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A Model for Construction of Height and Sex from Shoulder Width, Arm Length and Foot Length by Regression Method

Twisha Shah[1], Patel MN[2], Nath S[3] and Shobhana K Menon[*1]

[1]Department of Forensic Science, Gujarat University, Ahmedabad, Gujarat, India
[2]Department of Statistics, Gujarat University, Ahmedabad, Gujarat, India
[3]Retired Professor, Department of Anthropology, University of Delhi, India

[*]**Corresponding author:** Shobhana K Menon, Department of Forensic Science, Gujarat University, Ahmedabad 380009, Gujarat, India, Tel: +91-079-26300435, E-mail: shobhanamenon07@gmail.com

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Abstract

Anthropometry is a systematic study of measurements on man and it involves scientific techniques for taking various measurements and somatic observations on the living man. As crime rate is increasing day by day, issue for human identification is of prime note. A forensic anthropologist would attempt to answer the following key questions relating to origin, age, sex, height and race after examining the remains. For instance height and sex determination is of utmost importance for human identification. No organized studies are yet available for sex and height estimation of people of Gujarat. The present study examines relationship between height and sex with shoulder width, arm length and foot length among two communities, Muslim and Hindu of Gujarat, India. A comparative study on measurements of shoulder width, arm length and foot length were taken among 160 adults (20-50 years) of which 80 were Muslim and 80 were Hindu of Gujarat. Linear and Multiple regression equations were calculated for determining height and it was observed that Hindu showed significantly higher correlation coefficient value (r) than Muslim of Gujarat. All the variables showed positive significance with male and gave higher mean values than female samples. Linear regression showed more reliable results compared to multiple regression analysis. Logistic regression models were prepared and were known that sex estimation from shoulder width in Hindu and from arm length in Muslim gives more reliable results compared to other measurements.

Keywords: Sex; Height; Gujarat; Shoulder width; Arm length; Foot length

Introduction

Identification of any individual is of supreme importance for any forensic investigation. Many bodily parts are often recovered from the crime scene, in natural disasters like tsunami, earthquakes, floods etc as well as man-made disasters like bomb blasts, road accidents, train collision, plane crash or homicidal cases. In such cases, identification has always been a difficult task for the experts. To eliminate this difficulty new methods are being developed. When any foot or arm or other body parts are recovered at scene of crime, their dimensions can provide valuable information about the height and sex of the body. There is a statistically significant correlation based on a relationship between body length and body segment which can be calculated using various statistical equations to estimate living height and sex. These dimensional relationships have been of interest to many artists, scientists, anatomists, anthropologists and in medico legal case work over many years. These body segments proportions vary between populations due to genetics and the environment in which they live. Various parts of the body respond and develop differently due to the environment and genetics. Height can be determined by various other anthropometric measurements. As a rule of thumb, the larger the length of skeleton the taller will be the individual and its height. Techniques used, so far, for sexual dimorphism have been primarily focused on pelvis bone [1-3] where due to the needs to do with reproduction, some differences are seen, and also in cranial morphology and size [4] which is varied and represented visibly. Anthropological measurements are done to study the variation between individuals and ethnic group. Many attempts have been done for sex determination from foot, foot index, foot shape and foot bones [5-13]. Similarly, researchers have attempted height determination from foot length and breadth [14-21], small bones of foot [22,23] and foot prints [24,25]. Different researchers have used various parameters of body dimensions of living population of India to formulate equations for estimating height and sex. Through the anthropometric dimensions, it is possible to study body proportions, size and shape of man in formulating standards which will be useful in identification. So far very little anthropological data and studies have been reported on Gujarat people. Human growth and development is one such aspect which helps in understanding variation in human population groups. During literature survey, we observed no such reported work on height and sex estimation using shoulder width, arm and foot length of Gujarat people. Muslim population comprises of approximately 12 % of national total (excluding Jammu and Kashmir) in 2001 census of India [26]. On going through the literature survey it was known that in 2005, Jyoti R Ghosh et al. [26] did a comparative study on anthropometric variables in two communities Hindus and Muslims of West Bengal, India.

There has been mark scarcity of data on anthropometry among Muslim in India [27] and no study have been reported on comparative study of anthropometric variable among Hindu and Muslim male and female of Gujarat.

