights ulnar lengths of both hands of male and female study participants. The analytical component was used to evaluate the correlation between the height and length of ulna bone and to arrive at a regression equation for height with length of ulna in both sexes

SAMPLE SIZE:

Based on the intense review of literature on estimation on estimation of human stature from length of ulna in indian population[21], with a mean of 26.92, SD of 1.32 for males and with a mean of 21.75, SD of 0.92 for females and with the limit of accuracy as 1% of the mean, the sample size was calculated to be 162.

$N = 1.96^2 x 1.32^2 / 0.269^2 = 96$ males and

$N = 1.96^2 x 0.92^2 / 0.22^2 = 66$ females

About 10 % of the sample size (20) was added to take care of any refusal to participate in the study and the total sample size arrived for the study is 182. The final corrected sample size was 200.

STUDY POPULATION:

The study subjects are all medical and paramedical students of various batches in Government Kilpauk Medical College and Hospital of age group between 18 to 22 years who belonged to Chennai population (Born & Brought up in Chennai).

STUDY PERIOD:

The data collection was spread over a period of six months extending from the month ofOctober 2016 to February 2017.

ELIGIBILITY CRITERIA:

Inclusion criteria was male or female healthy medical and paramedical students of age(18-22) years from KMC, Chennai who were born and brought up in Chennai**, subjects with skeletal abnormalities like achondroplasia, polio, scoliosis, previous fractured forearm, amputated upper limb and students from other than those not born and brought up in Chennai were excluded out from the study.**

TOOLS FOR DATA COLLECTION:

Written informed consents were obtained from the study participants prior to the interview as enclosed in Annexure I. Participants were asked to visit the department of forensic medicine at Government Kilpauk Medical College, Chennai. Interview schedule includes a structured questionnaire as enclosed in Annexure II. After getting informed written consent, all male student measurements were carried out by the primary investigator himself and all females by a trained female tutor of the same department under the supervision of the department Professor & HOD to avoid observational bias.

Measurements were taken using standard anthropometric instruments namely vernier calipers and stadiometer. Length of ulnar was measured with the help of **Vernier caliper from tip of olecranon process to tip of styloid process with the forearm flexed 90* and hand touching the opposite shoulder for both sides. Height was measured in standing position with barefoot in the stadiometer with head oriented in Frankfurt plane.** Measurements were taken by the sliding the horizontal part to the vertex in the sagittal line. All measurements were taken **around 2 to 4 PM to avoid diurnal variation.**

Fig. 23 - STADIOMETER

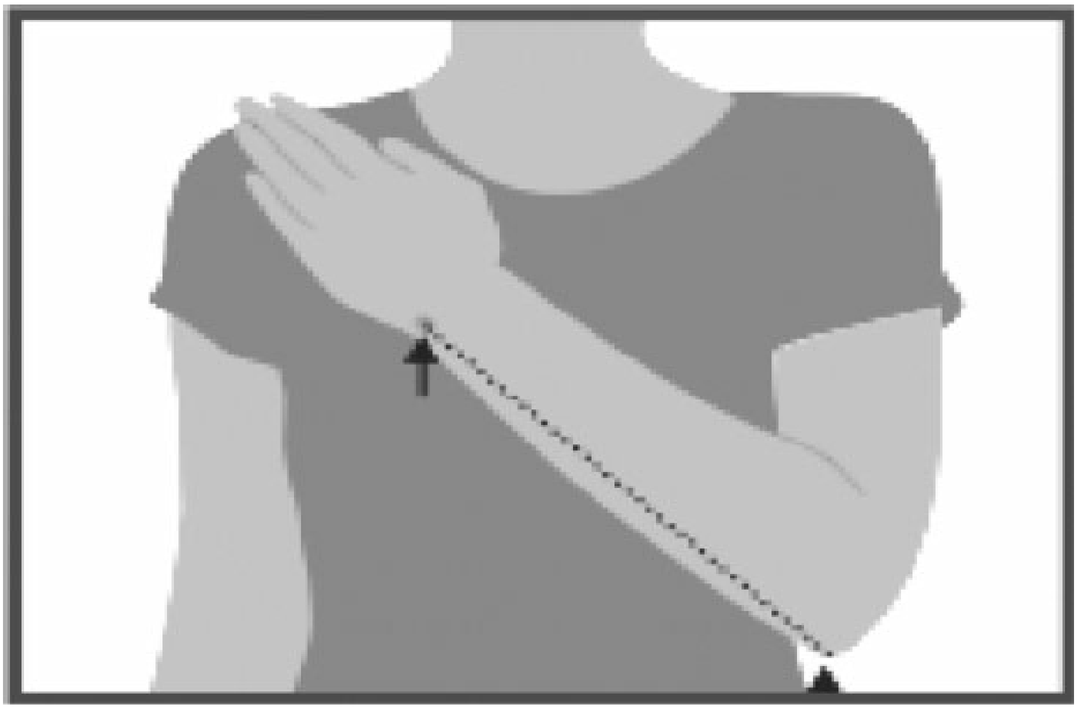


Fig. 24 - METHOD TO MEASURE ULNAR LENGTH

Fig. 25 - VERNIER CALIPER

Fig. 26 - MEASUREMENT OF ULNAR LENGTH IN MALES

Fig. 27 - MEASUREMENT OF ULNAR LENGTH IN FEMALES

DATA ENTRY AND ANALYSIS:

Data entry and analysis was done using Statistical Package for Social Sciences – Version 16.0. Descriptive statistics (the number and percentage) of the background variables were calculated.(T)test was used to find out the association between right and ulna with reference to gender**. ANOVA test was done to find out the correlation. The regression equation was derived at and a p value of <0.05 was considered significant.**

RESULTS

The observations were analyzed separately for both right and left ulna in each sex on all subjects and results are tabulated. The mean ages of the study subjects (Male 21.184 ± 3.27 and Female) 21.01 ± 3.31) were not significantly different between genders. Significant ($P < 0.05$) Gender differences in mean height and length of ulna was found in the study. Mean right and left ulna lengths of the male (26.614±2.92 and 26.492±2.85) were significantly larger than that of the females (24.944±2.64 and 24.780±2.58) of all ages. Significantly larger than that of the females of all ages.

