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Estimation of Stature from Different Anthropometric Measurements of Gorkha Soldiers

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ABSTRACT

Stature is one of the most important elements in the identification of a person. Many different anthropometric dimensions can be used in the estimation of stature. Establishing the identity of an individual from body fragments has become an important necessity in recent times due to natural and man-made disasters. This study was performed on 226 Gurung soldiers of Gorkha regiment of Indian Army. The studied soldier's age range was 18 yr - 48 yr. Six anthropometric measurements (stature, hand length, arm length, standing knee height, foot length and leg length) were measured and stature is estimated with the help of these measurements.There was no significant difference between actual and estimated stature. All anthropometric measurements were highly correlated with stature at significance level $p< 0.001$ but leg length had better correlation ($r = 0.816$) compared to other variables. Stature can be estimated with the help of standing knee height ($r = 0.686$, $p<0.001$) and arm length ($r = 0.653$, $p<0.001$). It can be concluded that leg length was a very good predictor of stature estimation for the studied population.

Keywords: Forensic science; Anthropometry; Stature estimation, Leg length

1. INTRODUCTION

Stature of an individual is one of the important parameter which contributes greatly to the process of identification even after death. It plays a significant role in the field of forensic anthropometry. In recent times man-made disasters like mass accidents, terror attack, war, plane crashes and bomb blasts and natural disasters like floods, tsunamis cyclones and earthquakes etc. are very common in every country. These disasters are causing major human harm and in most of the cases, it is very difficult to identify an individual. Therefore, establishing the identity of an individual from crippled, disintegrated and amputed body segments has become necessity. It is very useful both for legal and humanitarian causes[1]. So, estimation of stature from different anthropometric dimensions is a very important tool to identify defence personnel from their body parts in the war situation. It is well known that each and every dimension as arm length, leg length, and hand length, etc. of human body has definite and proportional biological relationship with stature. This relationship that helps to calculate the height of an individual, from different anthropometric dimensions has always been of great interest to anatomists, anthropologists and forensic experts. Estimation of stature from anthropometric measurements is considered relatively a central position for both in the research of anthropology and in the identification necessitated for medico legal expert or medical jurisprudence.

Anthropologists or Forensic experts can measure the dimensions of available body parts for examination, and put these values of anthropometric dimensions into a regression equation as per gender and ethnic group. With the help of this regression equation, a height range can be calculated, which can exclude the individuals that fall outside those limits[2] many studies have shown the correlation of stature with body appendages[3-11] and with long bones[12-21].

To establish the benchmarks of height reconstruction, scientist or anthropologist have followed the technique suggested by Allbrook[22], to conquer the lack of non-availability of recorded skeletal material in India, where he measured the long limb bone dimensions among living people and formulated multiplication factors and regression formulae for determination of stature. Reconstruction of stature from various bones of the human skeleton has been achieved by many scientists with varying degree of accuracy[8].

There is important number of reasons to estimate an individual stature from different techniques or procedures. Estimation of stature from various segment of human body has been achieved by many anthropologist of forensic expert but degree of accuracy was found different[8]. Stature can be estimated from the fragments of the bones which help in resolving mass disaster cases in forensic examination and even help in establish archeological survey. Nutrition stature as well as pharmacokinetic parameters relies on body measurements which includes body weight as well as height. Individual suffering from deformities of vertebral column makes the measurements of standing height difficult[23]. Therefore, the present study was done keeping in mind the following aims and objectives:

- To estimate stature (S) from various anthropometric measurements using different regression equations.

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- To indicate the most useful variable in stature estimation from five anthropometric measurements such as leg length, foot length, standing knee height, arm length and hand length.

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2. MATERIALS AND METHODS

2.1 Study Sample

This study was performed on 226 Gorkha personnel serving at different location and in different battalion of Indian armed forces. These soldiers belonged to Gurung ethnic group and originally belong to Nepal. The studied soldier's age range was 18 yr - 48 yr. Written consent is given by all volunteers to participate in this study and ethical committee approved this study. Anthropometric data of these Gorkha soldiers were very valuable for the present study undertaken by the organisation to analyse the Gorkha troops of Indian armed forces.

