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"Estimation of stature from the measurement of foot length, hand length and head length in Maharashtra region."

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Abstract:

Background: Estimation of height from measurement of various body parts is of particular interest to many anthropologists, anatomist and forensic scientist for its importance in medico-legal cases.

Aim & Objectives: Our aim was to investigate the relationship between personal stature and head length, foot length and hand length & to derive a regression formula to predict the height of an individual using foot length, hand length and head length altogether.

Materials and Methods: The present study was conducted on 1000 apparently healthy, Maharashtra medical students in the age group (years) of 19-22. All these measurements were done by using standard anthropometric instruments and standard anthropometric techniques.

Observation and Results: Data was analysed separately for male and female and for both genders together. All the parameters correlate significantly with stature but foot length in both the sexes depicts higher correlation coefficients with stature ('r'=0.850) than that any of the parameter. Estimation of stature using multiple regression analysis using multiple parameters (foot length, hand length and head length) gives the multiple correlation coefficient 'R' for both sexes together, which is higher (0.879) than the values obtained through simple linear regression equation which uses single parameter.

Conclusion: It is concluded that multiple linear regression analysis is better over simple linear regression analysis for estimating accurate stature.

Key words: stature, head length, foot length, hand length.

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Introduction: The determination of stature is a major step in the identification of dismembered remains. Anthropometric techniques are commonly used by anthropologist and adopted by medical scientist to estimate body size for the purpose of identification. Many studies have been carried out to estimate stature by taking measurements of long bones and radiographic materials[1].

Height is fundamental for assessing growth and nutrition, calculating body surface area, and predicting pulmonary function during childhood. There are studies, in which an attempt has been made to establish the correlation between stature, foot length, hand length and head length in various combinations but so far no definite attempt has been done in estimating stature by using above three parameters together.

Aims & objective: This study extends the findings of previous studies by exploring data that is height, foot length, hand length and head length measurements, using linear (simple and multiple) regression models. These formulae are applicable to that population from which the data has been taken.

Material & Method:

Samples for the study consisted of consecutive 1000 (Males=536 and Females=464) asymptomatic, apparently healthy, young adult Maharashtrian medical students from Government medical college.

Their nutritional and socioeconomic statuses were not assessed. The age range was between 19-22 yrs. A slow decline in the height is known to occur as the age advances and therefore older subjects were not studied[2]

The subjects were studied for four parameters i.e. Stature, Foot length, Hand length & Head length. All the measurements are taken using standard anthropometric instruments in centimetre to the nearest millimetre according to techniques described by Vallois[2].

Height of the individual was measured in standing erect anatomical position with standing height measuring instrument.

Head length was measured by vernier calliper from glabella to inion.

Foot length was considered as the maximum length between the most prominent posterior point of the heel and the tip of hallux and the tip of the second toe if it is larger than the hallux

Hand length –The distance between the midpoint of the interstyloid line and the tip of the middle finger in extension was measured as the length of the hand as described by Amirsheybani et al (2001)[(3,4)].

Observation and Result:

The data was analysed using SPSS software & the methods used were Linear and Multiple linear regression analysis.

The observations were done on 535 males and 465 females, total 1000 Maharashtrian students.

TABLE 1: Regression equation for height with other Parameters:

Total cases

Parameter	CorrelationCoefficient (r)	Regression Equation	'p' value
Foot Length(FL)	0.849	Height=55.5+4.5FL	<0.001
Hand Length (HnL)	0.828	Height=59.7+5.7Hnl	<0.001
Head Length(HdL)	0.531	Height=67.0+5.5Hdl	<0.001