The aims of the research untaken were to determine the equations for height and sex from shoulder width, arm length and foot length of Muslim and Hindu of Gujarat when used in identification of individuals and so establish if it is sufficiently accurate. The relationship of shoulder width, arm length and foot length was determined with height and sex in the selected community and derived formulas for estimating sex and height. So far not much published work has been seen for estimating height and sex using shoulder width. Hence this is the novelty of our work in respect to measurements taken and the ethnic group selected.

Materials and Methods

A total of 160 subjects (128 male and 32 female) aged between 20-50 years belonging to Muslim (n=80) and Hindu (n=80) communities in the Ahmedabad district of Gujarat, India participated in this study. Subjects below 20 years and above 50 years of age were excluded to avoid growth factor before 20 years and aging process after 50 years. Subjects were grouped based on their communities and sex. Before starting study, the aims and objectives of the study was made understand to the volunteers and informed consent of the subjects was taken. Participants included in the study were studied for measurements of shoulder width, arm length and foot length. Measurements were taken of friends, relatives, college students, employs etc in the afternoon. Individual with any facial or genetic abnormalities, growth related disorders or facial trauma were excluded from the study. Measurements on the subjects were taken by locating the landmarks properly by palpating. Length of foot, arm and shoulder were measured to calculate formulas for height and sex. Subjects were asked to stand in a Frankfurt Horizontal plane. All the measurements were taken thrice and mean was calculated to ensure accuracy of the measurement taken. All measurements are recorded to the nearest millimetre or centimetre. All the measurements have been taken following the techniques of Martin and Saller (1957) [28] and Singh and Bhasin [29]. The landmarks in the study were defined as follows:-

Foot length

Subjects were asked to remove their shoes and stand erect. Vernier calliper was used to measure the distance from the most backward and prominent part of the heel (pternion) and the most distal part of the longest toe of the foot (acropodian).

Arm length

Measurement was done by the standard steel tape by making subjects to stand straight. Distance was measured from tip of the acromion to the tip of the middle finger.

Height (height–vertex)

It was measured as the vertical distance from the vertex to the floor, where the vertex is the highest point on the head when the head is held in Frankfurt Horizontal (FH) plane. The subject was made to stand barefoot in an erect posture against the wall with both feet kept close together and hands kept on the sides, and height was measured using the standometer that was held vertically in front of the subject in mid-sagittal plane. Precautions were taken not to exert pressure as that may affect the contact measurement.

Shoulder width

Acromion is the most lateral point on the lateral margin of the acromial process when the subject stands in normal position with his arms hanging by the sides. This point can be located palpating the scapular spine with the middle and first finger from the sterna end to lateral wards. It is easier to locate this point on lightly built individual [29].

Results were assessed with SPSS 20.0 version for Windows. Descriptive statistics for all the measurements were discussed further. Sample observations are independent (since the study is related to two groups only, hence ANOVA cannot be applied). Relation between height and all measurements were determined by Pearson Correlation Analysis. Formula for estimating height was worked out by using linear and multiple regression analysis and sex was estimated by employing logistic regression. According to Singh and Bhasin [29] the standard error of the mean is an estimate of the sampling error of the mean. Standard error indicates the amount of difference that will be anticipated in the statistical constant, if a new sample is drawn from the same population. The SEM tells us that if we repeated the same set of measurements many times and calculated the SEM each time, the real mean would lie within the confidence interval calculated (sample mean ± 2SEM) in 95 out of 100 cases (95 % chance that the real mean is within the calculated confidence interval for our sample mean). The SEM can be calculated as follows:

$$SEM = \frac{SD}{\sqrt{n}}$$

Where, SEM= Standard Error of Mean

N= number of values

SD = standard deviation

The equation shows that as the number of subjects measured increases, the SE will decrease and the predictions will be more accurate.

Results

The descriptive statistical analysis and t-test of all measurements in Muslim and Hindu groups were shown in Table 1.

