A STUDY TO CORRELATE THE STATURE WITH THE LENGTH OF ULNA IN LIVING HUMANS IN VARIOUS AGE GROUPS

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Abstract
Aim: The purpose of the study was to establish the correlation between length of ulna with height of a person in various age groups and in both sexes. The study also intended to compare the two basic parameters used globally for such correlations, namely multiplication factor (M.F.) and regression equation; and try to comment on the efficacy of one formula over the other.
Introduction: Height of an individual has evoked great interest since ancient time. The subject as a whole has been dealt with in different ways to predict the human stature. In ancient times, physicians & surgeons like **Charak & Sushruta**[1] were well acquainted with the relation of different parts of body with height. According to Charak, the height of an average man should be 84 -anguls, thigh-21 anguls, forearm -15 anguls & arm-16 anguls. Dwarfism and gigantism, both resulting from hormonal dysfunction, are examples of variations in normal body height.
Method & Material: In the present study 504 individuals were studied. Study ranged across the age groups from 8 years to 22 years. Equal participation of males and females was ensured. Thus, 252 males (50%) and 252 females (50%) were included in the study.
Observation: On an average the M.F. for male is between 6.05 – 6.76 for right ulna and 6.08-6.79 for left ulna.
Discussion: It was observed that height estimation using M.F. is much simpler, easy and less time consuming; yet enough efficient; as compared to using regression equation.
Conclusion: 1) M.F. is more applicable in medico-legal cases where one may be confronted with a single or fragmented bone, and person's height needs to be ascertained. 2) Regression equation is applicable in sample study of large population.
Keywords: ulna, multiplication factor, regression equation

1. Introduction

Human stature has always been a symbol of an authority, physical prowess and dominance over other living beings, whether in human or in animal kingdom. Man has always tried to impress others by virtue of his height and built since beginning of civilization.

The height of an individual has changed from earlier times to the present. It is a well known fact that anthropometric studies of bones give us information regarding age, race, sex and height of a person. This information is of great value to the medical detectives in determining the age, race, sex and height of a deceased person. There are two ways by which we can determine the height of an individual i.e. from cadaveric bones and in living subjects. According to Trotter & Gleser (1952) [2] there is an increase in height of 2.5cm after death when measurement is taken in recumbent position. Hence, the present study is done on living persons belonging to the age group between 8-22 years.

The forearm bone ulna is mostly subcutaneous throughout its length and easily approachable for measurement, Hence ulna was selected for estimation of height in present study. This collected data can be used medicolegally to determine the stature, sex, race, age and built of an individual from remains either in-toto or in fragments.

2. Material and method

The project **"A study to correlate the stature with the length of ulna in living humans in various age groups"** was carried out in Smt. B.K. Shah Medical Institute and Research Centre, Piparia,Vadodara, Gujarat.

2.1 Material

1) Spreading caliper.
2) Anthropometer.

Spreading caliper: It is used for taking measurement on the living and the skeleton. In present study, a blunt ended spreading caliper of size 30 cm was used.

Anthropometer: This instrument gives a direct and accurate reading, to the nearest millimeter, over a range of 50 mm to 570 mm

Care was taken to use same instrument for all measurements in order to avoid instrumentation error.

2.2 Method: The study was spread over a period of one and a half years. A mix of 504 students,

from Shree Ambe School, Vadodara; and medical students of Smt. B.K. Shah Medical Institute & Research Centre, Piparia, between the age group of 8-22 years were selected for the study. In all, 252 males and 252 females were studied. To record stature, measurements were taken from crown to heel in standing erect posture, using anthropometer. Length of ulna was measured with the help of a spreading caliper. The measurement was done from tip of olecrenon process to tip of styloid process, with elbow flexed and palm spread over opposite shoulder. In each student, measurements of length of right and left ulna were taken separately for calculation. Height was measured in centimeters;

Measurement of ulna using spreading caliper

Data was analyzed after classifying the individuals in 14 groups, with one year age difference. Comparative analysis of various groups was done using standard statistical methods. The analyzed data was recorded and tabulated for observation and interpretation in the light of relevant precedence.

2.3 Statistical formulae

Standard Deviation (S.D.): Standard deviation is a measure of the scatter of observations around their mean.

Defined as "Root – Mean – Square – Deviation"

$$SD = \frac{\sum(X - X)^2}{n - 1}$$

Statistical formulae for height estimation

A) Anatomical method:

Multiplication factor (M.F.): Multiplication factor of ulna was calculated by the following formula.

$$\text{Multiplication factor} = \frac{\text{Height of subject in cm}}{\text{Length of ulna in cm}}$$

Estimated Stature:

Estimated stature = Length of ulna × M.F.

B) **Mathematical method:**

Step 1: Regression coefficient (b):

Regression coefficient is a measure of the change in one character with one unit change in the other.

