Stature Prediction Model Based On Hand Anthropometry

Arunesh Chandra, Pankaj Chandna, Surinder Deswal, Rajesh Kumar Mishra, Rajender Kumar

***Abstract*—**The arm length, hand length, hand breadth and middle finger length of 1540 right-handed industrial workers of Haryana state was used to assess the relationship between the upper limb dimensions and stature. Initially, the data were analyzed using basic univariate analysis and independent t-tests; then simple and multiple linear regression models were used to estimate stature using SPSS (version 17). There was a positive correlation between upper limb measurements (hand length, hand breadth, arm length and middle finger length) and stature ($p < 0.01$), which was highest for hand length. The accuracy of stature prediction ranged from ± 54.897 mm to ± 58.307 mm. The use of multiple regression equations gave better results than simple regression equations. This study provides new forensic standards for stature estimation from the upper limb measurements of male industrial workers of Haryana (India). The results of this research indicate that stature can be determined using hand dimensions with accuracy, when only upper limb is available due to any reasons likewise explosions, train/plane crashes, mutilated bodies, etc. The regression formula derived in this study will be useful for anatomists, archaeologists, anthropologists, design engineers and forensic scientists for fairly prediction of stature using regression equations.

***Keywords*—**Anthropometric dimensions, Forensic identification, Industrial workers, Stature prediction.

I. Introduction

IT is well known that body segments exhibit consistent ratios among themselves and relative to the total body height. The ratios between body segments are age, sex, physical activity and race dependent [1], [2]. Prediction of stature from incomplete human limbs and skeletal remains is particularly important in personal identification. The estimation of stature using different parts of the body is crucial for formulating a biological profile during the process of personal identification, especially when mutilated and amputated limbs or body parts are found [3], [4]. The human limbs sent to forensic pathology center to determine their identity are not always intact. Therefore, sometimes in case of plane/train crashes, wars, bomb blasts, assault cases, natural disasters, explosions, etc., only human limbs or some parts of the human body are available for identification. Establishment of alternative methodologies for personal stature estimation is important for a number of reasons. Firstly, in instances where stature estimates needed to be made from fragments of human limbs in archeological procedures or in forensic examinations after mass disasters or genocide [3]. Secondly, estimates of pharmacokinetic parameters and evaluation of nutritional status rely on accurate measurement of not only body weight but also height. However, a number of common disease or deformities of the vertebral column make it difficult to accurately measure standing height in many subjects [4], [5].

Prediction of stature is considered as an important anthropometric parameter for personal identification which is often required in medical jurisprudence or by the medico-legal experts. Many human features have been used to estimate stature from skeletal remains and body parts owing to the established relationship between stature and different parts of the body [6] as there are definitive biological relationships of different degrees between various dimensions/measurements of the extremities and stature, many studies have used the measurement of the upper and lower limbs to estimate stature. Some examples include metatarsals [7], foot [8]-[11], tibia [12], femur [13], head length [14], phalanges [15], hand [16], [17], ulnar length [18]-[20], upper arm length [21] and clavicle [22].

While some studies have used bones or bony parts, either directly [23]-[26] or by employing a radiological technique [27], [28]; others have employed anthropometry [29] [31], print [32], [33], or impressions [34] with high success. Although it has been shown that the lower limb measurements are more strongly associated with stature than upper limb measurements [35], there is still a need to assess the correlation of the upper limb measurements with stature because the lower limbs may not always be available. An extensive literature review revealed that most of the earlier studies utilizing measurements of the upper limb to estimate stature are focused on the hand or isolated bones, and only a few studies have correlate measurements of the majority of the upper limb parts to stature [19]. Stature and six upper limb measurements of Turkish subjects were previously studied to assess the correlation between stature and the total arm length, upper arm length, forearm length, wrist width, hand length, and hand breadth [30]. The best predictor of stature was the forearm (radial) length for males and the upper arm length for females. Akhlaghi et al. [36] found a meaningful relationship between stature and upper limb measurements (the total arm