2.2 Anthropometric Measurement

All anthropometric measurements such as stature, leg length (LL), foot length (FL), standing knee height (SKH), arm length (AL) and hand length (HL) were made on 226 soldiers by trained personnel following standard techniques recommended by Lohman[24].

2.2.1 Stature

In the Frankfort horizontal plane (F-H Plane), height was measured from the standing surface to height point of the head (vertex) using GPM anthropometric rod to the nearest 0.1 cm

2.2.2 Leg Length

Ask the soldiers to stand straight with their heel together and same weight distribution on both feet. It is measured from the floor to the top of the iliac crest while soldiers stand is also called as iliac crest height.

2.2.3 Foot Length

It is measured from the most anterior to posterior projecting part of the foot.

2.2.4 Standing Knee Height

Ask the soldiers their heels together due to which their weight distributed evenly between both feet. Detect the patella (ball of knee) on the front the knee and find the center of the knee cap. Vertical distance from the floor to the drawn midpatella landmark at the center of the knee.

2.2.5 Arm Length

Horizontal distance between the back of the shoulder (acromial landmark) to stylion landmark on the wrist.

2.2.6 Hand Length

The measurement is taken with a sliding caliper from midpoint of a line joining the styloin process of radius and ulna bones of forearm to the tip of middle finger[25].

Data analysis was done using Statistical Package of Social Science version 11.5 (SPSS) for computation of mean, standard deviation (SD), correlation, regression equations and standard error of estimation (SEE) for reconstruction of stature from the six anthropometric dimensions of the body as stature, LL, FL, SKH, AL and HL. Estimated stature calculated using single and multiple linear regression equations were compared with actual stature using paired t-test.

The regression equations were appraised by testing the significance using the standard error of estimate (SEE) and coefficient of determination (adjusted R^2).

3. RESULTS

Descriptive statistical data such as minimum, maximum, mean, SD and SEE of anthropometric variables of 226 Gorkha soldiers are shown in Table 1. It is observed from Table 1 that the actual stature of soldiers ranged between 152.80 cm - 190.60 cm and its mean and SD were 165.57 cm and 5.53 cm, respectively. Table 1 describe that all anthropometric variables were highly correlated with stature at significance level $p < 0.001$ but leg length has better correlation ($r = 0.816$) compared to other variables and hand length has weakest correlation ($r = 0.544$) with stature estimation. The equations for all anthropometric variables obtained by using single linear regression defined that the least SEE in stature estimation was 3.20 cm when stature was estimated by using leg length. SEE for stature estimation by other variables were shown in Table 2. By applying multiple linear regressions many formulas were obtained by which stature could be estimated using different set of anthropometric variables and its respective SEE shown in Table 2. It is clear from Table 3 that the minimum and maximum SEE were 2.66 cm and 2.98 cm, respectively. Table 2 shows a comparison between actual stature and estimated stature obtained by using single linear regression equation for all anthropometric variables such as LL, FL, SKH, AL and HL of soldiers of Indian army. The widest range of estimated stature was observed 153.77 cm - 183.79 cm in leg length used regression equation. The mean of estimated stature obtained from different anthropometric variables are approximately similar to the actual stature. Anthropometric measurements were repeated on randomly selected 30 Gorkha soldiers for detecting inter observer error indices which was explained as $p > 0.05$ for Stature, LL, AL, FL and HL and $p > 0.01$ for standing knee height. Hence, Table 4 explained that all these anthropometric variables were not statistically significant.