Variables	Group	Mini	Maxi	Mean	S.D	t	df	Sig. (2-tailed)
Shoulder width	Muslim	33.3	47.0	8.4	4.4389	-3.047	78	0.003*
	Hindu	32.5	44.4	9.2	2.4790	-9.830	78	0.000*
Foot Length	Muslim	21.4	29.2	24.9	1.553	-6.091	78	0.000*
	Hindu	21.8	29.0	25.1	1.598	-6.352	78	0.000*
Arm Length	Muslim	63.0	89.0	77.0	4.516	-5.487	78	0.000*
	Hindu	68.0	89.0	78.0	4.567	5.735	78	0.000*
Height	Muslim	133.0	181.0	159.9	10.014	-5.828	78	0.000*
	Hindu	141.0	178.0	160.1	8.535	-7.450	78	0.000*

* p-value < 0.05

Table 1: Descriptive with respect to Muslim (n=80) and Hindu (n=80) of Gujarat

Correlation with height and other variables in both the study groups in male and female groups were evaluated by Pearson Correlation Analysis. It was known that all the variables in both the study groups show significance with height at p-value < 0.05. Shoulder width, foot length and arm length were evaluated using linear and multiple regression analysis for each group separately. Obtained R, R^2 and Standard Error of Estimation (SEE) were presented in Table 2, 3 and 4 for each group respectively. 'R' value is called correlation coefficient which shows relation with height and other variables viz., shoulder width, arm length and foot length in the selected group. We have checked all models using the variables individually and together for estimation of height. R^2 is the proportion of variation in height explained by the variables in both the groups. Adjusted R^2 calculates the consistence of sample values and universal values with standard errors of the estimation (SEE). Both linear regression and multiple regression equations were formulated to check the best reliable models to estimate height.

Sexes	Variable	R	R^2	SEE	Equation Height=
Both (n=80)	Shoulder width	0.473*	0.224	8.8780	119.362+1.068(Shoulder width)*
	Foot Length	0.781*	0.609	6.3006	34.223+5.033(Foot length)*
	Arm length	0.751*	0.564	6.6587	31.722+1.664(Arm length)*
Male (n=64)	Shoulder width	0.377*	0.142	8.5589	134.162+0.737(Shoulder width)*
	Foot Length	0.709*	0.502	6.5206	44.556+4.647(Foot length)*
	Arm length	0.663*	0.439	6.9193	47.258+1.476(Arm length)*
Female (n=16)	Shoulder width	0.301	0.090	3.8317	83.683+1.859(Shoulder width)
	Foot Length	0.081	0.007	4.0047	137.564+0.492(Foot length)
	Arm length	0.464	0.216	3.5586	97.205+0.716(Arm length)

*p-value < 0.05

Table 2: Linear regression for estimating height in both the sexes of Muslim group of Gujarat (n=80)

Sexes	Variable	R	R^2	SEE	Equation Height=
Both (n=80)	Shoulder width	0.745*	0.555	5.7302	59.475+2.565(Shoulder width)*
	Foot Length	0.780*	0.608	5.3791	55.648+4.163(Foot length)*
	Arm length	0.849*	0.721	4.5405	36.310+1.586(Arm length)*
Male (n=64)	Shoulder width	0.568*	0.322	5.6981	68.500+2.350(Shoulder width)*
	Foot Length	0.667*	0.445	5.1558	78.939+3.283(Foot length)*
	Arm length	0.798*	0.637	4.1724	56.294+1.344(Arm length)*
Female (n=16)	Shoulder width	0.278	0.078	5.0886	119.471+0.836(Shoulder width)
	Foot Length	0.500*	0.250	4.5875	77.924+3.066(Foot length)*
	Arm length	0.600*	0.360	4.2382	67.298+1.120(Arm length)*

*p-value < 0.05

Table 3: Linear regression for estimating height in both the sexes of Hindu group (n=80)

Sex	Study group	R	R^2	SEE	Equation Height
Both	Muslim	0.851*	0.724	5.3623	5.227+0.224(Shoulder width)+3.080(Foot length)*+0.899(Arm Length)*±SEE
	Hindu	0.884*	0.781	4.0684	23.888+0.945(Shoulder width)*+1.027(Foot Length)*+0.940(Arm Length)*±SEE
Male	Muslim	0.800*	0.641	5.6312	6.133+0.208(Shoulder width)+3.135(Foot length)*+0.880(Arm Length)*±SEE
	Hindu	0.819*	0.671	4.0335	35.879+0.708(Shoulder width)+0.838(Foot Length)+0.708(Arm Length)±SEE
Female	Muslim	0.491	0.241	3.7807	85.481-1.1458(Foot Length)+0.625(Arm Length)+1.485(Shoulder width)±SEE
	Hindu	0.628	0.394	4.4549	48.507+0.470(Shoulder width)+0.913(Foot Length)+0.859(Arm Length)±SEE