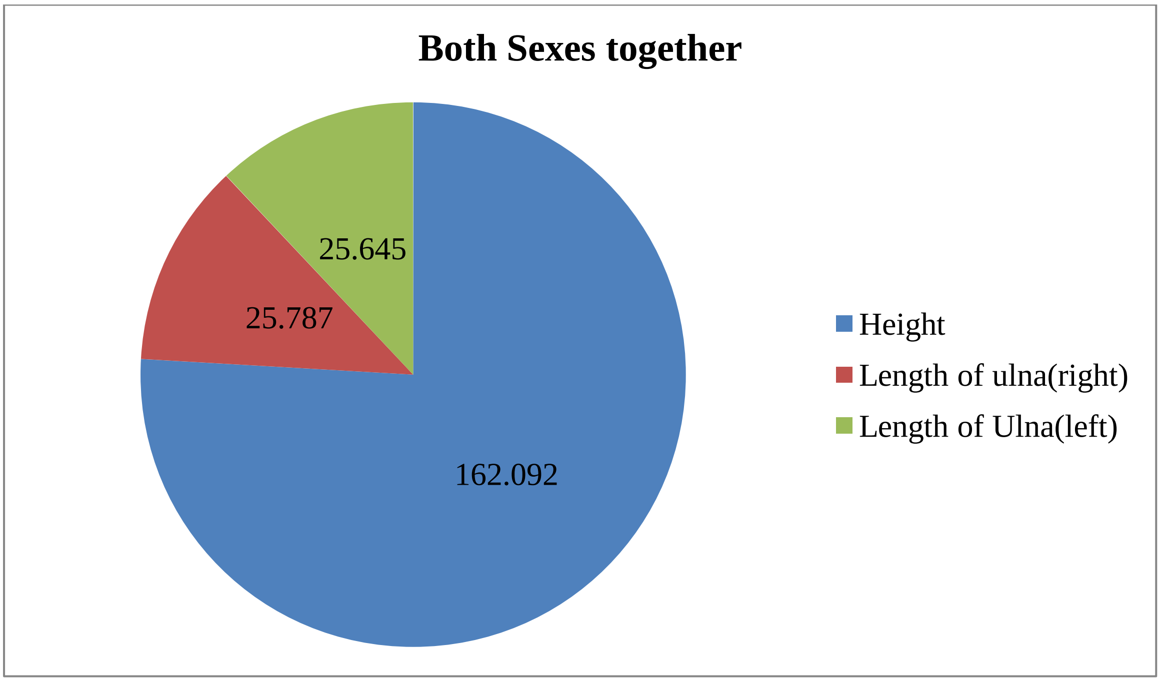
Table No. 1. Mean, SD for all the parameters

A. Both sexes together

Parameters (cm)	**Mean**	**SD**
Height	162.092	10.14
Length of Ulna (right)	25.787	2.89
Length of Ulna (left)	25.645	2.85

Table no. 1.A shows that, the mean height of total subjects.

Pie Diagram 1(A)

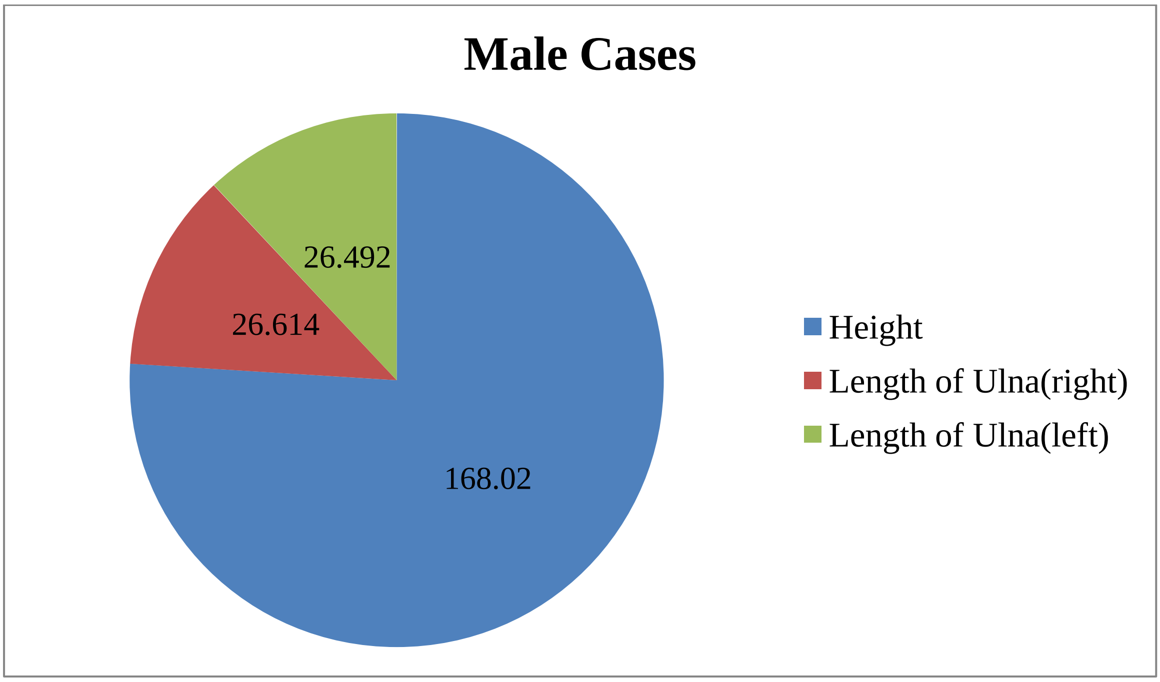


B. Male Cases:

Parameters (cm)	Mean	SD
Height	168.020	9.76
Length of Ulna (right)	26.614	2.92
Length of Ulna (left)	26.492	2.85

Table no. 1.B shows the mean height of male subjects

Pie Diagram 1(B)



C. Female Cases

Parameters (cm)	Mean	SD
Height	156.044	6.21
Length of Ulna (right)	26.492	2.85
Length of Ulna (left)	24.780	2.58

Table no.1.c shows that mean height of female subjects.