4. DISCUSSIONS

On the basis of different anthropometric measurement many prediction equations were established to estimate stature as shown in Table 2. Out of five anthropometric measurements

Table 1. Descriptive statistics for anthropometric measurements (n=226)

Parameters	Min	Max	Mean	SD	Correlation between Stature and other anthropometric parameters		
Stature (cm)	152.80	190.60	165.57	5.53	r	R^2	p
Leg length (cm)	80.20	108.00	91.11	4.18	0.816(**)	0.667	0.000
Standing knee height (cm)	41.00	56.40	47.17	2.52	0.686(**)	0.471	0.000
Arm length (cm)	47.40	67.80	54.65	3.39	0.653(**)	0.427	0.000
Foot length (cm)	20.90	29.00	24.41	1.04	0.566(**)	0.321	0.000
Hand length (cm)	14.50	22.30	17.69	0.88	0.544(**)	0.296	0.000

* Correlation is significant at the 0.05 level (2-tailed).
** Correlation is significant at the 0.01 level (2-tailed).

Table 2. Single linear regression equations for stature from anthropometric measurements

Parameter	Equations	Estimated stature (Range) (cm)	Mean (cm)	SEE (cm)
Leg length (LL)	S=67.154+1.080*LL	153.77 -1 83.79	165.55 ± 4.51	3.20
Standing knee height (SKH)	S=94.469+1.507*SKH	156.26 - 179.46	165.56 ± 3.80	4.03
Arm length (AL)	S=107.258+1.067*AL	157.83 - 179.60	165.57 ± 3.61	4.20
Foot length (FL)	S=92.043+3.012*FL	154.99 - 179.39	165.56 ± 3.13	4.56
Hand length (HL)	S=104.942+3.427*HL	154.63 - 181.36	165.57 ± 3.01	4.65
Actual stature		152.80 - 190.60	165.57 ± 5.53	

Table 3. Multiple linear regression equations for stature from anthropometric measurements

Parameter	Equations	SEE (cm)
LL, HL	S=52.985+0.946*LL+1.494*HL	2.98
LL, HL, AL	S=50.096+0.766*LL+1.414*HL+0.378*AL	2.81
LL, HL, AL, SKH	S=47.364+0.641*LL+1.209*HL+0.332*AL+0.429*SKH	2.69
LL, HL, AL, SKH, FL	S=43.007+0.611*LL+0.947*HL+0.313*AL+0.421*SKH+0.538*FL	2.66

Table 4. Inter observer error calculated in six anthropometric measurements using paired t-test (n=30)

Parameters	Mean	Std. deviation	Std. error mean	95% Confidence interval of the difference		t	Sig. (2-tailed)
				Lower	Upper		
S	-0.553	7.910	1.444	-3.507	2.400	-0.383	0.704
LL	2.057	5.755	1.051	-0.092	4.206	1.957	0.060
SKH	1.413	3.271	0.597	0.192	2.635	2.367	0.025
AL	-1.237	4.439	0.810	-2.894	0.421	-1.526	0.138
FL	0.266	1.515	0.277	-0.300	0.831	0.961	0.345
HL	0.093	0.950	0.173	-0.261	0.448	0.538	0.595

leg length of soldiers showed best correlation ($r = 0.816$, $p<0.001$) with stature and its respective SEE was 3.20 cm and hand length showed weakest correlation ($r=0.544$, $p<0.001$) which exhibited the highest error of estimation (SEE= 4.65 cm).

SEE is very good parameter to check the validity of estimated stature values with actual stature values. In the present study SEE range in estimated stature obtained by using single linear regression were 3.20 cm to 4.65 cm. These SEE value were lesser compared to SEE obtained in a study performed by Krishan and Sharma for India population[8]. Many other studies also showed minimum errors in linear regression equations for relation of FL with stature [26-28] but in the present study the minimum SEE was observed in single linear regression equation for relation of leg length. For leg length it was observed on the basis of single linear regression equation that correlation coefficient $r=0.816$ and coefficient of determination $R^2 = 0.667$ which means that 66.7 per cent of stature can be explained by leg length which was the best predictor compared to the rest of the anthropometric measurements. This was similar to result of many earlier studies which suggest that the appendages with long bone have better correlation with stature[12-21].

