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Original Article

A Comparative Approach between Multiplication Factor & Linear Regression Model in Predicting Stature from Dimensions of Hand

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ABSTRACT

Forensic investigation requires examination of evidences to determine the identity of the individual to whom the evidence belongs. Thus forensic identification of unknown evidences, mutilated & skeletal remains becomes the main stay in forensic science, criminal proceedings and in the court of law. The prediction of stature is one of the important parameter along with age, sex when rendering biological profile of an individual. Forensic experts use various approaches to predict stature along with anatomical method. However, in many cases they are forced to use only mathematical model or formulae to derive stature due to non – availability of entire skeleton. Two most widely used mathematical model for predicting stature are multiplication factor method and linear regression analysis method. The approach of the present study is to compare between the two methods which can better predict stature and to derive prediction error to demonstrate the reliability and accuracy of using these methods. The research study is based on 180 individuals with equal percentage of males and females within age group 18 to 60 years. Stature, Right Hand Length (RHL), Left Hand Length (LHL), Right Hand Breadth (RHB), Left Hand Breadth (LHB) were taken as anthropometric measurements from each individual. Multiplication factor and linear regression equation were derived for prediction of stature from hand dimensions. Derived factors and equations were applied to the actual hand dimensions collected in the study. Then the comparison was made between the actual stature and the predicted stature from Multiplication factor (MF) and Linear Regression equation (RG) to find the prediction error. The results were analyzed statistically using IBM SPSS Version 20.0 computer software. Statistical analysis revealed that sex differences were found to be significant for all the variables at $p < 0.001$ by student's t-test. It is evident from the study that the range of prediction error in case of RG analysis is lesser as compare to MF analysis. This shows that the prediction of stature is more reliable and accurate in case of regression analysis and hence confirming the fact that regression analysis method can better predict stature with minimum range of error in comparison with multiplication factor method.

Introduction

Forensic anthropology occupies an important place and a branch which was earlier a part of physical anthropology, has now not only achieved differentiation, but has emerged as a distinct discipline. It achieves its orientation and subject matter from forensic science. [1-3]. "Forensic science' may be defined as "scientific discipline which is directed to the recognition, identification, individualization and evaluation of the physical evidence by the application of principles and methods of natural sciences for the purpose of administration of criminal justice". Thus, forensic anthropology is the use of anthropology to gather and examine scientific evidence. Evidence can be defined as any object or statement by a witness that has bearing in a court of law. Evidence can take two forms: testimonial and physical (real) evidence. Testimonial evidence is evidence given in the form of statements made under oath, usually in response to questioning. Physical evidence is any type of evidence having an objective existence, that is, anything with size, shape, and dimension. Just like blood spatter or a discarded weapon at a crime scene, a lesion on a humerus that was used to determine the identity of an individual or a cut mark on a rib suggestive of the circumstances of death constitute "evidence". Examination of unknown evidences, mutilated & skeletal remains to determine the identity of the individual to whom the evidence belongs becomes the main stay in forensic science, criminal proceedings and in the court of law. The prediction of stature is one of the important parameter along with age, sex when rendering biological profile of an individual and anthropometry provides the base line to reconstruct stature in forensic examination of unknown mutilated skeletal remains. [4-6].Various studies on prediction of stature were conducted in the recent past from measurements of various dimensions of human body. [7-14].

There are two basic approaches to predict stature i.e. anatomical method (stature measured directly using anthropometer) also referred to as "Fully method" [15] and mathematical method (derivation of formula or equation to

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predict stature from different parameters of human body). It is considered that anatomical method provides best prediction of stature when entire skeleton is available. [16]. However when fragmented or mutilated parts are recovered for forensic examination to reveal identification, forensic experts are forced to use mathematical models as it can predict stature even with a single bone. This is based on the principle that stature is highly correlated with the dimension of the human body.