Fig. Pie Diagram 1(C)

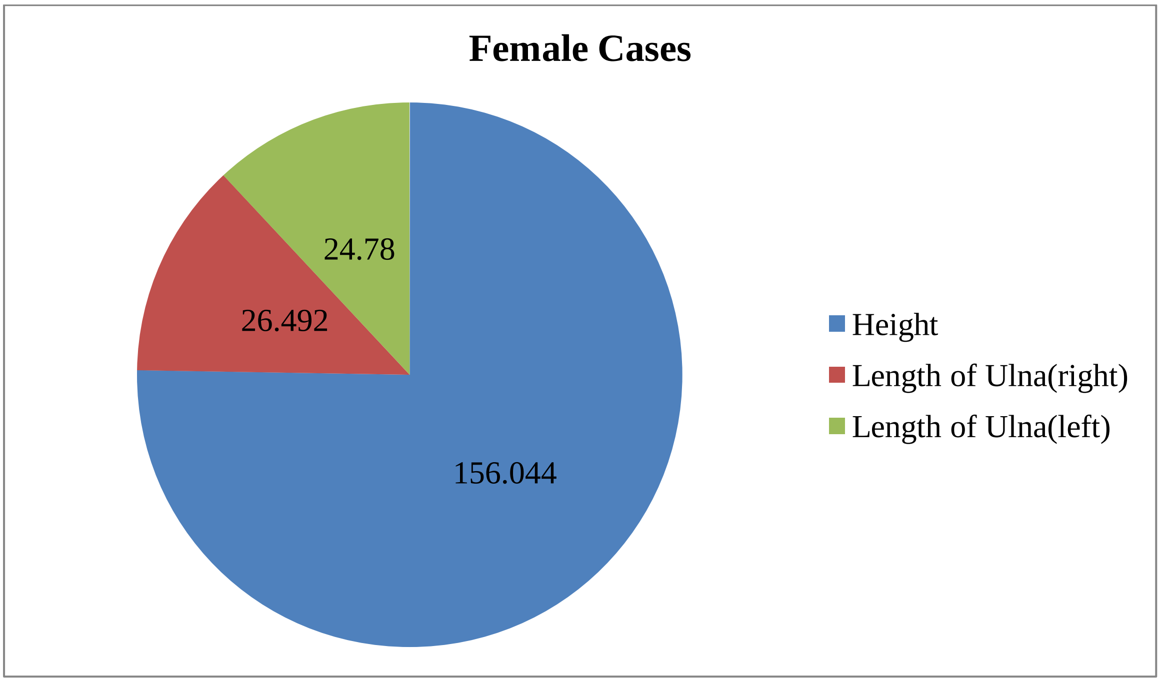


Table 2. Comparison of length of right and left ulna

Subject	Z value	P value
Both sexes together	0.62	>0.05
Male	0.76	>0.05
Female	0.69	>0.05

*independent T test

Table No. 2 shows Comparison of right and left ulna. From the table 2, it is found that the mean value of length of right and left ulna of study group is statistically insignificant in male, female and both together (P >0.05). So for further statistical analysis, Length of left ulna will be considered, as per recommendation of the international agreement for paired measurements at Geneva (1912).

