Estimation of stature from femur length in north Indian male population

Arif Viqar[1,*], Munish Khanna[2]

[1]Assistant Professor, [2]Associate Professor and Head of Dept., [1]Dept. of Forensic Medicine, [2]Dept. of Anatomy, Pt. Jawahar Lal Nehru Government Medical College and Hospital Chamba, Himachal Pradesh, India

***Corresponding Author:**
Email: arifviqar1@gmail.com

Abstract
Stature is one of the important criteria for establishing identification of unknown person/dead body. Evaluation of stature is difficult in mutilated dead bodies which may be burnt or completely skeletonised. In this study on male subjects, stature was determined through the determination of percutaneous measurement of femur length. This study utilized simple linear regression and multiple regression analyses to estimate stature. Regression formulae and multiplication factors were developed for various combinations to reach the best estimate possible.

Keywords: Femur length, Stature, Males.

Introduction
Stature estimation forms a major domain of medico-legal investigations used in the identification of unknown fragmentary and mutilated remains. A number of multiplication factors and regression equations have been developed to reconstruct stature from long bones throughout the world.[1-6] Various long bones have been employed for stature estimation using variety of methodologies.[7] However, long bones of lower limb contribute most to the standing height, hence, most predictive equations are based on length of lower limb.[8] Existing equations given by western workers involves an error of 5 to 8% while doing the estimation of stature for Indian population.[9] This is because variations in length of limb bones, relative to stature, have been observed according to race.[5,10] In the current study we selected femur length as a criterion to determine the stature in male subjects.

Materials and Methods
The stature of an individual may be estimated by adopting Anatomical method, if complete skeleton is available for examination or by following Mathematical method where only a single long bone is available. A single long bone may serve the purpose as a strong correlation has been observed between a long bone and stature. All methods of stature estimation are based upon the fundamental assumption that the longer the bone, the taller the individual[11,12] The present study comprised of 150 male students of MMIMS&R Mullana, Ambala within the age range of 21 to 30 years. Subjects were measured for femur length, in accordance with the standard measurement techniques recommended.[13,14] All observations were recorded in centimetres (cm). Each subject was measured for the following percutaneous dimensions.

Stature (S): It was obtained as the vertical distance between the standing surface and the highest point on the head (vertex) when the subject was standing in the standard standing position, using anthropometer (stadiometer).

Femur Length (FEML): It was measured when the subject stands erect with the left leg placed slightly ahead of the right one and the foot partly inverted to relax the soft tissues. The measurement was obtained as the distance from the upper most point on the greater trochanter to the lower most point palpable on the lateral femoral condyle, using rod compass (spreading calliper).

Subjects outside the age group defined were excluded from the study; also were excluded, those with any congenital deformity or those with pathological conditions involving bones like fractures, osteoporosis, rickets, dislocations scoliosis and kyphoscoliosis etc.

This study utilized simple linear regression and multiple regression analyses to estimate stature. As these measurements are hypothesized to be predictive of stature, the regressions were performed with stature as the dependent variable and the selected measurement(s) as the independent variable(s).

The data was analyzed using SPSS version 20 software. Regression formulae and multiplication factors were developed for various combinations to reach the best estimate possible. The regression formula is of type, $Y=A+B(X)$, it is a simple regression equation since here x is the only independent variable, where, Y= Height of individual to be estimated, A= Regression constant, B= Regression coefficient, X= Percutaneous length of the long bone (tibia/fibula/radius/ulna).

Multiplication factor for the individual long bones were calculated for each person and mean of all was calculated. The following equation was used to get the multiplication factor: $K=H/L$ Where, H= Height, L = Length of long bone (tibia/fibula/radius /ulna), K= A constant multiplication factor which was specifically determined for individual long bone from the various data so obtained.

Results

The study was conducted between the age group of 21 to 30 years; the mean ± SD age of sample population was 22.31 ± 1.61 years. Stature of the sample population studied ranged between a minimum of 152.4 cm and maximum of 193 cm with a mean ± SD being 173.89 ± 6.77 cm.; p value <0.001.

Percutaneous femur lengths of the sample population were compared on both sides (Table 1). The mean percutaneous femur length in the subjects (combined right and left) was 45.72 ± 2.02 cm.

Table 1: Comparison of the mean percutaneous femur length of the two sides

Length (in cm)		Male		
		Mean	SD	p value
Femur	Right	45.75	2.03	< 0.001
	Left	45.68	2.01	< 0.001
	Combined	45.72	2.02	< 0.001

The mean percutaneous measurement was 45.75 ± 2.03 cm and 45.68 ± 2.01 cm for left and right femur, respectively. However, the difference between mean lengths of right and left side femur was statistically not significant (p>0.05; Table 2).