Two most widely used mathematical model for predicting stature are multiplication factor method and linear regression analysis method. Multiplication factor is derived as the ratio of stature with the hand dimensions. Mean multiplication factor thus calculated is used to estimate stature for each individual. Linear regression analysis method is establishing linear relationship between the variables on the basis of derived equation. Regression equations are used as if one variable is known the other can be predicted.

In predicting stature by linear regression analysis method, stature becomes the dependent variable whereas hand dimensions as independent variable. [14]. All the studies cited used either or both the mathematical methods to predict stature.

Studied have witnessed that linear regression analysis method is more accurate as compare to multiplication factor method but the degree of variability between the methods is the main objective of the present study by comparing between the methods which can better predict stature and also by deriving prediction error which will give a range as prove to demonstrate the reliability and accuracy of the methods. This will help to provide better prediction method with minimum range of error.

2. Materials & Methods

2.1 Sample Collection –

The present research includes a sample of 180 individuals (90 males and 90 females) within age group 18 to 60 years. The study was conducted in Rajasthan and the samples belong to endogamous Bhil population. Only individuals without any deformity were considered for the study.

2.2 Anthropometric Measurements –

Stature, Hand Length (HL) and Hand Breadth (HB) were taken as anthropometric measurements from each individual. Stature was measured using standard anthropometric rod following techniques developed by Weiner and Lourie 1981 [17] and Hand dimensions were measured using Sliding caliper and according to the techniques described by Singh and Bhasin. [18]. Hand dimensions were taken from both the right and left side of hand of each individual.

2.3 Statistical Analysis –

The research data so obtained were computed and analyzed using IBM SPSS (Statistical Package for Social Sciences, Version 20) computer software. Descriptive statistics i.e. mean, standard deviation, range was calculated for each variable. Multiplication factor for prediction of stature was derived which is obtained by dividing stature with the hand dimensions for each individual. Male – female differences were observed in stature, hand measurements and derived Multiplication factor for stature prediction using student's t-test at $p<0.05$ as level of significance. Linear regression model or equation was derived for prediction of stature from hand dimension with stature as dependent variable and hand dimensions i.e. Right Hand Length (RHL), Left Hand Length (LHL), Right Hand Breadth (RHB) & Left Hand Breadth (LHB) as independent variable. Derived multiplication factor and linear regression model were tested for each individual variable and predicted stature was calculated from both the methods. Actual stature (the stature taken directly using anthropometer) and the predicted stature from both the method (Multiplication factor method & linear regression model) were compared and prediction error was calculated by calculating difference between them. Predicted error is the difference between the predicted stature and actual stature.

2. Results:

Table 1a shows Descriptive statistics for stature and hand dimension in males and among females in Table 1b. All the variables (Stature, RHL, LHL, RHB, and LHB) show significant male-female differences at $p < 0.001$. It is observed from the table that the dimensions of males are statistically larger than the females. This is also evidenced by Sangeeta & Kapoor [12] while estimating stature from hand outlines. The descriptive statistics of the derived multiplication factor for predicting stature from hand dimensions was depicted in Table 2a for males and in Table 2b for females. Male – female differences for the derived multiplication factor are statistically significant at $p < 0.001$. Table 3 represents derived linear regression equation for predicting stature from dimensions of hand. Hand measurements show significant correlation with stature in males as well as in females at $p < 0.001$. This is also suggested by Kapoor, Saini and Choudhary in their research work. [11]. Table 4a depicts comparison between actual stature and predicted stature from multiplication factor and regression equation in males and Table 4b depicts for females. Mean actual stature and predicted stature from both the methods did not show much difference however much higher standard deviation was observed for multiplication factor method. It is also observed that the range of predicted stature in case of regression analysis method is narrower and for multiplication factor method it is much broader comparatively. This narrow range depicts that regression analysis method for stature prediction over-predict the minimum and under- predict the maximum whereas multiplication factor method for stature prediction under – predict the minimum and over-predict the maximum thus making the range broader and less reliable. This is proved after calculating prediction error for both the methods depicted in Table 5. The range of prediction error is significantly larger in Multiplication factor method than regression analysis method in both males and females.