Arunesh Chandra is with the Department of Mechanical Engineering, Krishna Institute of Engineering & Technology, Ghaziabad-201206, Uttar Pradesh, India (phone: 01232-227978; fax: 0120-2675091; e-mail: arunesh.chandra@kiet.edu).
Pankaj Chandna is with the Department of Mechanical Engineering, National Institute of Technology, Kurukshetra-136119, Haryana, India (e-mail: pchandna08@gmail.com).
Surinder Deswal is with the Civil Engineering Department, National Institute of Technology, Kurukshetra-136119, Haryana, India (e-mail: sdeswal@nitkkr.ac.in).
Rajesh Kumar Mishra is with the Department of Applied Science, Krishna Institute of Engineering & Technology, Ghaziabad-201206, Uttar Pradesh, India (e-mail: rkmishra73@rediffmail.com)
Rajender Kumar is with the Section of Basic Engineering of COAE&T, CCSHAU, Hisar-125004, Haryana, India (e-mail: rksingh@hau.ernet.in).

length, upper arm length, forearm length, hand length, hand breadth, and the length of the second to fifth fingers) of Iranian subjects.

Many studies have established a positive correlation between stature and hand dimensions in different populations [37]-[41] and offered regression equations. Estimation of stature from hand length and length of phalanges can be used as an alternative method to measure stature and has been reported in related studies [15], [29], [30], [41]. When stature cannot be measure directly due to deformities like kyphosis, lordosis and scoliosis, contracture or sometimes only impression of any of the phalanges or outline of the palm may be available in these cases, only possibility is to use that information to measure the dimensions of the outlines available and estimate the stature to which those may belong.

Despite its significance and potential practical utility, little is known concerning the relationship between hand dimensions and stature among north Indians, inhabitants of the South-Asian country. Hence, this study was designed to elucidate the norms for hand dimensions and to propose population and gender specific regression models for stature estimation using the linear dimensions of the hand. Present study was, therefore, conducted to find out correlation between right hand upper limb measurements likewise arm length, hand length, hand breadth and middle finger length with body stature to evaluate the reliability of estimation of stature and developing regression equations for each hand dimensions in the Haryanvi male industrial workers population of north India.

II. Materials and Methods

A. Subjects

An important planning goal of the industrial workers (subjects) survey was to be as inclusive as possible in the recruitment of subjects. No restrictions were placed on the height, weight, social status or ethnic group of the subjects. Age of the subjects varies from 18 to 62 years with an average age of 36.49 years. Mean Stature height and body weight of the subjects are found as 1641 mm and 63.13 kg with standard deviation of 73.12 mm and 10.39 kg respectively. Subjects are selected according to their availability and willingness to participate without payment or any other kind of rewards, based on their origin and racial strain criteria for ensuring that the samples are true representatives of their respective target population. Industrial workers with any disease, deformity, injury, fracture, amputation or history of any surgical procedures of either hand were excluded from the study. Out of 20 major districts 12 districts were chosen as sampling location to represent a wide diversity of geographical areas across Haryana. The number of subjects selected for measurement, from 12 districts of four divisions in Haryana is provided in Table I.

B. Relative Accuracy

In collecting anthropometric data, the number of subjects needed for a study, should be normally calculated based on a number of factors. These are: the variability of the dimensions being surveyed, the level of accuracy and precision required for the final data. ISO 15535:2006 [42] specifies general requirements for anthropometric databases and their associated reports that contain measurements taken in accordance with ISO 7250 “Basic body measurements for technological design”. It provides necessary information, such as characteristics of the user population, sampling methods, measurement items and statistics to make international comparison possible among various population segments [43].

TABLE I
Subjects Measured Division-Wise

Location	Districts Considered	Number of Subjects
Ambala Division	Ambala, Kurukshetra and Yamuna Nagar	305
Rohtak Division	Karnal, Panipat and Sonipat	326
Gurgaon Division	Gurgaon, Faridabad and Mahendragarh	586
Hissar Division	Hissar, Bhiwani and Jind	323

Subjects were informed with the objectives of the study, hand anthropometric dimensions, clothing requirements, measurement procedures and freedom to withdraw. Total of 1540-convenient sample of industrial worker were measured from 38 small-and medium-scale industries.

