Original Research

Estimation of Stature from Long Bones of the Lower Limb - A Cadaver Based Study

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Abstract

Background and objectives: Stature of a person is an important parameter of personal identification. In this study stature (body total length) was estimated from the measurement of length of femur and tibia belonging to unclaimed cadavers. **Methodology**: a total number of 51 unidentified dead bodies (42 males and 9 females) in age group of 18-80 years were studied. Length of the body of the study subject in lying position on autopsy table, length of the fresh (wet) and dry bones of femur and tibia were measured. Regression formulae and Multiplication factors were derived for both sexes for fresh and dry bones of femur and Tibia for estimation of stature. **Results**: Among males**;** Wet femur shows highest correlation with the stature, while wet tibia shows least correlation, though both show significant correlation for the estimation of stature ($P< 0.0001$). Among females**;** Dry femur, and combined dry femur and tibia shows highest correlation with the stature, while wet tibia shows least correlation, though both shows significant correlation for the estimation of stature ($P< 0.0001$). **Interpretation and Conclusion**: This study will be useful to the forensic medical experts when only the lower limb is available for forensic investigation in estimating stature and inanthropological research projects. Regression formulae are dependable than multiplication factor for estimation of stature.

Key words: forensic, regression formula, Stature estimation, lower limb bones, cadaver based study.

Introduction:

Stature establishment has always been an important parameter in the fixation of identity right from our ancient times.[1] Many factors are taken into consideration for the establishment of identity in these cases, amongst which height of the person is one. Estimation of the upright height of an individual is exclusively a metric procedure.[2]The regression formulae of Trotter and Glesser for the long bones were used to reconstruct the stature of an individual.[3]These measurements are based on maximum length of the adult bones. And the reconstruction of the stature from the available skeletal remains forms part of forensic anthropological analysis for the purpose of identification.[4]

Stature is a unique biological entity, that it can be measured not only in the living, but also from the skeleton long after the death of a person.[5] Intact long bones recovered among the human remains are ideal to reconstruct stature of an unidentified individual. In order to assist the process of identification of such cases, the researchers have formulated regression equations from the skull,[6-8] metacarpals,[9,10] long bone fragments,[11,12] hand and foot dimensions,

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shoe prints[13,14] and metatarsals.[15,16] In 1899, Pearson derived regression equations using Rollet and Manouvrier data and suggested that regression equations were population specific.[17] Limited literature is available regarding stature estimation from long bones of lower leg of people of Kakinada region of Andhra Pradesh.

Long bones of lower limb are the most accurate estimators of stature among Thai populations.[18] In 2009, Hasegawa et.al concluded that lower limb bones (femur and tibia) were more accurate stature estimation predictors than the humerus.[19] Femur and Tibia were selected in this study because these are the most commonly used long bones which helps in estimating the height of the individual with more accuracy compared to other long bones.[20,21]

In present study an attempt was made to use the length of long bones of lower limbs for calculating the stature of the individual by formulating regression formulae. Regression formulae are more dependable than multiplication factor for estimation of stature.[22]

Aims and Objectives:

1. The aim is to statistically correlate the lengths of long bones of lower limb with stature of the corresponding human body.

2.To derive regression formulae to estimate stature from length of femur or tibia and from both bones.

Materials and Methods:

The present study includes 102 bones (51 femur and 51 tibia) collected from 51 unclaimed untraced bodies that came to the Department of Forensic Medicine and Toxicology/Mortuary, for autopsy to Govt. General Hospital campus, Rangaraya Medical College, Kakinada by taking necessary permissions and informed consent and after intended compulsory procedures. Both wet and dry bones were prepared whichever necessary for the study, and their measurements were taken by osteometric board. Wet length indicates the length of the bone which is measured immediately after dissection.

Dry bones were prepared after necessary procedure and allowing them to dry up to few months at room temperature. The study group included adult population of aged about 18 years to 80years. Hepburn type of Osteometric board is used to measure the length of the bones, which is made up of wooden material with a scale on one end. The readings are in millimetres and centimetres. Length of the body was measured by the centimetre and millimetre scale on autopsy table. Both the lengths of bones will be correlated by statistical analysis. To analyse these data, SPSS software of 17 version is used.

Regression formulae were derived using online statistical calculations website: https://www.graphpad.com/quickcalcs/linear1/

Inclusion and exclusion criteria

a) Adult age groups (≥18 years) are taken in to the study.
b) Corpses with congenital and acquired deformities were excluded from the study.
c) Mutilated and decomposed corpses were excluded from the study.

Results:

a total number of 51 unidentified dead bodies (42 males and 9 females) in age group of 18-80 years were studied. Regression formulae and Multiplication factors were derived for both sexes for fresh and dry bones of femur and Tibia for estimation of stature. Among males**;** Wet femur shows highest correlation with the stature, while wet tibia shows least correlation, though both show significant correlation for the estimation of stature ($P< 0.0001$). Among females**;** Dry femur, and combined dry femur and tibia shows highest correlation with the stature, while wet tibia shows least correlation, though both shows significant correlation for the estimation of stature ($P< 0.0001$). Correlation coefficients and regression equations for estimation of stature of males, females and total cases are given in Table 1, 2 and 3.