As shown in Table 5 there was no significant difference between estimated stature obtained by using single linear regression equation and actual stature of Gorkha soldiers for all anthropometric measurements. The second best predictor of stature found in the present study was standing knee height (SKH), because SKH also has very good correlation with stature ($r=0.686$, $p=0.001$) and SEE in regression equation for this parameters was 4.03 cm. Similar result was found in previous studies performed by Han TS and Lean ME[28]. It was clear from Table 1 that standing knee height also had a very good correlation with stature ($r=0.686$, $p<0.001$) and can explain 47.1 per cent of prediction of stature attributed to SKH and SEE for this regression equation was 4.03 cm. Many studies also conclude that SKH was a good predictor of stature. Knee height in the elderly group (aged 65 year) does not depend on the age of this population is a tested hypothesis by Zhang[30], *et al.* This performed on 247 (130 men and 117 women) adult ethnic Chinese living Melbourne, Australia. In this study it was observed that knee height has a valid estimation of maximum stature during early adulthood than arm span because knee height does not depend on age. The findings of this study suggested that knee height provided a valid estimation of maximum stature during early adulthood than arm span because knee height is independent of age. Table 1 also showed that 42.7 per cent and 29.6 per cent of prediction of stature can be done by arm length and hand length respectively.

Table 5. Comparison of actual stature and estimated stature by using multiple linear regression equations

Parameter	Estimated stature (Range) (cm)	Mean (cm)	r	R^2
LL, HL	154.93 - 188.47	165.60 ± 4.67	0.844	0.712
LL, HL, AL	154.11 - 189.98	165.55 ± 4.78	0.864	0.746
LL, HL , AL, SKH	153.88 - 190.26	165.53 ± 4.84	0.876	0.767
LL, HL, AL, SKH, FL	154.43 - 190.68	165.52 ± 4.86	0.879	0.773
Actual Stature	152.80 - 190.60	165.57± 5.53	-	-

The R^2 values for Indian Gorkha soldiers was 0.321 which indicated 32.1 per cent of the prediction of stature attributed to foot length which was higher to R^2 values obtained in a study performed by Abdi Ozaslan[31] but lower than study performed by Sonali and ashish[32]. Similar trend was found for R^2 value for hand length. Krishnan[8] concluded that the measurement of feet and hands can provide good reliability in estimation of stature. Stature can be predicted using multiple linear regression equations as shown in Table 2 which give better result as single linear regression equation. SEE for these equations were also shown in the Table 2. SEE range for this equation was found between 2.66 cm to 2.98 cm. It was clear from Table 2 that SEE for single regression equations were greater than SEE of multiple linear regression equations. Similar to our result, it was observed by Sonali that single linear regression model for constructing height with the help of feet length and hand length[5]. The multiple linear regression equations for anthropometric measurements had correlation coefficient r = 0.879 and coefficient of determination R^2 = 0.773 which means that 77.3 per cent prediction of stature can be done by a combination of LL, HL, AL, SKH and FL. This regression equation also had smallest value of SEE (= 2.66 cm) and estimated stature range from this equation was 154.43 - 190.68 cm. Other combination of anthropometric measurements such as (LL, HL), (LL, HL & AL) and (LL, HL, AL & SKH) also had very good prediction power for stature estimation such as 71.2 per cent, 74.6 per cent and 76.7 per cent, respectively and SEE for these regression equations were observed 2.98 cm, 2.81 cm and 2.69 cm, respectively.

Law enforcement agencies and forensic scientists can also use this method for stature estimation.

5. INFERENCES

Since leg length (r = 0.816, p <0.001) and standing knee height (r = 0.686, p <0.001) have better correlation with stature compared to other anthropometric parameters such as arm length, foot length and hand length and since there is no significant difference between actual stature and estimated stature, it can be concluded that with the help of anthropometric dimension such as leg length and standing knee height, a particular soldier/person height can be predicted. Other anthropometric parameter such as arm length, foot length and hand length could also be useful for the estimation of stature for identification.

6. LIMITATIONS

Present prediction equations were derived with the help of a single and multiple regression and are applicable only for male Gurung soldiers of Gorkha regiment of Indian army.

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