Research Article

Estimation of Stature from Percutaneous Lengths of Tibia and Fibula of Scheduled Castes of Haryana State, India

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Abstract

The paper presents unilinear and mutiunilinear regression formulae for the reconstruction of stature from percutaneous lengths of tibia and fibula of Scheduled Caste males and females of Haryana State of India. The study is based on a cross-sectional sample of 202 individuals (101 males and 101 females) aged 18 to 21 years. Left and right radial subcutaneous lengths of tibia and fibula of each subject were measured using standard instruments and techniques. Percutaneous mean lengths of tibia and fibula were significantly greater in the males as compared to females ($P<0.05$).Bilateral differences in percutaneous lengths were not significant for tibia as well as fibula ($P<0.05$). Percutaneous tibial and fibular lengths showed significant correlation ($P<0.05$) with stature in both sexes; the correlations were stronger in females. The r^2 values suggest that tibia was a better predictor of stature for males and the fibula for females. The estimates are better if mutiunilinear equations of tibia and fibula are used together. The regression formulae reported here have important applications in forensic science for identification of unknown human remains, particularly partial, mutilated and dismembered ones, especially of Haryana State of north India.

INTRODUCTION

Establishment of identity of unknown human remains is a challenging task in medico-legal cases, especially when the remains are partial, mutilated or dismembered. Such situations usually arise in cases of natural disasters, rail and aircraft accidents, wars and terrorist explosions. Many times, only parts of human body, such as limbs, are available for identification. Being an individual characteristic, stature is one of the important parameters for personal identification. Estimation of stature, therefore, plays an important role in medico-legal cases in the identification of unknown bodies, parts of bodies or even skeletal remains. There exists a strong relationship between stature and dimensions of different body parts, particularly bone lengths, which forms the basis for stature estimation [1]. Out of various body parts, long bones play an important role for stature estimation in forensic investigations [2-16]. The lengths of long bones of lower limbprovide better estimates of stature as compared to the bones of upper limb [17].

Since the pioneering work of Rollet [18], a number of authors developed regression equations for estimation of stature from various long bones [19-24]. Though many equations for estimation of stature from long bones have been developed, there are apprehensions regarding the accuracy of the use of of population specific formulae on other human populations [11,25,26].Since the relationship between long bones and stature is influenced by ethnicity and gender of an individual, there are no universally applicable formulae for stature estimation from the length of long bones [26]. Studies have reported significant differences in proportion of limb dimensions due to hereditary, environmental, ethnic and dietary factors, which also influence the stature of a person [27-29]. Therefore, population-specific formulae are more reliable for estimation of stature in medico-legal cases [11, 26,30-33]. However, there are some difficulties in developing population specific formulae for estimation of stature from long bones [1]. One the main problem is the unavailability of documented skeletal collections with accurate ante-mortem stature records for different Indian populations [1,34,35]. However, in the absence of documented skeletal collections, the formulae can be developed from the percutaneous bone measurements of living populations. This may not be an ideal solution, but it has the advantage of avoiding serious errors that could result due to the use of formulae developed for another population.

A number of researchers have used percutaneous lengths of limb bones for estimation of stature [8,26, 36-50]. In a vast and multi-ethnic country like India, body proportions vary from population to population. Consequently, formulae developed for population of one state may not necessarily be applicable on population of another state [51]. There is, thus, a need to develop population specific stature estimation formulae for forensic purposes. Moreover, due to secular changes in stature, fresh formulae are required for each generation [1,24,52]. It is known that secular trends in stature are accompanied by changes in body [53-56].Though some populations from India have been covered [1,36-39,46,48,57,58] , but a vast majority remains to be investigated. No formulae for estimation of stature from lower limb bones are available for population from Haryana State of India. In view of the paucity of information from Haryana, we present here linear regression models to predict stature on the basis of percutaneous lengths of tibia and fibula of a population from Haryana State of India.

MATERIALS AND METHODS

This paper is based on a cross-sectional sample of 202 adult individuals (101 males and 101 females) ranging in age from 18 to 21 years. The data for the present work was collected from the various senior secondary schools and colleges of Naraingarh area of Ambala District of Haryana State of India. Only normal healthy individuals were included in the study. Individuals suffering from deformities of lower limbs, such as polio, bow legs, etc., were not included in the study. The following three anthropometric measurements were taken on each individual with the help of GPM anthropometer (Model No. 101) following the protocols of Weiner and Lourie [59]:

1. Stature: It was taken as a straight distance from the highest point on the head (vertex) to the floor with the subject standing erectwith head in the Frankfort-Horizontal plane (eye-ear plane).