Table 1: Correlation coefficients and regression equations for estimation of stature of males

Variable	R	r^2	SL	INT	SEE	T	P
Femur wet length	0.83	0.68	2.09	71.75	3.45	9.30	<0.05
Femur dry length	0.81	0.65	1.96	78.58	3.62	8.65	<0.05
Tibia wet length	0.75	0.56	1.99	86.85	4.08	7.13	<0.05
Tibia dry length	0.76	0.57	2.01	86.84	4.02	7.28	<0.05
Femur +Tibia wet length	0.82	0.68	1.11	71.65	3.47	9.21	<0.05
Femur +Tibia dry length	0.81	0.66	1.08	75.74	3.56	8.87	<0.05

Table 2:Correlation coefficients an d regression equations for estimation of stature of females

Variable	R	r^2	SL	INT	SEE	T	P
Femur wet length	0.94	0.89	2.51	51.59	2.66	7.44	<0.05
Femur dry length	0.95	0.90	2.56	50.14	2.56	7.78	<0.05
Tibia wet length	0.94	0.87	2.30	72.39	2.83	6.95	<0.05
Tibia dry length	0.94	0.88	2.27	74.00	2.79	7.05	<0.05
Femur + Tibia wet length	0.95	0.89	1.22	61.00	2.59	7.66	<0.05
Femur + Tibia dry length	0.95	0.90	1.22	61.70	2.56	7.76	<0.05

Table 3: Correlation coefficients and regression equations for estimation of stature of total Cases

Variable	R	r^2	SL	INT	SEE	T	P
Femur wet length	0.87	0.73	2.25	64.43	3.42	11.58	<0.05
Femur dry length	0.84	0.70	2.15	69.94	3.60	10.77	<0.05
Tibia wet length	0.80	0.64	2.14	80.25	3.97	9.32	<0.05
Tibia dry length	0.80	0.64	2.16	80.67	3.94	9.41	<0.05
Femur + Tibia wet length	0.86	0.74	1.18	66.07	3.40	11.65	<0.05
Femur + Tibia dry length	0.85	0.72	1.15	69.43	3.51	11.17	<0.05

Table 4: Total Cases : x: femur length [wet] : Y: total height

Coefficients

Model	Unstandardized Coefficients		Standardized Coefficients	T	Sig.	95.0% Confidence Interval for B	
	B	Std. Error	Beta			Lower Bound	Upper Bound
1 (Constant)	64.434	8.566		7.522	.000	47.220	81.649
Femur length wet	2.250	.194	.856	11.588	.000	1.860	2.640

a. Dependent Variable: total height

Y=2.250 X +64.434±8.566

The 'R' is the Pearson product moment correlation coefficient. 'R' is the square root of R-squared and is the correlation between the observed and predicted values of dependent variable. 'R-square' is the proportion of variance in the dependent variable, which can be predicted from the independent variable.

Among the males, when all the available age groups are taken in to consideration for the study,

Regression formulae

x: femur/ tibial / combined length [wet/dry]
Y: stature/ length of the body

1) for the wet femur: Y = 2.091(X) + 71.847. Coefficient of determination [R2]: 0.68
2) for the dry femur: Y = 1.958(X) + 78.584. Coefficient of determination [R2]: 0.65
3) for the wet tibia: Y = 1.985(X) + 86.852. Coefficient of determination [R2]: 0.56
4) for the dry tibia: Y = 2.008(X) + 86.836. Coefficient of determination [R2]: 0.57.
5) for the wet femur and tibia: Y = 1.108(X) + 72.077. Coefficient of determination [R2]: 0.68.
6) for the dry femur and tibia: Y = 1.065(X) + 76.621. Coefficient of determination [R2]: 0.66.

This implies wet femur and wet (femur and tibia) calculated from regression formula derived for males is the nearest possible value to the estimation of stature calculated by standard method.

Among the females, When all the available age groups ae taken in to consideration for the study,

Regression formulae

1) for the wet femur: Y = 2.506(X) + 51.593. Coefficient of determination [R2]: 0.89
2) for the dry femur: Y = 2.561(X) + 50.138. Coefficient of determination [R2]: 0.90
3) for the wet tibia: Y = 2.295(X) + 72.384. Coefficient of determination [R2]: 0.87
4) for the dry tibia: Y = 2.273(X) + 74.002. Coefficient of determination [R2]: 0.88.
5) for the wet femur and tibia: Y = 1.216(X) + 61. Coefficient of determination [R2]: 0.89.
6) for the dry femur and tibia: Y = 1.218(X) + 61.702. Coefficient of determination [R2]: 0.90.

This implies dry femur and dry (femur and tibia) calculated from regression formula derived for females is the nearest possible value to the estimation of stature calculated by standard method.