Regression coefficient or b of Y on X is written as

$$a) \quad bY.X = \frac{\sum(X - \bar{X})^2 \ (Y - \bar{y})^2}{\sum(X - \bar{X})^2}$$

Step 2: Estimated height (Y) is obtained by regression equation

$$Y = \bar{y} + bY.X\,(X - \bar{X})^2$$

Where

$(X - \bar{X})^2$ is the length of ulna.

$\bar{X}$ is mean of the length of ulna.

Y is actual height of person.

$\bar{y}$ is mean of actual height.

3. Observation: Following tables are self-explanatory.

Table 1: Comprehensive analysis of the study - male

Age grp in years	Mean actual ht. (cms)	Left ulna						
		Av. length (cm)/±	Mf mean	Est .ht. By mf	Est.ht. By Reg.equ.	Av. length (cm)/±	M.f .mean	Est .ht. By m.f.
8-9	126.61	18.85	6.72	126.61	126.61	18.80	6.74	126.61
9-10	131.33	19.50	6.75	131.76	131.35	19.50	6.75	131.76
10-11	135.77	20.10	6.76	135.78	135.78	20.01	6.79	135.78
11-12	144.38	21.78	6.63	144.39	144.43	21.76	6.63	144.39
12-13	145.50	21.82	6.67	145.50	145.53	21.76	6.69	145.50
13-14	159.11	24.07	6.62	159.11	159.14	24.04	6.63	159.11
14-15	159.38	24.62	6.48	159.39	159.38	24.60	6.49	159.39
15-16	164.94	25.53	6.46	164.94	164.98	25.45	6.48	164.94
16-17	169.35	26.08	6.50	170.06	170.06	26.03	6.51	170.06
17-18	167.44	26.08	6.43	167.44	167.47	26.04	6.44	167.44
18-19	171.55	26.95	6.37	171.56	171.55	26.90	6.38	171.56
19-20	170.05	26.71	6.38	170.06	170.06	26.70	6.38	170.06
20-21	167.33	27.32	6.13	167.33	167.33	27.29	6.14	167.33
21-22	172.05	28.42	6.05	172.06	169.20	28.29	6.08	172.06

Table 2: Comprehensive analysis of the study - female

Age grp in years	Mean actual ht.(cms)	Right ulna				Left ulna			
		Av.length (cm)/±	Mf mean	Est .ht. By mf	Est.ht.by Reg.equ.	Av. length (cm)/±	M.f. mean	Est .ht. By m.f.	Est.ht.by Reg.equ.
8-9	122.94	18.66	6.60	122.94	122.94	18.64	6.60	122.94	122.96
9-10	132.83	19.46	6.83	132.83	132.86	19.47	6.83	132.83	132.86
10-11	136.50	20.57	6.64	136.50	138.89	20.52	6.65	136.50	136.53
11-12	140.27	21.19	6.62	140.28	140.29	21.13	6.64	140.28	140.29
12-13	147.22	22.52	6.54	147.22	147.23	22.48	6.55	147.22	147.23
13-14	154.00	23.32	6.61	154.00	154.01	23.27	6.62	154.00	154.01
14-15	157.11	23.88	6.58	157.11	157.12	23.83	6.59	157.11	157.16
15-16	157.22	23.76	6.63	157.22	157.22	23.69	6.64	157.22	157.22
16-17	153.17	23.47	6.54	153.33	154.23	23.44	6.54	153.33	153.57
17-18	152.55	23.87	6.39	152.56	152.58	23.85	6.40	152.56	152.47
18-19	158.00	24.48	6.46	158.00	158.03	24.46	6.46	158.00	157.99
19-20	159.16	24.65	6.47	159.17	159.10	24.65	6.47	159.17	159.17
20-21	155.38	23.62	6.58	155.39	155.38	23.59	6.59	155.39	155.39
21-22	157.88	24.65	6.41	157.89	157.88	24.61	6.42	157.89	157.88

M.F.: multiplication factor

4. Discussion and conclusions

The present study was carried out in the department of Anatomy, Smt. B.K. Shah Medical Institute and Research Centre, Sumandeep Vidyapeeth, Piparia. The purpose of the study was to establish the correlation between length of ulna with height of a person in various age groups and in both sexes. The study also intended to compare the two basic parameters used globally for such correlations, namely multiplication factor and regression equation; and try to comment on the efficacy of one formula over the other. All results thus obtained were compared and analyzed with findings of similar studies conducted down the timeline, across the globe

In the present study 504 individuals were studied. The individuals were segregated in 14 groups as per their age. Study ranged across the age groups from 8 years to 22 years. Equal participation of males and females was ensured. Thus, 252 males (50%) and 252 females (50%) were included in the study. The length of ulna was measured and height was estimated by multiplication factor.

Viz.;

$$\text{(A) Multiplication Factor (MF)} = \frac{\text{Height of subject in cm}}{\text{Length of long bone in cm}}$$

Estimated stature = Length of long bone × M.F.