Table 2: Mean percutaneous femur lengths of the two sides and their p value

Males					
Length (in cm)	Right		Left		p value
	Mean	SD	Mean	SD	
Femur	45.75	2.03	45.68	2.01	0.767

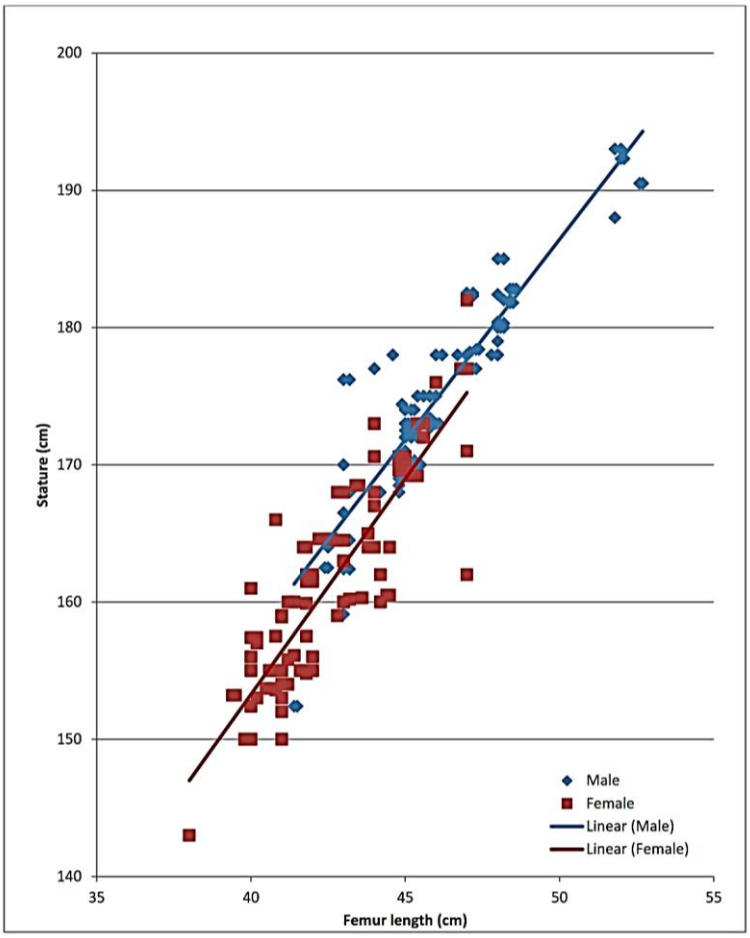

Fig. 1 Scatter diagram showing the plot of femur length with stature

Stature Estimation from Femur Length

Table 3 depicts regression analysis and correlation of the percutaneous femur length with stature of the population sample studied. A positive correlation was observed between the stature and the femur length and the correlation was highly statistically significant (p<0.001). The slope and intercept was used to devise regression equation for estimation of stature from the lengths of femur (Fig. 1).

Table 3: Statistical regression analysis of the percutaneous femur length with stature of the male population sample

	Male		
	R	**L**	**T**
Slope	2.95	2.95	2.95
Intercept	38.94	39.07	39.05
SEE	3.18	3.25	3.21
Pearson correlation	0.884	0.878	0.881
Df	149	149	299
p value	< 0.001	< 0.001	< 0.001

For calculating the stature the regression equation was derived for right sided femur as, stature = 38.94 + 2.95 x femur length, for left sided femur as, stature = 39.07 + 2.95 x femur length and for both sides femur as stature = 39.05 + 2.95 x femur length (Table 4).

Table 4: Regression equation for stature estimation from femur length

Sex	**Side**	**N**	**Regression equation**
Males	**Right**	150	y = 38.94 + 2.95x
	Left	150	y = 39.07 + 2.95x
	Combined	300	y = 39.05 + 2.95x

y is Stature of individual and x is length of femur

In total, for calculating the stature the regression equation was derived as stature = 18.04 + 3.39 x right femur length, stature = 17.85 + 3.39 x left femur length and for both sides femur as stature = 17.97 + 3.39 x femur length.

The stature calculated from femur length as per regression equation is 173.89 with a standard deviation of 6.77.

Multiplication factor derived from the percutaneous femur lengths to calculate stature from the total population sample is 3.8.

The stature calculated from femur length by using multiplication factor is 174.19 with a standard deviation of 7.98.

Discussion

Stature estimation is present study was done on the male students of MMIMSR Ambala; these students were from different regions of North India. Average stature, estimated through measurement of Femur length, is 174.19 cm. In this study, femur was selected as it provides the most accurate estimate of stature by a good margin (SD = 6.77 cm in males), and 95% confidence interval of 0.60. (Table 5)

Table 5: Estimated stature from femur length in the population sample using different formulae

Author	**Population (race/ region)**	**Equation for stature from Femur**		**Mean**	**SD**	**95% CI**
Pearson[1]1899	British	Males: S=81.231+1.880(FEML)		167.41	3.95	0.39
Trotter and Gleser[5] 1952	American whites	Males: S=61.41+2.38(FEML)		170.51	5.00	0.49
Singh and Sohal[15]1952	East Punjab	Multiplication factor 3.63	Male	166.40	7.63	0.75
Present study Regression Equation	MMIMSR, Mullana	Males: S=39.05 + 2.95(FEML)		173.89	6.77	0.60
Present study Multiplication Factor		Males S = 3.80 x (FEML)		174.19	7.98	0.78

Our study shows positive correlation between stature as measured by regression equations and multiplication factors with that of the actual height amongst the North India population. The regression equations when applied to a fresh sample of MMIMSR Mullana showed a mean difference between actual height and estimated height is less than 1 cm ($p>0.05$). Therefore the derived regression equations are valid and applicable to the North Indian population. However the derived regression equations for the North Indian population do not match with any of the other races, nations or the religions studied, as these are individually different. This finding substantiates the views expressed by other workers that, state wise and population wise, different regression formulae are required for estimation of stature.

Conclusion

There is a positive correlation between femur, one of the long bones of the lower limb, with the stature. Race and gender specific regression equation and multiplication factor are needed for the accurate stature reconstruction. We have come out with new regression equation and multiplication factor to determine stature from the femur length, the same can be extrapolated to region of north Indian population with fair degree of accuracy.

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