*p-value < 0.05

Table 4: Multiple regressions for estimating height based on both the sexes of both the study group

Logistic regression was performed using the variables separately for determining equations to estimate sex in Muslim and Hindu of Gujarat respectively which are shown in Table 5. The limit value for logistic regression model were positive values evaluated as male and negative values were evaluated as female. The established model can estimate sex using shoulder width, arm length and foot length respectively in both the study group.

Study Group	Variable	Equation Gender =
Muslim	Shoulder width	-9.552+0.290(Shoulder width)*
	Foot Length	-47.575+2.026(Foot Length)*
	Arm length	-29.978+0.417(Arm Length)*
Hindu	Shoulder width	-72.655+1.953 (Shoulder width)*
	Foot Length	-35.846+1.533(Foot Length)*
	Arm length	-34.232+0.469(Arm Length) *

[a] If sex is positive we can predict male and if negative we predict female

*p-value < 0.05

Table 5: Logistic Regression for Sex estimation of Muslim and Hindu group

We have also applied these equations for our data and found correct percentage of accuracy in the determination of sex. These results are given in the following Table 6.

Study group	Sexes	Shoulder width			Foot length			Arm length		
		Correct	Incorrect	% Accuracy	Correct	Incorrect	% Accuracy	Correct	Incorrect	% Accuracy
Muslim	Male	63	1	98.4	61	3	95.3	62	2	96.9
	Female	0	16	0	7	9	43.8	7	9	43.8
	Total			**78.8**			**85.8**			**86.3**
Hindu	Male	62	2	96.9	59	5	92.2	59	5	92.2
	Female	13	3	81.3	9	7	56.3	8	8	50
	Total			**93.8**			**85**			**83.8**

Table 6: Percentage of correctly classified for sex estimation

Discussion

In the present study height, shoulder width, foot length and arm length were measured for 160 samples of which 80 were Hindu and 80 were Muslim. There were significant differences between measurements in male and female and between Muslim and Hindu groups (p-value < 0.05). The mean values of all measurements were quite high in male than in female. From Table 1, it was observed that the mean values of all measurements were significantly higher in Hindu group than in Muslim group. Highest correlation was observed with height and other variables for both the selected groups. It can clearly see from Table 2 that in Muslims the highest correlation coefficient 'R' was observed in foot length in males and in case when sex is unknown. But none of the variables show correlation with height in Muslim females. Hence we can conclude that linear regression models for Muslim female using any variables are inappropriate. From Table 3 Hindu females show no significant difference between shoulder width and height but gives appropriate models with foot length and arm length. All the variables viz., shoulder width, foot length and arm length show significant correlation with height in Hindu males and even when sex is unknown.

We also tried to evaluate formulas for estimating height using all the variables together by applying multiple regressions in both the study groups. It was observed that females of both groups showed no significance with height (Table 4). But males and when both the sexes were together showed significance (p-value < 0.05). Highest correlation 'R' was seen in both the study groups when sex was unknown. But for satisfactory results linear regression equations are more appreciated compared to multiple regression equations. It can be concluded that compared to Muslim, correlation coefficient value 'R' in Hindu is higher and more significant. In 2005, Jyoti R Ghosh et al [26] did a comparative study on anthropometric variables in two communities Hindus and Muslims of West Bengal, India and found a significant difference in both the communities.

Logistic regression equations were formulated for estimating sex in both the study groups. In these equations (Table 5), we observed that all variables viz., shoulder width, foot length and arm length are statistically significant variables for determining the sex in both the study group. Table 6 shows that among all the variables in both the study group, the highest percentage of accuracy with 93.8 % was seen in shoulder width of Hindus. In Muslims, arm length shows highest accuracy of 86.3 % followed by foot length and shoulder width. The result shows 96.8 % probability in the case of male Muslim samples whereas only 29.2 % of probability is seen in female samples. Hence in Muslim we can determine sex for male but not for female. Similarly, the assurance level of Hindu male sample is 93.7 % whereas for female samples is only 62.5 %. Hence the accurate estimation for sex in both the study group in male is more than in female.