The relative accuracy of measured data was calculated using [42]

$$n \geq \left[3.006 \times \frac{CV}{x} \right]^2$$

Here n is a sample size, x is percentage of relative accuracy and CV is the coefficient of variation. For finding out the relative accuracy of the data if the value of CV = 10 (on higher side of measured variables as maximum value is 6.19 for middle finger length) is considered. Thus sample size (1540) defines 0.76 % of relative accuracy for the different percentile values for a 95% confidence interval for the 5^{th} and 95^{th} percentile: Hence with relative accuracy of 0.76 % the study overall became highly redundant, making its results reliable.

C. Physical Field Conditions

Measurement under field conditions presented physical challenges not found in a static laboratory setting. Locations of 38 industries varied widely in terms of the physical spaces available for measurements, the organizational support provided and the living conditions for field staff. However, specifications were provided in advance to each industrial heads/officers to define the minimum type and number of physical spaces necessary for measurement and all industrial sites provided that minimum. Ethical research guidelines were followed and all participants were volunteers.

D. Traveling and Field Staff

Initially the pilot study was conducted and the purpose of the pilot study is to verify the upcoming problem and to find the solution for the problems. The next progress is to go to the workers field area and do the measurements process to get the required data. The traveling survey team consisted of members (student volunteers) from National Institute of Technology (NIT), Kurukshetra, the proper training on use of apparatus was provided to survey team (eight graduates, two post-graduate and a doctoral student). Under the supervision of trainer and faculty members, they started data collection only after their measurements are considered accurate, reliable and consistent. This team spent fifteen months traveling with their measuring equipments to the different locations, reaching sites by roadways where possible, but also traveling over land by rented vehicles on gravel roads to more remote locations. Upon arriving at each site, the traveling team took on average one day to review and adjust the physical area and to set up and calibrate the measuring equipments. All the measurements were taken by one observer in order to avoid inter-observer error. Measurements were, wherever possible, conducted in an enclosed area or room to ensure the privacy of subjects. Before taking the measurements, each subject is advised to be barefooted and to wear light clothes so as to reduce the margins of errors. All measurements were taken on level, non-carpeted floor well lit for maximum accuracy. The measurements were taken in proper order and in the same sequence for all subjects between 9:30 am to 5:00 pm. The measurement process itself took between two to three days for each industry and the whole survey took about fifteen months, from May 2009 to July 2010 to collect data from thirty eight different industries of Haryana.

E. Land Marking

The techniques of measurements are as per the guidelines in NASA [44] as regard the measurement landmark and positioning of the hand, it has been noted that the dimensions of a straight, flat hand are significantly longer than those of the relaxed comparing the anatomical landmarks of the stylion, wrist crease and proximal edge of the wrist. Chandra et al. [45] suggested that wrist crease is the best land mark for easy identification of hand measurements thus the right hand is held out horizontally such that the palm faced upwards and the fingers are extended. When the whole measurements were to be taken, the fingers were kept close together (adducted) when individual finger measurements were to be taken; the fingers were kept separated (abducted). As the finger segments are small dimensions in measurements and a systematic difference in measurements may result in a relatively large absolute percentage difference [45]. Once located, the palpated landmarks were marked on the skin, using an eyebrow pencil to make a dot. These small black dots were then considered as landmarks and all measurements were taken twice for landmarks and it is the mean of the two readings that is finally recorded. During the measurement of hand dimension, proper care has been taken to avoid any excessive compression of underlying tissues and to record the measurement precisely.

F. Equipments Used

Survey team measured and collected right hand dimensions of hand length, hand breadth, middle finger length with Mitutoyo digital vernier caliper (resolution of 0.01 mm); arm length and stature with a Hardenpen anthropometer (sensitivity of 1 mm). The various landmarks and other requirements of the selected hand dimensions for estimation are:

Stature - It was measured as vertical distance from the vertex to the floor. Measurement is taken by making the subjects to stand erect on a horizontal resisting plane bare footed with shoulder blocks and buttocks touching the wall. Palms of hand were turned inwards and fingers horizontally pointing downwards. Anthropometer was placed in straight vertical position in front of the subject with head oriented in eye-ear-eye Plane (Frankfurt Plane). The movable rod of the anthropometer is brought in contact with vertex in the mid saggital plane [43], [46].

Arm length - Measurement is taken from most superior lateral point of acromion process (acromial landmark) to the lower and lateral border of styloid process of radius (radial landmark). The arm is positioned in the anatomical position, relaxed at the side of the subject [43].