Pie Diagram of left and right Ulna

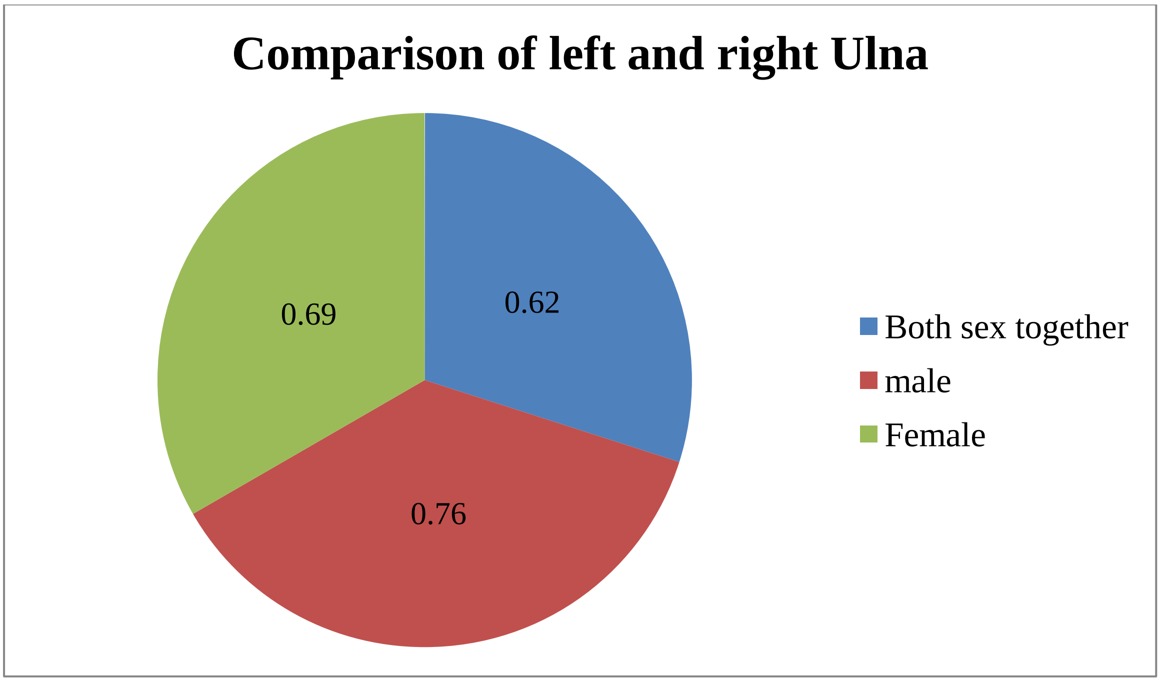


Table No. 2 shows Comparison of right and left ulna. From the table 2, it is found that the mean value of length of right and left ulna of study group is statistically insignificant in male, female and both together (P >0.05). So for further statistical analysis, Length of left ulna will be considered, as per recommendation of the international agreement for paired measurements at Geneva (1912).

Correlation coefficient:

Pearson's correlation coefficient was used to examine the relationship between length of ulna and height. Correlation coefficient between total height and length of ulna was found to be statistically significant and positive in both males and females.

Table No: 3 Pearson's correlation coefficient

Subjects	Correlation Coefficient (r)	Coefficient of determination (%)	P value
Both sexes together	**0.75**	**56.4**	**< 0.01**
Male	**0.86**	**73.1**	**< 0.01**
Female	**0.58**	**33.6**	**< 0.01**

Table No. 3 shows that the correlation of height with length of ulna is 0.86in males, 0.58 in females and 0.75 in both together, which are positive and statistically highly significant (P < 0.01) i.e. if length of ulna increases or decreases, the height of the subject also increases or decreases and vice versa.

Linear Regression Equation:

Regression analysis was performed for estimation of stature using the length of ulnas as independent variable.

Table 4: Regression equation for height with length of ulna in male, female and both sexes together

Subjects	**Correlation Coefficient (r)**	**Regression equation**	**P value**
Both sexes together	**0.75**	**Y = 93.54+ 2.67X**	**< 0.01**
Male	**0.86**	**Y = 90.57+ 2.92X**	**< 0.01**
Female	**0.58**	**Y = 121.52+ 1.39X**	**< 0.01**

Y = height and X= ulnar length

Table no. 4 shows the linear regression equation for height with length of ulna in male, female and both together, where,

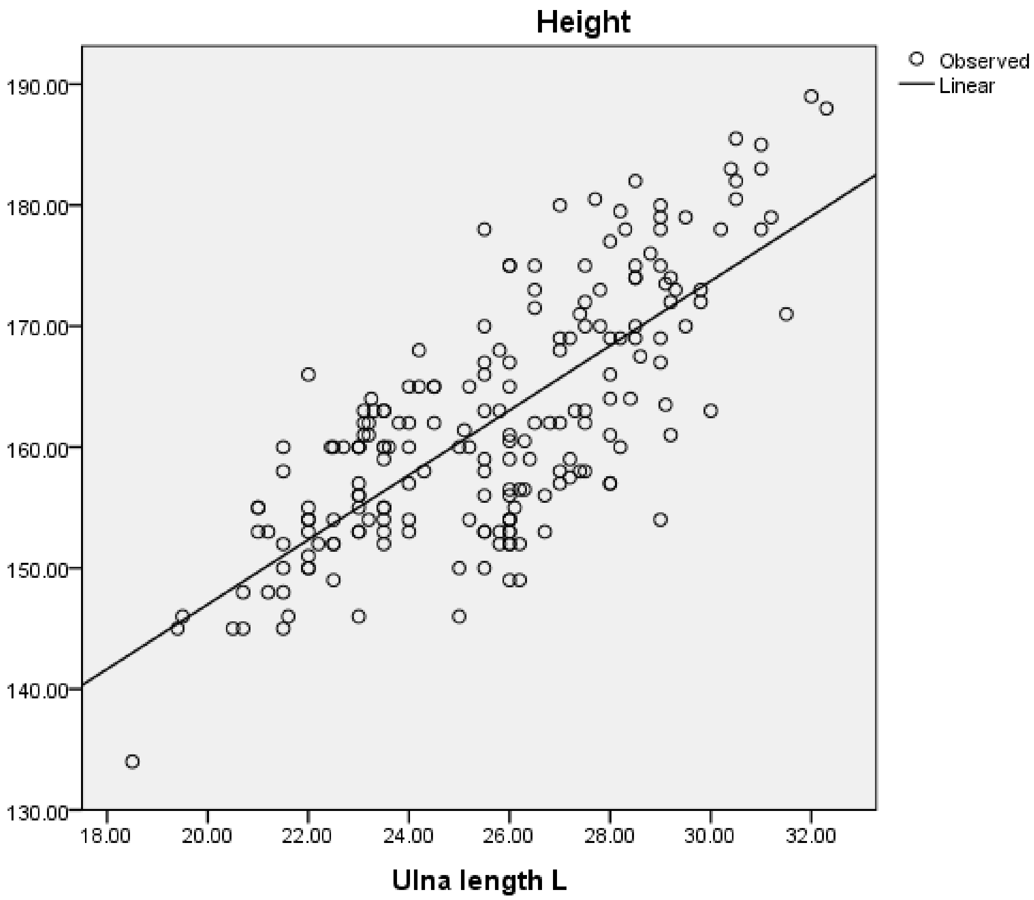
Y = Height/ Stature (cm)

X = Length of ulna (cm)

93.54, 90.57, 121.52 are intercept (constant) for male, female and both together respectively.