2. Percutaneous Length of Tibia: It was take as the distance between the highest point on medial border of the head of the tibia (tibiale) to the most distal point on the medial malleolus (spherion). The subject was asked to sit facing the observer with ankle resting on the knee, so that the medial aspect of the tibia faced upwards. It is easier to access the tibiale point in a sitting position. The cross-pieces of the rod compass of the anthropometer were applied to the tibiale and spherion landmarks to record the percutaneous length of tibia. The measurement was taken on left as well as right tibiae.

3. PercutaneousLength of Fibula: It was taken as the distance between the highest point on the head of fibula to the most distal point on the lateral malleolus. The subject, in a standing position, was instructed to keep one leg on a low table. The required landmarks are easier to locate in this position. Cross-pieces of the rod compass of the anthropometerwere applied to the highest point on the head of fibula and the most distal point on the lateral malleolus to take the measurement. This measurement was taken on left and right sides of each individual.

For statistical analysis SPSS software version 16 was used. The significance of bilateral and gender differences were estimated with the help of one-way ANOVA.Association of numerical parameters was assessed by Pearson's correlation coefficient (r). Regression formulae were calculated using the simple linear regression based on the least-squares method.Population-specific least squares regression formulae for estimating stature from percutaneous bone lengths were developed by regressing stature on the percutaneous bone lengths for males and females. Percutaneous lengths of tibia and fibula were employed to estimate stature. Regression formulae and r-square values (r^2) and standard error of the estimate (SEE) are reported.

RESULTS

Table 1 shows the means of stature and percutaneous lengths of tibia and fibula of left and right sides. As expected, the males were taller and their mean percutaneous lengths of tibia and fibula were significantly greater than that of the females. The results of one-way ANOVA analysis (Table 2) indicate significant sex differences ($P<0.001$). Although the left tibial and fibular percutaneous lengths were fractionally greater (except for fibula in case of females), the overall bilateral differences, as revealed by a one-way ANOVA analysis (Table 3), were not significant in both sexes ($P<0.05$). The percutaneous lengths of tibia and fibula showed strong correlation with stature (Table 4). The correlations were comparatively stronger in females ($P<0.05$).

Table 5 shows the regression equations for estimation of stature from percutaneous lengths of tibia and fibula of males and females in the present sample from Haryana State of India. The regression formulae are the most widely used methods of estimation of stature from the length of long bones. In this paper, linear regression analysis was used to compute the regression formulae for the estimation of stature from the percutaneous lengths of tibia and fibula of left and right sides. Since the relationship between long bones and stature is influenced by gender of an individual [26], separate regression equations for males and females are computed. Since bilateral differences were not significant, regression equations were also calculated for the combined means of the left and right sides. Using these equations, stature can be estimated from either left or right bones without any significant difference in the estimated stature.

It can be seen in Table 5, in males, standard errors of estimate (SEE) were less for tibia than for the fibula suggesting more accurate stature estimates using percutaneous tibial length. However, in case of females, the reverse was the case, where the standard errors of estimate were fractionally lower for fibula. It is also clear from Table-5 that the SEE was marginally lower, in males as well females, when stature was estimated using multiple linear equations considering tibia and fibula together. Overall, the r^2 values were clearly higher for females than the males for tibia as well as fibula suggesting more accurate estimates of stature from percutaneous lengths of leg bones in females. The values of r^2 were more for tibia in males and fibula in females, which suggest that tibia was a better predictor of stature for males and the fibula for females. In males as well females, the r^2

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Table 1: Mean±S.D. of Stature (cm) and percutaneous lengths of Tibia and Fibula (cm) of males and females of Haryana State of India.

Gender	Stature±S.D.	Left Tibia length±S.D.	RightTibia length±S.D.	LeftFibula length±S.D.	RightFibula length±S.D.
Males	167.21 ±5.01	38.29± 1.76	38.26±1.65	39.82±2.02	39.66±2.03
Females	154.72±5.41	35.43±1.71	35.26±1.69	36.35±1.85	36.39±1.95

Table 2: Results of one-way ANOVA for sex differences in mean Stature (cm), and percutaneous lengths of Tibia and Fibula (cm).