Hand length - Hand length is measured as hand is extended with palm facing up; this dimension is measured from the wrist crease directly below the pad of muscle at the base of the thumb to the tip of the middle finger. The hand and fingers must be held straight and flat, palm uppermost [47].

Hand breadth - Breadth of the hand was measured as the width of the hand from the lateral surface of metacarpal II to the medial surface of metacarpal V. The hand was placed on a table with the fingers together and the thumb out to the side with a caliper the breadth of the hand was measured at the level of the knuckles [47].

Middle finger length - It was measured as the distance from the most proximal flexion crease of middle finger, till the projecting point on the tip of the finger. It was measured with the help of a caliper [48].

G. Statistical Analysis

The data were analyzed using the Statistical Package for the Social Sciences (SPSS) version 17 (SPSS, Inc., Chicago, IL). The means, standard deviations, coefficient of variation (CV) and ranges (minimum and maximum) were used to summarize the anthropometric measurements. Pearson correlation coefficients were calculated to measure the strength of correlation between stature and the upper limb measurements [45]. Multiple regression equations for stature estimation were developed using the upper limb measurements. The simple linear regression models for estimation of stature were derived as Y (stature) = a (constant) + b (regression coefficient of the independent variable) X (individual variable) ± SEE (standard error of the estimate), the multiple regression models were derived as Y (stature) = a (constant) + b_1 (regression coefficient of the first variable) X_1 (first variable) + b_2 (regression coefficient of the second variable) X_2 (second variable) +. . . b_n (regression coefficient for the nth variables) X_n (n^{th} variable) ± SEE [19], [30], [49].

The accuracy of these equations was demonstrated by the obtained SEE. A low SEE indicated a higher accuracy. Simple and multiple regression equations for stature estimation were developed using the upper limb dimensions. A p-value of less than 0.05 was considered significant. The predictive values of all equations were compared. The developed equations were then tested by substituting the minimum, the maximum and the means of the upper limb measurements in respective regression equations to estimate the stature. A paired-samples t-test was used to compare the differences between the actual and estimated means using different equations.

III. Results and Discussions

Descriptive statistics for the stature, arm length, hand length, hand breadth and middle finger length of male industrial workers are presented in Table II. Based on these results, correlation coefficients were calculated and regression analyses conducted.

TABLE II
Descriptive Statistics for Stature and Hand Anthropometric Dimensions

Parameter	Mean	Std. Dev.	Min	Max	CV
Stature (*S*)	1640.08	73.12	1455.00	1821.00	-
Arm length (*AL*)	770.63	37.70	672.00	867.00	4.89
Hand length (*HL*)	186.52	8.13	166.00	208.00	4.36
Hand breadth (*HB*)	84.29	4.04	73.00	95.00	4.79
Middle finger length (*MFL*)	78.89	4.88	65.00	90.00	6.19

All dimensions are in mm.

TABLE III
Correlation between Stature and Hand Anthropometric Dimensions

Hand Parameter	Value of r
Arm length (*AL*)	0.565**
Hand length (*HL*)	0.598**
Hand breadth (*HB*)	0.460**
Middle finger length (*MFL*)	0.480**

r: correlation coefficient.
** Significant at 0.01 level (2 tailed).

Table III illustrates the correlation coefficients between stature and hand measurements of male industrial workers. All measurements presented statistically significant correlation coefficients with stature ($p < 0.01$). The correlation coefficients of the length measurements were greater than those of the breadth measurements. The greatest correlation was found for hand length (r= 0.598). The lowest correlation coefficient found was for hand breadth (r= 0.460) for male industrial workers of the Haryana state.

The simple linear regression equations and the SEE, which predict the deviation of the estimated stature from the actual stature, were derived for the stature estimation for each upper limb measurement, as shown in Table IV. The standard errors of the estimates ranged between ± 58.307 mm (hand length) and ± 64.089 mm (hand breadth) for male industrial workers. Low value indicates a greater accuracy of the estimated stature. The regression coefficients were found to be statistically significant in all derived equations. The predictive value, or the coefficient of determination, was greatest for the reconstruction of stature from the hand length.