Thus, in linear regression in the case of Muslims, male shows best results using all the variables while female shows inaccurate results with any variables. In Hindu, female shows more significance with foot length and arm length but less with shoulder width whereas in male all the variables gives best linear models for height estimation. In both the study group, highest correlation was experienced when sex is unknown in both linear regression and multiple regression equations. Sex estimation from shoulder width in Hindu and from arm length in Muslims gives best possible results compared to other measurements. In all male probability ratio is more than female during sex estimation. Following are the various works on stature and sex determination from many bodily measurements across the world.

Authors	Work	Study Group	Variables	Observations
R. Moudgil [7]	Sex	200 Gujjars, North India	Foot Index	No statistical significant difference was found in foot index between male and female. Therefore foot index cannot be used for sex determination
Ozden et.al [19]	Stature and sex	569 Turkey	Foot and shoe sizes	Equations were formulated
Krishan and Sharma [21]	Stature	246 Rajput, North India	Hand and Feet measurements	Foot length more trusted than hand length Multiple regression gives more appropriate values than linear regression Female values > Male values
Gulsah Zeybek [30]	Stature and gender	249 Turkey subjects	Foot measurements	No significant difference in left and right foot in male and female Highest correlation with foot length Male values > Female values
Jasuja et.al [31]	Stature	Jat Sikhs	Foot and shoe measurements	Foot length is more correlated compare to foot width
Singh and Phookan [32]	Stature	Male of 4 Thai communities of Assam	Foot size	Correlation with stature and foot length and stature and foot width Foot length more reliable compare to foot width
Giles and Vallanigham 33]	Height	U.S Army database	Foot and shoeprint length	Reliable
Mansur DI et.al [34]	Stature	440 Nepalese subjects	Foot length	Significant correlation between height and foot length Regression equations found
Dr. S. Khan-apurkar et. al [35]	Stature	1000 Maharastrian	Foot length, hand length and head length	Among all three variables foot length > in male and female Multiple regression more accurate than linear regression
Ozaslan et. al [36]	Stature	356 Turkey	Hand and foot dimensions	Length measurements more reliable than breadth Lower extremities are more defining than upper extremity Weak hand breadth and wrist results
Patel et. Al [37]	Stature	150 Hindu	Hand length	Strong correlation between hand length with stature
Tanuj Kanchan et.al [38]	Stature	200 Gujjars, North India	Foot dimensions	Multiple regression more reliable than linear regression Foot length > Foot breadth Male foot length > female
A. Ozalslan et.al [39]	Stature	337 Turkey subjects	Bi-acromial and Bi-iliocristal measure-mements	Different in sexes Best correlation of stature with biacromial breadth in male than bi-iliocristal breadth in male and female
PRESENT WORK	Stature and Gender	80 Muslim+80 Hindu=160 subjects	Shoulder width, arm length and foot length	Male mean values > Female mean values Hindu mean values > Muslim mean values Linear regression more reliable than multiple regression Logistic regression for gender estimation in male is more trusted than female

Table 7: Previous studies on stature and sex estimation on different races

The differences between both the studied groups can be due to the habitat, genetic factors, nutrition and physical activity or occupation. When previous studies were taken into account, the present work was an attempt on finding height and sex using shoulder width, foot length and arm length when numbers of missing incidence, accidents, natural disasters etc are most frequent. Our study gives reliable results for height and sex estimation in terms of foot length, arm length and shoulder width.

Conclusion

Sex and height estimation is of supreme importance in today's scenario to the forensic experts and anthropologists. There is a good correlation of sex and height with shoulder width, foot length and arm length. Regression equations derived in our study can be used accurately for height and sex estimation in Gujarati population. If either of the measurements (shoulder width, foot length or arm length) is known, height and sex can be calculated. This study will be helpful in many medico legal cases in establishing identity of an individual. Estimated equations cannot be applied to a variety of other population as population variation occurs due many other environmental factors.

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