Measurement	Treatment	Sum of Squares	Degrees of Freedom	Mean Square	F-value
Stature	Between Groups	7880.628	1	7880.628	289.70*
	Within Groups	5440.413	200	27.202	
	Total	13321.041	201		
Left Tibia Length	Between Groups	410.044	1	410.044	136.21*
	Within Groups	602.100	200	3.010	
	Total	1012.143	201		
Right Tibia Length	Between Groups	455.400	1	455.400	162.72*
	Within Groups	559.721	200	2.799	
	Total	1015.121	201		
Left Fibula Length	Between Groups	607.129	1	607.129	160.02*
	Within Groups	758.840	200	3.794	
	Total	1365.969	201		
Right Fibula Length	Between Groups	540.090	1	540.090	136.85*
	Within Groups	789.341	200	3.947	
	Total	1329.431	201		

* Significant difference (P<0.01)

Table 3: Results of one-way ANOVA for bilateral differences in percutaneous lengths of Tibia and Fibula.

Measurement	Treatment	Sum of Squares	Degrees of Freedom	Mean Square	F-value
MALES					
Percutaneous length of Tibia	Between Groups	0.036	1	0.036	0.012
	Within Groups	581.955	200	2.910	
	Total	581.991	201	-	
Percutaneous length of Fibula	Between Groups	1.236	1	1.236	0.302
	Within Groups	818.987	200	4.095	
	Total	820.223	201	-	
FEMALES					
Percutaneous length of Tibia	Between Groups	1.640	1	1.640	0.566
	Within Groups	579.865	200	2.899	
	Total	581.505	201	-	
Percutaneous length of Fibula	Between Groups	0.083	1	0.083	0.023
	Within Groups	729.194	200	3.646	
	Total	729.278	201	-	

was marginally higher when multiple linear regression equations were used (Table 5). The estimates of stature would, therefore, be better when tibia and fibula are considered together using multiple linear regression equations.

Table 6 shows a comparison of the actual measured and estimated stature from percutaneous lengths of tibia and fibula. The difference between estimated and actual measured stature was meagre and not significant (P<0.05). Thus, the equations presented here can be used in medico-legal cases to estimate stature of population of Haryana State of India from percutaneous lengths of tibia and fibula.

DISCUSSION

Stature estimation from different body parts is significant in medico-legal cases. It provides an important parameter for personal identification. Many times, dismembered, mutilated and comingled bodily parts of deceased persons are brought for forensic examination. In such situations, estimated stature from available body parts can prove vital to narrow down the investigation to a limited number of individuals.

Out of the anatomical and mathematical methods, the latter method has been more commonly used by forensic scientists for stature estimation due to non-availability of complete skeletons

in most medico-legal cases [60]. The mathematical method holds an advantage because it can be used even if a single limb/partial limb or single long bone is available to the examiner, given the proportional relationship that various body parts have with stature [29].

The results of the present study validate and support the hypothesis that there exists a strong relationship between stature and dimensions of different body parts, particularly bone lengths. The results of the present study also clearly demonstrate that the percutaneous lengths of tibia and fibula can be used for the estimation of stature.

Several authors have developed regression formulae for stature estimation from leg bones [22-24,61-63]. These formulae are based on well-documented skeletal remains of European White or African Black ancestry. Unfortunately documented skeletal remains are not available for Indian populations [1,34,35]. One of the alternatives is to use data from living populations. It may not be an ideal solution but, at least, it provides population specific formulae which, to some extent, can overcome the imprecisions in medico-legal cases that may result by using formulae developed for a totally alien population [1].

Furthermore, there is a need to develop population specific regression formulae because populations vary in their size and stature [63-64] and in the proportions of the body parts to stature [65-68, 24]. Limb length to stature proportions also differ between human populations. Therefore, the use of regression formulae for stature estimation across populations could be problematic due to differences in body proportions in different populations [59]. As early as 1929, Stevenson had observed that the regression formulae developed on one race when used for another race give unsatisfactory results [18].

Several recent studies also stressed upon the better reliability of population-specific regression formulae for estimation of stature in forensic cases [1,11,25,29,30,31] . Thus, it is advisable to develop population-specific regression formulae [59].

We conclude that the regression equations presented here can be used to estimate ante-mortem stature, with reasonable accuracy, of unknown mutilated or dismembered human lower limb remains from percutaneous lengths of tibia and fibula in medico-legal cases, particularly from Haryana state of north India. Side of the limb has no effect on the accuracy of the estimate. The estimates are better if mutiunilinear equations of tibia and fibula together are used.

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