TABLE IV
Linear Regression Equations for Estimation of Stature (in mm) from Upper Limb Measurements

Regression equation	±SEE	R^2	p-value
S = 916.709 + 0.946 x *AL*	± 59.795	0.319	0.000
S = 681.514 + 5.164 x *HL*	± 58.307	0.357	0.000
S = 964.558 + 8.201 x *HB*	± 64.089	0.211	0.000
S = 1051.856 + 7.536 x *MFL*	± 63.897	0.231	0.000

S: stature, AL: arm length, HL: hand length, HB: hand breadth, R^2: coefficient of determination, SEE: standard error of estimate.

A linear regression analysis was performed to obtain the relationship between stature and upper limb dimensions. The scatter plots and the fitted lines are shown in Figs. 1-4. These graphs explain the linear relation between stature and the upper limb (hand) dimensions.

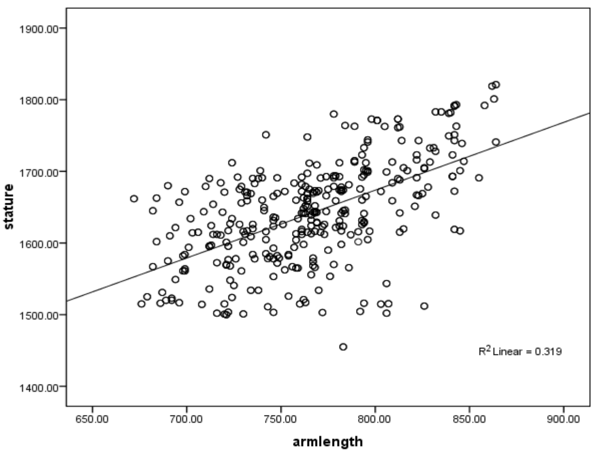

Fig. 1 Scatter plot and regression line demonstrating the relationship between stature and arm length (mm)

Multiple regression equations were formulated to assess whether the accuracy of the stature prediction was improved by using multiple variables (Table V). The multiple regression equations revealed a lower standard error of estimate (± 54.897 mm) with the developed estimate models utilizing different variables for male industrial workers of Haryana.

TABLE V
Multiple (Stepwise and Direct) Regression Equations for Estimation of Stature (mm) from Upper Limb Measurements

Method	Regression Equation	±SEE	R^2	p-value
Step wise	*S* = 681.514 + 5.164 x *HL*	± 58.307	0.357	0.000
	S = 631.574 + 3.195 x *HL* + 0.544 x *AL*	± 55.831	0.403	0.000
	S = 604.843 + 2.720 x *HL* + 0.493 x *AL* + 1.973 x *MFL*	± 55.324	0.413	0.000
	S = 543.335 + 2.083 x *HL* + 0.429 x *AL* + 2.029 x *MFL* + 2.723 x *HB*	±54.897	0.404	0.000
Direct	*S* = 591.067 + 4.045 x *HL* + 3.624 x *HB*	±57.269	0.362	0.000

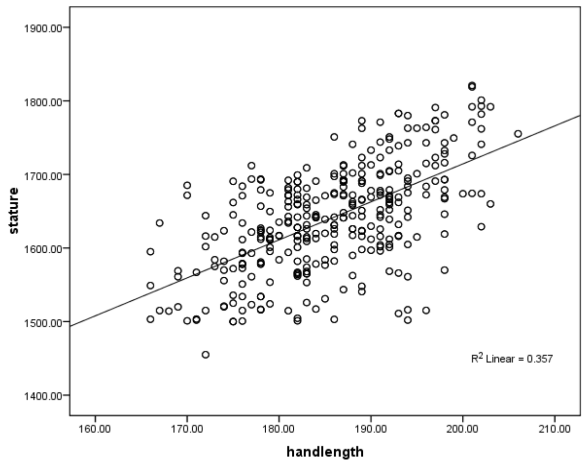

Fig. 2 Scatter plot and regression line demonstrating the relationship between stature and hand length (mm)