Among both sexes, when all the available age groups are taken in to consideration for the study,

Regression formulae

1) for the wet femur: Y = 2.250(X) + 64.434. Coefficient of determination [R2]: 0.73

2) for the dry femur: Y = 2.145(X) + 69.939. Coefficient of determination [R2]: 0.70
3) for the wet tibia: Y = 2.143(X) + 80.217. Coefficient of determination [R2]: 0.64
4) for the dry tibia: Y = 2.155(X) + 80.669. Coefficient of determination [R2]: 0.64.
5) for the wet femur and tibia: Y = 1.175(X) + 66.0744. Coefficient of determination [R2]: 0.74.
6) for the dry femur and tibia: Y = 1.146(X) + 69.431. Coefficient of determination [R2]: 0.72.

This implies wet (femur and tibia) calculated from regression formula derived for both sexes is the nearest possible value to the estimation of stature calculated by standard method.

Linear regression formulae are better than other methods in deriving the formulae. Formulae should be derived which help us in directly calculating stature from long bones. This should be done on a greater sample to minimise the standard error.

Discussion:

To begin with Rollet and Manouvrier were the pioneers in this work who started studying long bones. Rollet in a sample of 100 (50 males and 50 females) studied relationship between various long bone measurements and the stature.[23]In 1952, Trotter and Glesser in a sample of 100 (50 males and 50 females) studied estimation of stature from long bones. They concluded that increase in stature after 18 years is insignificant and there is no statistically significant alteration after age of 18 years[4].

In 2011, Ross and Manneschi in a study of 276 Chilean population studied dried limb bone lengths in relation to post-mortem stature and devised regression equations for femur, tibia and humerus.[23] In 2013, Jeong and Meadows Jantz conducted studies on stature of Korean population in a sample of 105 (55-males and 50-females) and developed regression equations. He concluded that length of long bones shows higher correlation with stature (9)

In 2016, Naema Mahmoud elhosary et.al in a comparative study of stature estimation from tibial length in Egyptian and Bengali adult population came to a conclusion that linear regression equations were ethnic and sex specific that cannot be applied to other ethnic group (or) population (24). In our current study mathematical method is being used to generate regression equations and stature is estimated directly from the lengths of long bones femur and tibia.

Regression equations are population specific, sex specific and also ethnicity specific. So, for the identification of unknown, regression equations were applied carefully to specific group of population and also for different sexes separately.

<u>In the present study</u>: 1) A<u>mong males;</u> Wet femur shows highest correlation with the stature, while wet tibia shows least correlation, though both shows significant correlation for the estimation of stature ($P < 0.0001$).

Individual wet and dry femur and tibia shows significant ($P < 0.0001$) correlation with the stature and also combined bones (femur and tibia) shows significant correlation to stature. Amongst which individual wet femur has the highest correlation with stature.

2) Among females; Dry femur, combined dry femur and tibia shows highest correlation with the stature, while wet tibia shows least correlation though both shows significant correlation for the estimation of stature ($P < 0.0001$).

Individual wet and dry femur and tibia shows significant ($P < 0.0001$) correlation with the stature and also combined bones (femur and tibia) shows significant ($P < 0.0001$) correlation to stature. Amongst which individual dry femur and combined dry femur and tibia has the highest correlation with stature.

3) When both sexes were combined, Wet femur shows highest correlation with the

stature, while wet and dry tibia shows least correlation though both shows significant correlation for the estimation of stature (P< 0.0001). Individual wet and dry femur and tibia shows significant (P< 0.0001) correlation with the stature and also combined bones (femur and tibia) shows significant correlation to stature. Amongst which individual wet femur has the highest correlation with stature.

The standard error of estimates (SEE) ranged between 3.45 and 4.08 for the males, between 2.56 and 2.83 for females and between 3.40 and 3.97 for the combined sample. The femur SEEs were greater in males compared to females, and the SEEs for the tibia were still greater in males compared to females. The SEE of the regression equations is considered a measure of precision and thus a small SEE indicates that estimates of stature, produced by the regression equation, are tightly clustered around the regression line

R2 is a statistic that gives some information about the goodness of fit of a model. In regression, the R2 coefficient of determination is a statistical measure of how well the regression line approximates the real data points. An R2 of 1 indicates that the regression lines perfectly fit the date.

Conclusion: Among males, wet femur shows highest correlation with the stature. Among females, dry femur and combination of dry femur and tibia shows highest correlation with the stature. When combined sexes are measured, wet femur shows highest correlation with the stature than tibia or combined bones. Individual femur and tibia and also combination of bones show significant correlation with the stature. Despite of this, both the bones selected for the study shows significant correlation with the stature. Regression equations derived should be used cautiously for different population groups as well as sexes. The purpose of selecting both the long bones of lower limb is accomplished.

Ethical clearance: obtained clearance from Institutional Ethical committee, Rangaraya Medical College, Kakinada.

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