TABLE 2: Regression equation for height with other Parameter

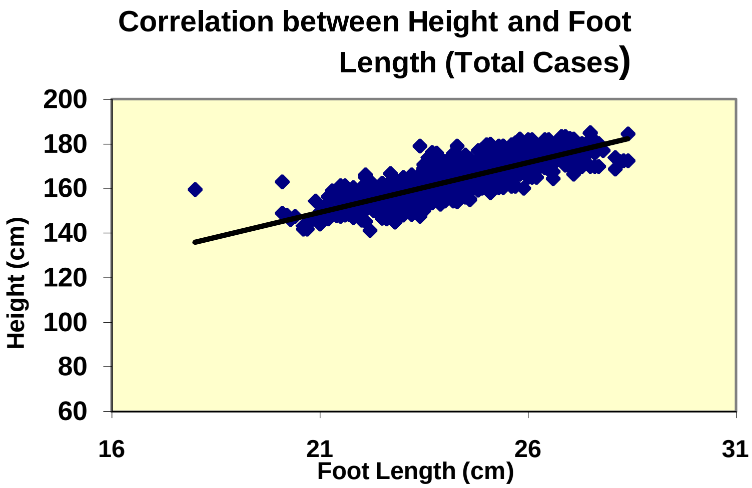
Female cases

Parameter	Correlation Coefficient (r)	Regression Equation	'p' value
Foot Length (FL)	0.702	Height=72.8+3.7FL	<0.001
Hand Length (HnL)	0.647	Height=84.9+4.3Hnl	<0.001
Head Length(HdL)	0.184	Height=127.7+1.7Hdl	<0.001

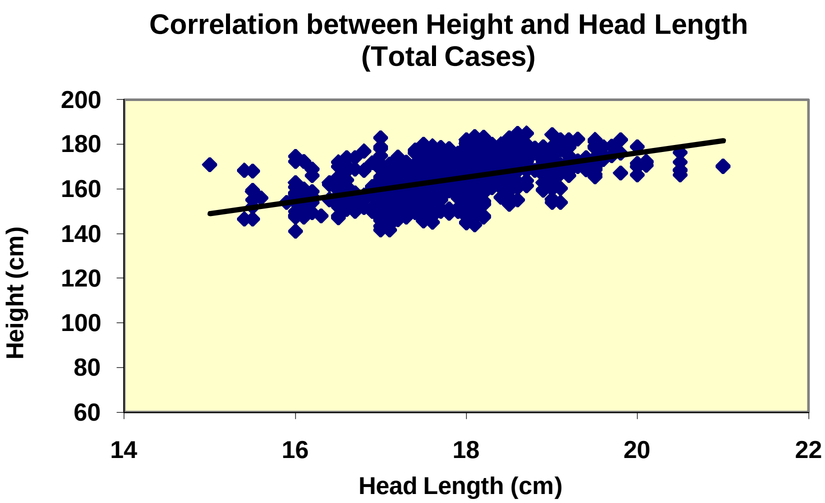
TABLE 3: Regression-height with other Parameter

Male cases

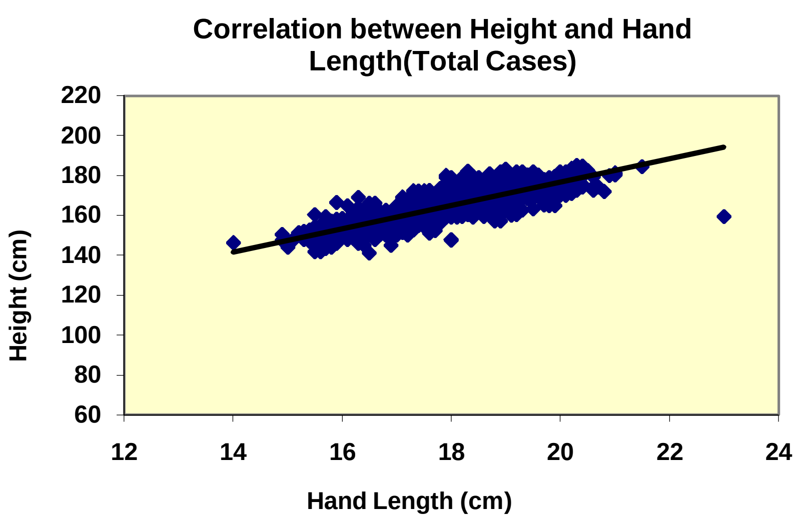
Parameter	Correlation Coefficient (r)	Regression Equation	'p' value
Foot length	0.645	Height =90.0+ 3.2FL	<0.001
Hand Length	0.616	Height =92.1+4.2HnL	<0.001
Head Length	0.218	Height = 140.7 + 1.6 HdL	<0.001



Graph 1A



Graph 1B



GRAPH 1C

The linear regression analysis of the data has provided the regression equation for each parameter to predict the height in combination data(table1) and in either sex (table 2 & 3) and. Graph 1A, 2B, 2C show regression lines for each parameter with height, drawn from the combined data analysis of male and female. These graphs explain the linear relation between height and the parameters under study.