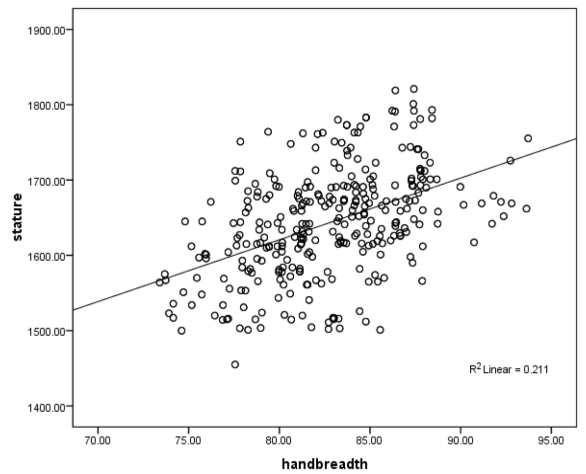

Fig. 3 Scatter plot and regression line demonstrating the relationship between stature and hand breadth (mm)

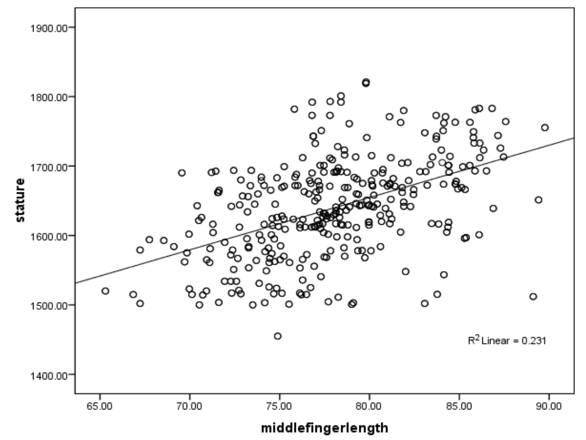

Fig. 4 Scatter plot and regression line demonstrating the relationship between stature and middle finger length (mm)

In general, the variables that were weighted most strongly in the multiple regression models were hand length and hand breadth.

Comparisons of the actual stature and the estimated stature from the minimum, maximum and means of the upper limb measurements were performed utilizing various regression equations (Table VI). The mean value estimates were close to the actual stature, and there were no statistically significant differences between them when utilizing different equations. The greatest variations were observed in the minimum and maximum values.

TABLE VI
COMPARISON OF ACTUAL STATURE AND ESTIMATED STATURE FROM UPPER LIMB MEASUREMENTS AND T TEST OF PAIRED MEAN DIFFERENCE

Parameters	Estimated Stature			
	Minimum	Maximum	Mean	p-value
HL	1538.74	1755.63	1644.70	0.104
AL	1552.42	1736.89	1645.72	0.047
MFL	1541.70	1730.10	1646.37	0.027
HB	1563.23	1743.65	1655.82	0.000
HL + AL	1527.51	1767.78	1646.73	0.020
HL + AL + MFL	1515.90	1775.60	1647.75	0.007
HL + AL + MFL + HB	1508.07	1789.84	1652.04	0.000
HL + HB	1527.09	1776.71	1651.07	0.000
Actual Stature	1455.00	1821.00	1640.08	

Anthropometry addresses measurements of the size, weight and proportions of the human body/skeleton [50], [51]. It has been used successfully for estimation of sex based on upper limb measurements [52]. However, despite the popularity of this technique for the estimation of stature there are some essential methodological considerations that need to be considered in forensic practice, such as the standardization of instruments and techniques, precision and reliability testing, human body asymmetry, diurnal variation, and effect of ethnicity and age, as these can be sources of error [53]. All these considerations had been made in this study.

The estimation of stature is an indispensable step in any forensic anthropological investigation involving the determination of attributes of the biological identity of unknown human remains. The correlation coefficients between the stature and the upper limb measurements were found to be highly significant and positively correlated, indicating that it is possible to derive regression equations for the estimation of stature from upper limb measurements. When assessing the accuracy of the simple regression equations using single dimensions, the SEE was the lowest for hand length measurements (± 58.307 mm), and hand length was found to be more predictive than arm length. The correlation coefficients of hand dimensions were greater for length dimensions ($r = 0.598$) than for breadth dimensions ($r = 0.460$). These finding indicates that hand length is more reliable than hand breadth for estimating stature among male industrial workers of Haryana state, which is in agreement with previous results recorded and studied for Egyptian [54], Iranian [36], Turkish [30], Sudanese [19] and Indian subjects [3], [41].