2.67, 2.92, 1.39 are regression coefficient for male, female and both together. F rom the above table it is seen that the regression formula within a region also varies between male and female population of that region.

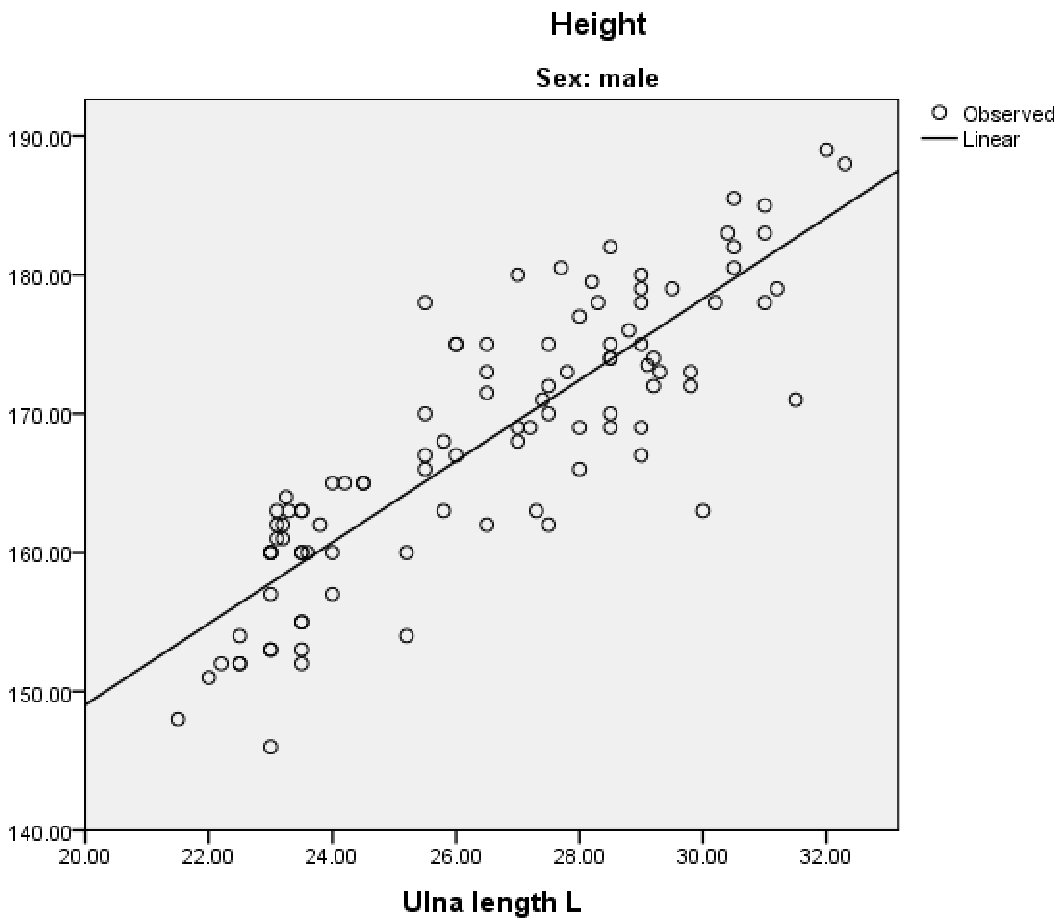
Graph No.1: Correlation of Height with length of ulna in both sexes together. (n = 200)



Graph 1

Graph no.1 shows positive correlation of Length of Ulna (Mean= 25.65cm) on X axis and Height of subjects (Mean =162.09cm) on y axis, indicating that increase in length of ulna leads to increase in total height of male subject (r= 0.75, P<0.01).). The significant correlation was further interpreted by linear regression. 56.4% variation observed in height is due to the increase in length of ulna. (r^2= 0.56)

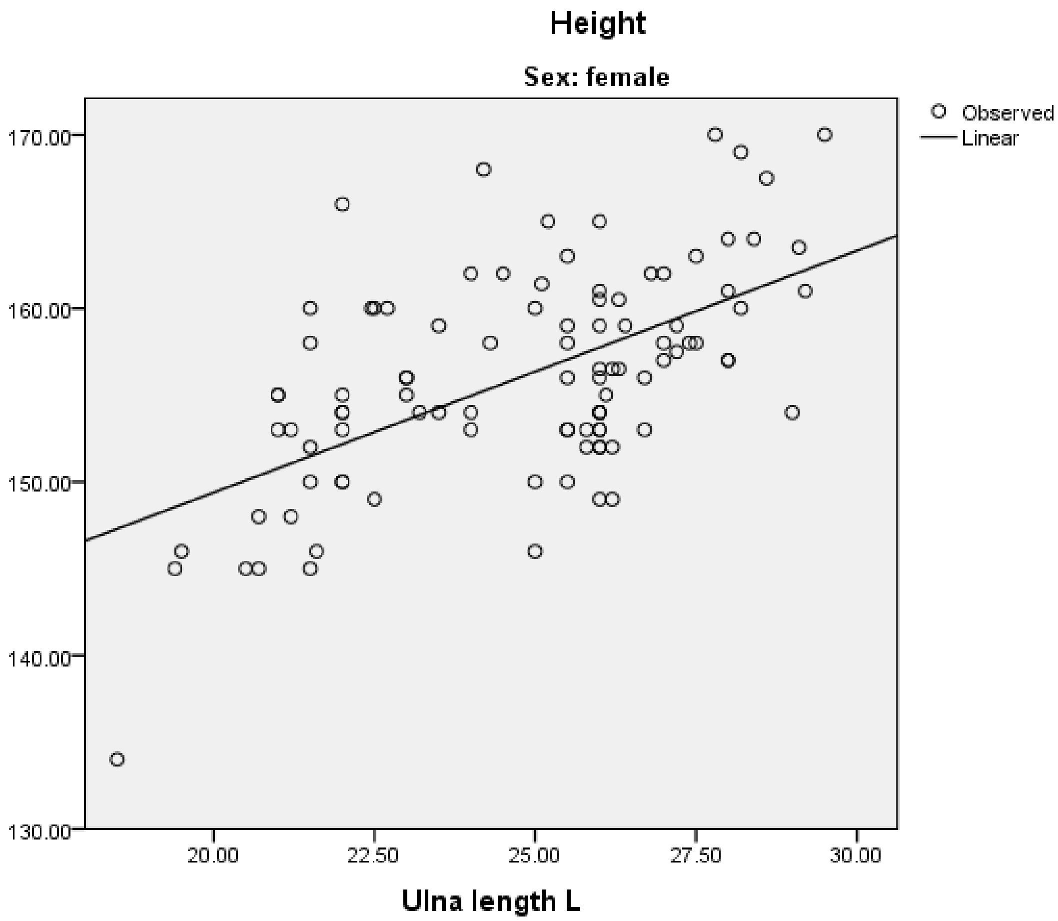
Graph No.2: Correlation of Height with length of ulna in males. (n=100)