This multiplication factor was introduced by Pan (1924), later used by Nat (1936)[3], Siddiqui et al (1944)[4], Singh et al (1952)[5], Lal et al (1972)[6]. Out of these authors only Lal et al (1972)[6] took age groups (18-19 yrs), (21-22-yrs) into consideration.

But in the present study the different age groups were studied and the height changes were estimated for every year, total of 14 groups, in both males and females.

(B) Height estimation was also done using regression coefficient (b) and finally regression equation (Y) which is taken as a measure of change in one character with one unit change in the other.

(C) Regression coefficient or b of Y on X is written as

$$bYX = \frac{\sum dxdy}{\sum dx^2} \quad \text{or} \quad \frac{\sum (x-\bar{x})(y-\bar{y})}{\sum (x-\bar{x})^2}$$

Estimated height $Y = \bar{y} + bY \times (x-\bar{x})$

This method was based on the work done by **Antii Telkka (1950)[4].**

(A) Multiplication Factor(MF): The MF was calculated by **Siddiqui et al (1944)[4], Lal et al (1972)[6],** the value 6.1 – 6.3 in males.While **Singh et al (1952)[5]** the MF of ulna which was less than 6.0 in males.

Lal and Lala (1972)[6] claimed that ulnar M.F. is better guide for calculation of height when it is not definitely known to which part of the country the individual belongs.

In present study,on an average the M.F. for male is between 6.05 – 6.76 for right ulna and 6.08-6.79 for left ulna. These findings are similar to the findings of **Nat (1936)[3] and Lal (1972)[6]**

According to Pan (1924) the M.F. of ulna in females was 6.0 whereas according to Lal et al

(1972) [6], the M.F. was ranging between 6.039 – 6.210.

In present study the M.F. works out to be on higher side. Right ulna– 6.39 - 6.83. Left ulna- 6.40 – 6.83.

Athawale (1963)[7] derived the regression formula in relation to length of radius and ulna. He observed that the average height of a person was 163.13 cm ± 0.63 and the average ulnar length was 26.79 cm ± 0.04.

In present study, the regression coefficient and regression equation was used effectively to estimate height. All the results were relate the 'p' value (< 2.03), thus making all interpretations highly significant.

Albrook D (1961)[8] derived regression formulae for estimation of stature from length of ulna as – Stature= 88.94 + 3.06 (Ulnar length) ± 4.4(standard error).

Athawale MC (1963)[7] studied 100 Maharashtrian males of age ranging from 25-30 years.

The regression formula derived for estimation of stature from length of long bones was,

Stature = 59.2923 cm + 4.1442 × average length of right and left radius (cm) ± 3.66 cm.

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

In present study the findings for males were derived as

Stature = 37.61 + 4.909 × average length of right ulna (cm) ± 4.555 cm.

Stature = 37.465 + 4.924 × average length of left ulna (cm) ± 4.525 cm.

The findings for females were derived as

Stature = 28.362 + 5.304 × average length of right ulna (cm) ± 5.415 cm.

Stature = 27.942 + 5.33 × average length of left ulna (cm) ± 5.403 cm.

Growth patterns of ulna in males and females.

Length of the bone is represented graphically and following observations are noted.

The ulnar length in females shows three activities of growth. They are between 9-15 years, 16-18 years and 20-22 years of age reaching a maximum of 24.65 cm at 19-20years of age.

Formicola (1996)[9] stated that regression equations were particularly useful when very short or very tall individuals were involved. At the same time, they were among the best predictors of stature in less extreme conditions.

Maijanen H (2009)[10] observed that in practice, differences between the versions as well as those between long bone-based equations and anatomical methods were small. Anatomical method is nevertheless more accurate than long bone regressions when individuals with atypical body proportions are examined.

Conclusions

1) The study concludes that in males, the M.F. for right ulna was 6.05-6.72, and 6.08-6.79 for left ulna.
2) Similarly in females, the M.F. for right ulna was 6.41-6.83, and 6.42-6.83 for left ulna.
3) The M.F. for ulna was on a higher side as compared to other studies.
4) It was observed that height estimation using M.F. is much simpler, easy and less time consuming; yet enough efficient; as compared to using regression equation. Both the methods have their own utilities. M.F. is more applicable in medico-legal cases where one may be confronted with a single or fragmented bone, and person's height needs to be ascertained. Regression equation is applicable in sample study of large population. It is also useful in cases of en mass medico-legal studies, like excavation of mass graves of war crimes. The equation can be of great help in archeological excavations, where approximate age of person is known.
5) It is observed that females grow steadily in height from the age of 8 years, till the age of 18-19 years. By then the ulna achieves its maximum length. In males, the growth starts at the age of 8 years and continues till the age of 19-20 years till the ulna reaches its maximum length. Thus it can be inferred that despite the fact that the height and ulnar growth initiates at the age of 8 years in both sexes, females acquire the maximum height and corresponding maximum length of ulna a year earlier than male

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