In regard to the multiple regression models developed for the upper limb dimensions, this study demonstrated a higher degree of prediction accuracy, as indicated by a lower SEE (±

54.897 mm) and higher R^2 (0.404) in comparison to the simple linear model. The variables selected in the best models included the hand breadth, although this value generally exhibited a lower correlation to stature in comparison to the others. This finding may indicate that, despite the stature estimation accuracy usually being more reliable when the length of the upper limb parts are used, a breadth of measurements should be considered even though they individually have a weaker correlation to stature. When these measurements are used in combination with length dimensions, they may increase the accuracy. When hand measurements were combined to develop a multiple regression model, the calculated SEE was (±57.269 mm), which is comparable to the developed single simple linear models for hand length. These findings are in agreement with those of [15] but contradict the findings of [36], who considered hand length and breadth together to be the most valid predictors of stature among upper limb measurements.

The results of the present study confirm that upper limb dimensions can be used successfully for stature estimation in the Haryanvi male industrial workers population. The developed equations are applicable to the population from which the data were collected. This study was conducted on the right hand side of subjects. The selected best models in this study do not contain hand breadth, which is affected by hand dominance in some studies of the best predictor models [3], [41], [54]. However, as this topic has not been studied in the male industrial population of Haryana state (India), it would be optimal to study both upper limbs.

IV. Conclusions

Stature estimations from limbs or dismembered body parts are important for personal identification, especially when the utility of DNA analysis is limited because of economic issues or other difficulties, such as wars or mass disasters. The present study conducted pioneering research in forensic anthropology among the male industrial population of Haryana (India). According to these results, the upper limb measurements present a significant correlation with stature. In this study, new forensic standards for industrial workers of Haryana state (India) were outlined for stature estimation, and the regression equations were derived from upper limb measurements. These results indicate that stature can be predicted from these measurements with an SEE (± 54.897 mm).

There are lot of variations in estimating stature from upper limb measurements among people of different region, sex and race. Hence there is a need to conduct more studies among people of different regions, sex and ethnicity so that stature estimation becomes more reliable and identification of an individual is easily established. This should encourage others in taking up further research in the field.

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References

[1] L. M. Jantz, and R. L. Jantz, "Secular changes in long bone length and proportion in the United States 1800-1970," *Am. J. Phys. Anthropol.,* vol. 110, no. 1, pp. 57-67, 1999.

[2] P. L. Williams, L. H. Bannister, M. M. Berry, P. Collins, M. Dyson, and J. E. Dussek eds., "Gray's Anatomy: The anatomical basis of medicine and surgery," 38th Ed. New York: Churchill Livingstone, 2000, pp. 425-436.

[3] K. Krishan, "Anthropometry in Forensic Medicine and Forensic Science-Forensic Anthropometry," *The Internet Journal of Forensic Science,* vol. 2, no. 1, 2007.

[4] I. Ilayperuma, G. Nanayakkara, and N. A. Palahepitiya, "A Model for the Estimation of Personal Stature from the Length of Forearm," *Int. J. Morphol.,* vol. 28, no. 4, pp. 1081-1086, 2010.

[5] T. W. Auyeung, J. S. W. Lee, T. Kwok, J. Leung, P. C. Leung, and J. Woo, "Estimation of stature by measuring fibula and ulna bone length in 2443 adults," *J. Nut. Health Aging,* vol. 10, pp. 931-936, 2009.

[6] J. A. DiMaggio, and W. Vernon, "Forensic Podiatry - Principles and Methods," Springer, New York: Dordrecht Heidelberg, London: Humana Press, 2011.

[7] M. A. Bidmos, "Metatarsals in the estimation of stature in South Africans," *Journal of Forensic and Legal Medicine,* vol. 15, pp. 505-509, 2008.

[8] K. Krishan, and A. Sharma, "Estimation of stature from dimensions of hands and feet in a North Indian population," *Journal of Forensic Legal Medicine,* vol. 14, no. 16, pp. 327-332, 2007.

[9] S. R. Pandhare, D. Anjali, D. K. Patil, and M. M. Meshram, "Estimation of stature from inferior extremity length foot length in Children," *International Journal of Recent trend in Science and Technology,* vol. 3, no. 2, pp. 33-37, 2012.

[10] M. Rani, A. K. Tyagi, V. K. Ranga, Y. Rani, and A. Marari, "Stature estimates from foot dimensions," *Journal of Punjab Academic of Forensic and Medical Toxicology,* vol. 11, no. 1, pp. 26-30, 2011.