Graph 2

Graph no.2 shows positive correlation of Length of Ulna (mean= 26.49cm) on X axis and Height of male subjects (mean =168.02cm) on y axis, indicating that increase in length of ulna leads to increase in total height of male subject (r= 0.58, P<0.01).). The significant correlation was further interpreted by linear regression. 42% variation observed in height is due to the increase in length of ulna. (r^2= 0.34).

Graph No.3:Correlation of Height with length of ulna in females. (n=100)



Graph 3

Graph no.3 shows positive correlation of Length of Ulna (mean= 24.78cm) on X axis and Height of female subjects (mean =156.04cm) on y axis, indicating that increase in length of ulna leads to increase in total height of male subject (r= 0.86, P<0.01).). The significant correlation was further interpreted by linear regression. 42% variation observed in height is due to the increase in length of ulna. (r = 0.73)

DISCUSSION

Sex determination of an unknown individual and the estimation of stature is one of the most important aspects in forensic medicine and anthropological studies. Estimation of stature is essential for the calculation of body mass index, which is used for assessment of nutrition. However, its measurement is not always practical in old or frail bedridden patients who cannot stand or those who are suffering from vertebral column deformities. In such patients, formulae based on the ulna length provide an alternative stature predictor (19). Pan worked on cadavers and derived relation between total ulnar length and total height of an individual (20).

According to Trotter M et al., there is an increase in the height of 2.5 cm after death (21). Hence prediction of height using ulna in living has definitive advantage over the cadavers. Various authors have observed that there is secular change and allometry between sexes among population. As the rate of skeletal maturity in males and females tend to vary during the course of development, gender specific formulae is required for the estimation of height [14]. **In the present study, there was no statistical difference between the length of ulna between males and females**. The Correlation coefficient between the total height and ulna length was found to positive indicating a strong relationship between the two parameters. The positive correlation suggests if length of ulna increases or decreases, the height of the subject also increases or decreases and vice versa.

The present study deals with observations on correlation of total standing height with length of ulna. In anthropological studies and forensic examinations, prediction of stature from incomplete and decomposing skeletal remain is important in identifying an unknown individual.

The stature of an individual mainly being genetically predetermined is an inherent characteristic that needs to be estimated for identification of an unknown individual. **Therefore, formulae based on the length of ulna provide an alternative stature predictor under such circumstances**. The ulna has easily identifiable surface landmarks making the measurement possible[21].)

In this study the principal investigator targets the group who are medical and paramedical students from Government KilpaukMedical College and Hospital who were born and brought up in Chennai.One of its great limitations is that it depends on operator training and experience for correct interpretation, which can significantly alter results**. However, this was unlikely to be a problem in our study as the trained principal investigator himself performed the measurements in all subjects with the help of another female doctor who was also trained personally by him; hence the test was not read by multiple independent observers.**

SEX DIFFERENCES AND LENGTH OF ULNA

The average height of adult males within a population is significantly higher than that of adult females. The result obtained in this study is in agreement with the above statement. Studies on secular changes and algometry have demonstrated different limb proportions between sexes and among population[1-21]. As the rate of skeletal maturity in males and females tend to vary during the course of development, gender specific formulae is required for the estimation of height [4].

In the present study, there was no statistical difference between the length of right and left ulna both within each gender and between males and females. Our current study goes on to prove that there was no significant difference in the lengths of ulnar bone between male and female .

Correlation coefficient

The Correlation coefficient between the total height and ulna length was found to positive indicating a strong relationship between the two parameters. The positive correlation suggests if length of ulna increases or decreases, the height of the subject also increases or decreases and vice versa.

In the present study the regression formulae for estimation of stature by left ulna was derived, as the results from our study samples failed to prove that the differences in length between the right and left bones are significance, in other words the observed difference is only by chance. Hence for analysis of any kind, only the left ulna was considered in this study.

Allbrook[23] Derived regression formulae for estimation of stature from length of ulna as

Stature= 88.94 + 3.06(ulna length) ± 4.4 (SE)

Athwal[17] :100 Maharashtrian males of age ranging from 25- 30 years and derived a regression formulae for estimation of stature and left radius (cm) +3.66cm.

Stature = 56.9709cm+ 3.9613×average length of right and left ulna (cm) ± 3.64cm.

Lal and Lala [24]: worked on a population of 258 of age ranging from 12 to 21 years in north Bihar and stated that ulnar mean multiplication factor was comparable in all series. They claimed that ulnar multiplication factor is better guide for calculation of height when it is not definitely known to which part of the country the individual belongs.