Table – 1a

Descriptive statistics of stature and hand dimension in males.

Variable (cm)	Males (n = 90)				
	Mean	Standard Deviation	Range	Minimum	Maximum
Stature	163.2*	5.6	26.5	151.1	177.6
RHL	19.3*	1.2	5.6	16.9	22.5
LHL	19.2*	1.1	5.8	16.5	22.3
RHB	8.3*	0.4	1.9	7.3	9.2
LHB	8.2*	0.4	1.9	7.1	9.0

RHL - Right Hand Length, LHL - Left Hand Length, RHB - Right Hand Breadth, LHB - Left Hand Breadth, * - P < 0.001.

Table – 1b

Descriptive statistics of stature and hand dimension in females.

Variable (cm)	Females (n = 90)				
	Mean	Standard Deviation	Range	Minimum	Maximum
Stature	152.7*	6.4	31.7	139.0	170.7
RHL	17.5*	1.1	6.0	14.3	20.3
LHL	17.3*	1.0	6.2	13.9	20.1
RHB	7.6*	0.4	1.8	6.9	8.7
LHB	7.5*	0.4	1.7	6.8	8.5

RHL - Right Hand Length, LHL - Left Hand Length, RHB - Right Hand Breadth, LHB - Left Hand Breadth, * - P < 0.001.

Table – 2a

Descriptive statistics of the derived multiplication factor for predicting stature from hand dimension in case of males.

Variable (cm)	Multiplication Factor for Males (n = 90)				
	Mean	Standard Deviation	Range	Minimum	Maximum
RHL	8.48*	0.4	1.9	7.5	9.4
LHL	8.52*	0.4	2.0	7.7	9.8
RHB	19.71*	0.9	5.6	16.4	22.0
LHB	20.01*	0.9	4.2	18.1	22.3

RHL - Right Hand Length, LHL - Left Hand Length, RHB - Right Hand Breadth, LHB - Left Hand Breadth, * - P < 0.001.

Table – 2b

Descriptive statistics of the derived multiplication factor for predicting stature from hand dimension in case of females.

Variable (cm)	Multiplication factor for Females (n = 90)				
	Mean	Standard Deviation	Range	Minimum	Maximum
RHL	8.75*	0.4	2.5	7.5	10.0
LHL	8.83*	0.4	2.8	7.5	10.3
RHB	20.17*	0.9	4.3	18.3	22.6
LHB	20.46*	0.9	5.9	17.4	23.3

RHL - Right Hand Length, LHL - Left Hand Length, RHB - Right Hand Breadth, LHB - Left Hand Breadth, * - P < 0.001.

Table – 3

Linear regression equation derived for predicting stature from dimensions of hand in males and females.

Variable	Males (n = 90)	Females (n = 90)
RHL	113.967+2.554 (RHL*)	80.144+4.152 (RHL*)
LHL	115.247+2.500 (LHL*)	80.962+4.141 (LHL*)
RHB	120.691+5.559 (RHB*)	87.047+8.663 (RHB*)
LHB	117.825+5.559 (LHB*)	86.516+8.858 (LHB*)

Table – 4a

Comparison between actual stature and predicted stature from multiplication factor and analysis of regression equation in males.

Variable (cm)	Males (n = 90)				
	Mean	Standard Deviation	Range	Minimum	Maximum
Actual Stature	163.2	5.6	26.5	151.1	177.6
MF Stature					
RHL	156.8	12.4	65.7	125.1	190.8
LHL	156.7	12.2	67.3	122.7	190.0
RHB	158.7	9.9	42.2	139.2	181.3
LHB	158.6	10.0	39.8	139.1	178.9
RG Stature					
RHL	157.5	7.3	31.9	139.5	171.4
LHL	157.6	7.1	32.5	138.5	171.0
RHB	158.4	6.2	21.1	146.8	167.9
LHB	158.2	6.2	20.5	146.8	167.3

RHL - Right Hand Length, LHL - Left Hand Length, RHB - Right Hand Breadth, LHB - Left Hand Breadth, MF Stature – stature derived with multiplication factor, RG Stature – Stature derived with linear regression equation, * - P < 0.001.