It is obvious from the graphs that if one parameter changes the other also changes in that order. In simple terms it can be said that height can be predicted from foot length, hand length and head length with good accuracy.

The results of the tables show that, we can recommend estimating height from foot length as compared to other two parameters, even though they show significant 'p' value.

TABLE 4 : Multiple linear regression equation (total cases) :

Parameter	Multiple Correlation Coefficient (R and R^2)	Regression Equation	'p' value
Foot Length (FL) **Hand lth(Hnl)** **Head lth(Hdl)**	R = 0.879 R^2 = 0.773	Ht = 43.3 + 2.682FL + 2.724HnL + 0.387HdL	**<o.oo1**

TABLE 5 : Male cases:

Parameter	Multiple Correlation Coefficient (R and R^2)	Regression Equation	'p' value
Foot Length (FL)	R = 0.692 R^2 = 0.479	Ht = 75.313 + 2.070FL+2.267HnL Head length is not significant when taken with these two	0.0001
Hand Length (HnL)			
Head Length (HdL)			

TABLE 6: Female cases:

Parameter	Multiple Correlation Coefficient (R and R^2)	Regression Equation	'p' value
Foot Length (FL)	R=0.755	Ht = 59.451 + 2.552FL+2.295HnL	0.0001
Hand Length (HnL)	R^2=0.569	Head length is not significant when taken with these two.	
Head Length (HdL)			

The multiple regression equation model (Dawson and Trap 2004) with the explanatory variables or regressors, foot length, hand length and head length is proposed as a statistical model to explain the total variation in stature, the response or the dependant variable. This allowed the estimation of stature based on foot length, hand length and head length.

The multiple linear regression model was considered separately for male, female and both genders together. In the present study group, height (Y) is dependant variable and the explanatory variables were foot length (X_{FL}), hand length (X_{Hnl}) and head length (X_{Hdl}).

R^2 is called as coefficient of determination; this determines the strength of association between the parameters.

$R^2 \times 100$ gives the contribution of significant factors to dependant variables.

Table 4 presents multiple linear regression equation for the estimation of stature from combination of the dimensions of foot, hand and head (total cases). When we compared this table with Table 1, we found that the value of correlation coefficient of multiple regression equation is greater than the correlation coefficients obtained through simple linear regression equation. Interpretations suggested that the multiple regression equations are better indicators of stature estimation. Multiple linear regression equation for male and female study group shows the multiple correlation coefficient R = 0.692 and R = 0.755 respectively. The values are statistically significant with p value > 0.0001. In the model of multiple linear regressions we used forward step method in which the parameters are added one by one, the parameter which does not affect the value of the model is automatically eliminated from the equation, as here in this case occurs with Head length.

The R^2 value for male is 0.479 which indicates 47.9% of the prediction of the height can be attributed to foot length, hand length. Head length is not significant in this case.

Similar is true for female where head length is not significant when taken with hand length and foot length. The R^2 value for female is 0.569 that means 56.9% of the prediction of height can be attributed to foot length and hand length. The results of the present study show that the dimensions of hands, foot and head can successfully be used for estimating the stature.

TABLE 7: Table of comparison between r & R obtained through linear regression & multiple regression equation.