Maloykumar [17]:derived regression equation for estimation of stature from the length of ulna in males of West Bengal in age range of 20-50 years.

a) **Estimation of height from right ulna;**

   $Y1 = 50.642 + 4.1896X1 \pm 7.7302$

b) **Estimation of height from left ulna;**

   $Y2 = 76.289 + 3.256X2 \pm 9.082$

ILAYPERUMAL [14]: Derived regression equations for stature estimation from length of ulna in both males and females in Srilankan population.

Thummar B et.al [25]:derived regression equation for estimation of stature from length of right and left ulna in both males and females.For males regression equation for right ulna is

Y = 181.11+3.117X and for left ulna equation is

Y = 65.76+3.667X,

For females equation for right ulna is

Y = 17.10+5.34X and for left ulna equation is

Y = 18.95+5.33X

SUMMARY

From the present study, it has been concluded that

- Mean height and length of ulna is more in males than in females.

- Gender differences in mean height and length of ulna were found to be highly significant ($P < 0.05$

- **There is positive correlation between stature and length of ulna.**

- **Simple linear regression equation so far derived can be used for estimation of height in Chennai region**.

- **If either of the measurement (length of ulna or total height) is known, the other can be calculated.**

CONCLUSION

In the present study an attempt was made to document a relationship between the ulna and height in Indian population. There was no statistical significance difference between the right and left ulna. A positive correlation was found between stature and length of ulna. Simple linear regression equation derived can be used for estimation of height from ulna and vice versa. Thus the data of this study will be of practical use in Medico legal investigations and in anthropometry. Hence the present study would be useful for Forensic Medicine experts and Anthropologists.

RECOMMENDATIONS

The derived regression equation can be of help in artificial limb centres for construction of prosthesis required in cases of amputations following.

1. Gangrene.
2. Trauma.
3. Very rarely Frostbite in Sailors and so on.
4. This study is helpful to provide database for biometrics. The data collected can be used for future anthropological studies in Chennai.

Fig. 28 - Upper Limb Prosthesis

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ANNEXURE I

CONSENT FORM

STUDY DETAIL : ESTIMATION OF STATURE BY LENGTH OF ULNA.

STUDY CENTRE : DEPARTMENT OF FORENSIC MEDICINE, GKMC.

STUDENT NAME :

AGE :

IDENTIFICATION NUMBER :

I confirm that I have understood the purpose and procedure of the above study. I have the opportunity to ask questions and all my questions and doubts have been answered to my complete satisfaction.

I understand that my participation in the study is voluntary and that I am free to withdraw at any time without giving reason, without my legal rights being affected.

I understand that the sponsor of the clinical study, others working on the sponsor's behalf, the ethical committee and the regulatory authorities will not need my permission to look at my health records, both in respect of the current study and any further research that may be conducted in relation to it, even if I withdraw from the study I agree to this access. However I understand that my identity would not be revealed in any information released to third parties or published, unless as required under the law. I agree not to restrict the use of any data or results that arise from this study.I hereby give valid consent to participate in this study.

Signature

Name and address:

Place: Date:

Signature of the investigator:

Name of the investigator :

Place: Date:

ANNEXURE II

PROFORMA

Name of the Student :

Date of birth :

Age :

Sex :

Persuing course @ KMC :

Entire schooling done @ Chennai :

Place and time of Examination :

History of fracture of any long bone :

History of any orthopedic surgery :

SIGNATURE OF THE INVESTIGATOR **SIGNATURE OF GUIDE**

ANNEXURE - III				
ID NO	SEX	HEIGHT	R ULNA (CM)	L ULNA (CM)
1	MALE	183	31	31
2	MALE	182	30	28.5
3	MALE	168	27	27
4	MALE	175	29	28.5
5	MALE	173	27	26.5
6	MALE	172	27.5	27.5
7	MALE	180	27	27
8	MALE	170	28	27.5
9	MALE	182	30	30.5
10	MALE	180	29	29
11	MALE	167	26	25.5
12	MALE	175	28	27.5
13	MALE	178	28.3	28.3
14	MALE	180.5	27.4	27.7
15	MALE	171	27.3	27.4
16	MALE	177	28	28
17	MALE	173.5	29.3	29.1
18	MALE	160	25.4	25.2
19	MALE	179	30.2	29.5
20	MALE	170	29.3	28.5
21	MALE	169	27.4	27.2
22	MALE	185.5	31.2	30.5
23	MALE	179	29	29
24	MALE	171.5	26	26.5
25	MALE	178	29	29
26	MALE	169	27	27
27	MALE	180.5	31.3	30.5
28	MALE	172	29	29.2
29	MALE	179.5	28.5	28.2
30	MALE	178	30.2	30.2
31	MALE	174	29.4	29.2
32	MALE	175	29.5	29
33	MALE	178	31.2	31
34	MALE	166	28	28
35	MALE	169	29.5	29
36	MALE	173	29.8	29.8
37	MALE	174	29	28.5
38	MALE	183	30.6	30.4
39	MALE	185	31	31
40	MALE	174	28.6	28.5
41	MALE	163	25.9	25.8
42	MALE	189	32.5	32
43	MALE	169	28.5	28.5
44	MALE	173	29	29.3
45	MALE	176	28.8	28.8
46	MALE	179	31	31.2
47	MALE	172	29.8	29.8
48	MALE	171	31.5	31.5
49	MALE	163	30	30
50	MALE	167	29.5	29
51	MALE	188	32.5	32.3
52	MALE	160	23.5	23.5
53	MALE	165	24	24.2
54	MALE	157	23	23
55	MALE	146	23.2	23
56	MALE	160	24	24
57	MALE	163	23.6	23.5
58	MALE	160	23.7	23.6