Table – 4b

Comparison between actual stature and predicted stature from multiplication factor and analysis of regression equation in females.

Variable (cm)	Females (n = 90)				
	Mean	Standard Deviation	Range	Minimum	Maximum
Actual Stature	152.7	6.4	31.7	139.0	170.7
MF Stature					
RHL	159.8	9.0	46.7	133.9	180.6
LHL	160.0	8.9	40.3	138.6	178.9
RHB	157.7	8.8	40.2	139.2	179.4
LHB	158.6	9.2	41.8	139.1	180.9
RG Stature					
RHL	158.4	5.6	24.7	143.7	168.4
LHL	158.4	5.6	21.8	146.0	167.7
RHB	157.6	5.7	20.6	146.8	167.4
LHB	157.8	5.7	21.1	146.8	167.9

RHL - Right Hand Length, LHL - Left Hand Length, RHB - Right Hand Breadth, LHB - Left Hand Breadth, MF Stature – stature derived with multiplication factor, RG Stature – Stature derived with linear regression equation, * - P < 0.001.

Table – 5
Prediction Error in predicting stature upon implication of multiplication factor and regression analysis in males and females.

Predicted Error (cm)	Males (n = 90)			Females (n = 90)		
	Range	Minimum	Maximum	Range	Minimum	Maximum
Error using MF-						
RHL	41.1	-17.9	23.2	27.3	-9.7	17.6
LHL	45.6	-20.9	24.7	28.1	-12.9	15.2
RHB	48.1	-17.9	30.2	33.6	-17.2	16.4
LHB	32.2	-16.8	15.4	43.8	-19.1	24.7
Error using RG equation-						
RHL	27.9	-10.5	17.4	18.6	-8.1	10.4
LHL	27.8	-9.8	18.0	21.2	-9.3	11.9
RHB	28.3	-11.5	16.8	31.5	-17.6	13.9
LHB	23.2	-11.4	11.8	33.3	-14.9	18.4

RHL - Right Hand Length, LHL - Left Hand Length, RHB - Right Hand Breadth, LHB - Left Hand Breadth, MF Stature – stature derived with multiplication factor, RG Stature – Stature derived with linear regression equation, * - $P < 0.001$.

4. Discussion

Stature can be predicted with anatomical method and mathematical model. Anatomical method works well when complete skeleton is available however mathematical models are employed in case of commingled remains. Multiplication factor method and regression analysis method are the two basic mathematical models which are most widely used for stature estimation. These methods are compared in the present study. It can be revealed that all the variables are statistically significant sex differences. Linear regression analysis derived represents higher correlation between hand dimension and stature in both males and females. On comparison of mean actual stature and predicted stature from MF method and RG method it is evident that there is lesser difference between them. However, range denotes the accuracy of regression analysis method in stature prediction. Further the predicted error calculated suggests that the prediction error is greater in MF method and thus has limited utility in stature prediction as compare to RG method. Earlier studies also demonstrate that regression analysis method can better predict stature. [11,12,19]. Similar findings also reported by Krishan, Kanchan and Sharma & Sahni, et al. [20,21] in their study on stature estimation that regression analysis method can better predict stature than multiplication factor method.

5. Conclusion

The present study concludes with the narrow range of prediction error that regression analysis method is better than multiplication analysis method to predict stature. Thus it is concluded that prediction of stature is more reliable and accurate with regression analysis method than multiplication factor method. This is evidenced & proved with the minimum prediction error in regression analysis method.

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