GENDER	DV	EVs	R/r	R^2	P Value
	Ht	Ft lth	0.645		0.000
MALE	Ht	Hnl	0.616		0.000
	Ht	Hdl	0.218		0.000
	Ht	Fl,Hnl,Hdl	0.692	0.479	0.000
	Ht	Ft lth	0.702		0.000
FEMALE	Ht	Hnl	0.645		0.000
	Ht	Hdl	0.184		0.000
	Ht	Fl,Hnl,Hdl	0.755	0.569	0.000
	Ht	Ft lth	o.849		0.000
BOTH	Ht	Hnl	0.828		0.000
	Ht	Hdl	0.531		0.000
	Ht	Ft,Hnl,Hdl	0.879	0.773	0.000

DV = Dependant variable, EV = Explanatory variable, R=Multiple correlation coefficient, r= correlation coefficient, R^2 =Coefficient of determination.

From table it is very clear that the correlation coefficient obtained through simple linear regression equation is smaller than correlation coefficient obtained through multiple regression equation. This means that the multiple linear regression equation model for male, female &both genders together group fits very well to the observed data..

Discussion: All the human beings occupying this globe belong to the same species i.e. *Homo sapiens*. No two individuals are exactly alike in all their measurable traits, even genetically identical twins (monozygotic) differ in some respects. These traits tend to undergo change in varying degrees from birth to death, in health and disease, and since skeletal development is influenced by a number of factors producing differences in skeletal proportions between different geographical areas, it is desirable to have some means of giving quantitative expression to variations which such traits exhibit. Anthropometry constitutes that means, as it is the technique of expressing quantitatively the form of the human body. In other words, anthropometry means the measurement of human beings, whether living or dead or on skeletal material.

Abdel-Kamel (1990)[5] In their study, used multiple linear regression model. The coefficient of determination(R^2) was 0.72 which declared 72% of variation in height could be attributed to hand length and hand breadth, out of which 68% variation in height relates to variations in hand length and only 4% relates to variations in hand breadth which means that hand length was highly predictive of stature when compared to hand breadth. Similar to above finding we found that the 'r' value (coefficient correlation) for hand length was 0.828 and the R^2 (coefficient of determination) value was 0.685, that means 68.5% variations in stature can be explained by hand length. The coefficient of determination obtained through multiple regression model is 0.773 (table-4) which means that 77.3% of prediction of height can be attributed to the foot length, hand length and head length.

Significant sex differences in stature and hand measurements were observed which is similar with our study. In the present study, males show higher mean values in each anthropometric dimension than among females. These statistically significant differences may be attributed to the early maturity of girls than boys; consequently the boys have two more years of physical growth. In the present study height is estimated using simple and multiple linear regression models. We compared the results of these models (Table 7) and found that the multiple regression model is better than simple linear regression model for estimating the stature. The multiple correlation coefficient 'R' for both sexes together 0.879 and the R^2 (coefficient of determination) is 0.773 which means that 77.3% of prediction of height can be done by foot length, hand length and head length together, this is in contrast to 72% by foot length, 68% by hand length and 28% by head length alone.

Similar to our results, Sanli SG (2005)[6] also stated that the multiple linear regression model is best fitted than simple linear regression model for estimating height from foot length and hand length. The R value was 0.928 while R^2 value was 0.861.

Krishnan K (2007)[1] concluded that the dimensions of hands and feet can provide good reliability in estimation of stature. It was observed that the multiple regression equations reveal lower values of Standard Error of Estimate (SEE) than the values given by linear regression equations. Interpretations suggest that the multiple regression equations are better indicators of stature estimation. This method of stature estimation can be used by law enforcement agencies and forensic scientists. The only precaution which must be taken into consideration is that these formulae are applicable to the population from which the data have been collected due to inherent population variations in these dimensions, which may be attributed to genetic and environmental factors like climate, nutrition etc. The results obtained in our study correlates with the previous studies.

Conclusion: All the parameters correlates significantly with stature but foot length in both the sexes depicts higher correlation coefficients with stature (‘r’=0.850) than that any of the parameter. Estimation of stature using multiple regression analysis using multiple parameters (foot length, hand length and head length) gives the multiple correlation coefficient ‘R’ for both sexes together, which is higher (0.879) than the values obtained through simple linear regression equation which uses single parameter.

Hence it is concluded that multiple linear regression analysis is better over simple linear regression analysis for estimating accurate stature.

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