59	MALE	155	23.5	23.5
60	MALE	178	25.9	25.5
61	MALE	175	26	26
62	MALE	170	25.5	25.5
63	MALE	157	24.5	24
64	MALE	165	24	24.5
65	MALE	163	23.5	23.3
66	MALE	167	26	26
67	MALE	166	25.5	25.5
68	MALE	168	25.9	25.8
69	MALE	154	25.4	25.2
70	MALE	162	26.5	26.5
71	MALE	169	28	28
72	MALE	163	27.5	27.3
73	MALE	162	23.6	23.8
74	MALE	165	24.5	24
75	MALE	173	28	27.8
76	MALE	162	27.5	27.5
77	MALE	162	23.2	23.2
78	MALE	163	23.1	23.1
79	MALE	164	23.5	23.25
80	MALE	161	23	23.1
81	MALE	175	26.5	26.5
82	MALE	175	24	24.5
83	MALE	160	23	23
84	MALE	160	23.5	23.5
85	MALE	162	23.3	23.1
86	MALE	163	23.5	23.5
87	MALE	161	23	23.2
88	MALE	175	26.3	26
89	MALE	160	23.2	23
90	MALE	160	23	23
91	MALE	148	21.5	21.5
92	MALE	152	22	22.5
93	MALE	152	22.5	22.2
94	MALE	152	22.5	22.5
95	MALE	154	23	22.5
96	MALE	153	23	23
97	MALE	152	23.5	23.5
98	MALE	153	23.8	23.5
99	MALE	153	23.4	23
100	MALE	151	22.5	22
101	MALE	155	23	23.5
102	FEMALE	157	28	28
103	FEMALE	154	26	24
104	FEMALE	161	28	28
105	FEMALE	153	27	26.7
106	FEMALE	159	26	26
107	FEMALE	156.5	26.5	26.3
108	FEMALE	162	27.2	26.8
109	FEMALE	157.5	27.4	27.2
110	FEMALE	149	27.5	26.2
111	FEMALE	161	29.3	29.2
112	FEMALE	156	26	26
113	FEMALE	160	28.5	28.2
114	FEMALE	161.4	25.3	25.1
115	FEMALE	154	29	29
116	FEMALE	169	28.5	28.2
117	FEMALE	160.5	26	26

118	FEMALE	158	27.2	27.4
119	FEMALE	156.5	27	26
120	FEMALE	153	26	26
121	FEMALE	170	30	29.5
122	FEMALE	160.5	27	26.3
123	FEMALE	167.5	28.3	28.6
124	FEMALE	164	28.5	28.4
125	FEMALE	161	26	26
126	FEMALE	163.5	29.5	29.1
127	FEMALE	159	27.5	27.2
128	FEMALE	159	26.4	26.4
129	FEMALE	152	26.3	26.2
130	FEMALE	157	26.4	27
131	FEMALE	155	26	26.1
132	FEMALE	152	25.8	26
133	FEMALE	156	27	26.7
134	FEMALE	149	26	26
135	FEMALE	152	26.2	26
136	FEMALE	158	27.3	27
137	FEMALE	157	28	28
138	FEMALE	153	25.8	25.5
139	FEMALE	152	26	25.8
140	FEMALE	154	26	26
141	FEMALE	162	27.3	27
142	FEMALE	156.5	26	26.2
143	FEMALE	164	28.5	28
144	FEMALE	154	26.5	26
145	FEMALE	146	25.5	25
146	FEMALE	163	27.9	27.5
147	FEMALE	158	27.6	27.5
148	FEMALE	153	26	25.5
149	FEMALE	154	26	26
150	FEMALE	153	25.9	25.8
151	FEMALE	148	21	21.2
152	FEMALE	165	26	26
153	FEMALE	150	25.9	25.5
154	FEMALE	150	25.5	25
155	FEMALE	160	25.4	25
156	FEMALE	156	25.5	25.5
157	FEMALE	163	25.9	25.5
158	FEMALE	165	25	25.2
159	FEMALE	153	24.5	24
160	FEMALE	162	24	24
161	FEMALE	154	23.5	23.5
162	FEMALE	154	23	23.2
163	FEMALE	149	22.5	22.5
164	FEMALE	156	23	23
165	FEMALE	156	23.2	23
166	FEMALE	150	21.7	21.5
167	FEMALE	153	21.5	21
168	FEMALE	148	20.9	20.7
169	FEMALE	155	22	22
170	FEMALE	160	22.5	22.45
171	FEMALE	160	22.7	22.7
172	FEMALE	158	21.5	21.5
173	FEMALE	150	22	22
174	FEMALE	166	22.5	22
175	FEMALE	146	19.5	19.5
176	FEMALE	160	21	21.5

177	FEMALE	145	19.6	19.4
178	FEMALE	155	21.5	21
179	FEMALE	150	22	22
180	FEMALE	155	21	21
181	FEMALE	145	20.5	20.5
182	FEMALE	168	24	24.2
183	FEMALE	155	23.5	23
184	FEMALE	160	22.6	22.5
185	FEMALE	146	21.6	21.6
186	FEMALE	134	18.5	18.5
187	FEMALE	153	22.2	22
188	FEMALE	153	21.2	21.2
189	FEMALE	158	25.5	25.5
190	FEMALE	159	26	25.5
191	FEMALE	145	21	21.5
192	FEMALE	170	28	27.8
193	FEMALE	152	21.5	21.5
194	FEMALE	154	22	22
195	FEMALE	159	24	23.5
196	FEMALE	153	26	26
197	FEMALE	145	20.5	20.7
198	FEMALE	158	24.3	24.3
199	FEMALE	162	24.5	24.5
200	FEMALE	154	22.5	22