[11] Bhavna, and S. Nath, "Estimation of stature on the basis of measurements of the lower limb," *Anthropologist Special,* vol. 3, pp. 219-222, 2007.

[12] M. A. Bidmos, "Estimation of fragmentary femora in indigenous South Africans," *International Journal of Legal Medicine,* vol. 122, pp. 293-299, 2008.

[13] S. KhanaPurka, and A. Radke, "Estimation of stature from measurement of foot length, hand length and head length in Maharastra region," *Indian Journal of Basic and Applied Medical Research,* vol. 1, no. 2, pp. 77-85, 2012.

[14] S. B. Habib, and N. N. Kamal, "Stature estimation from hand and phalanges length of Egyptians," *Journal of Forensic and Legal Medicine,* vol. 17, pp. 156-160, 2010.

[15] N. I. Ishak, N. Henry, and D. Franklin, "Estimation of stature from hand and handprint dimensions in a Western Australian population," *Forensic Science International,* vol. 216, no. 1-3, pp. 199.1-7, 2012.

[16] K. Krishan, T. Kanchan, and A. Sharma, "Multiplication factor versus regression analysis in stature estimation from hand foot dimensions," *Journal of Forensic and Legal Medicine,* vol. 19, no. 4, pp. 211-214, 2012.

[17] J. Tang, R. Chen, and X. Lai, "Stature estimation from hand dimensions in a population of Southern China," *Journal of Forensic Science,* vol. 57, no. 6, pp. 1541-1544, 2012.

[18] I. Duyar, and C. Pelin, "Estimating body height from ulna length: need of a population specific formula," *Eurasian Journal of Anthropology,* vol. 1, no. 1, pp. 11-17, 2010.

[19] A. A. Ahmed, "Estimation of stature from the upper limb measurements of Sudanese adults," *Forensic Science International,* vol. 228, no. 1-3, pp. 178.e1-178.e7, 2013.

[20] L. E. Ebite, T. C. Ozoko, A. O. Eweke, P. O. Otuagu, A. O. Oni, and F. A. E. Om`Iniabohs, "Height: Ulna ratio: A method of stature estimation in a rural community in Edo State, Nigeria," *The Internet Journal of Forensic Science,* vol. 3, no. 1, 2008.

[21] S. B. Datta, H. Azcorra, G. Valentin, B. Bogin, and F. Dickinson, "Estimation of stature from upper arm length in children aged 4.0 to 6.92 y in Merida, Yucatan," *Indian Journal of Pediatrics,* vol. 79, no. 5, pp. 640-646, 2012.

[22] J. Inder, and S. Singh, "Estimation of stature from clavicle," *Indian Journal of Medical Research*, vol. 44, pp. 137-155, 1956.
[23] L. Meadows, and R. L. Jantz, "Estimation of stature from metacarpal lengths," *Journal of Forensic Science*, vol. 37, no. 1, pp. 147-154, 1992.
[24] K. Chibba, and M. A. Bidmos, "Using tibia fragments from South Africans of European descent to estimate maximum tibia length and stature," *Forensic Science International*, vol. 169, no. 2-3, pp. 145-151, 2007.
[25] P. Mahakkanukrauh, P. Khanpetch, S. Prasitwattanseree, K. Vichairat, and D. T. Case, "Stature estimation from long bone lengths in a Thai population," *Forensic Science International*, vol. 210, pp. 279.e1-7, 2011.
[26] A. H. Ross, and M. J. Manneschi, "New identification criteria for the Chilean population: Estimation of sex and stature," *Forensic Science International*, vol. 204, pp. 206.e1-206.e3, 2011.
[27] J. I. Munoz, M. Linares-Iglesias, J. M. Suarez-Penaranda, M. Mayo, X. Miquens, M. S. Rodriguez-Calvo, and L. Concheiro, "Stature estimation from radiographically determined long bone length in a Spanish population sample," *Journal of Forensic Science*, vol. 46, no. 2, pp. 363-366, 2001.
[28] I. Haseqawa, K. Uenishi, T. Fukunaqa, R. Kimura, and M. Osawa, "Stature estimation formulae from radiographically determined limb bone length in a modern Japanese population," *Legal Medicine*, vol. 11, no. 6, pp. 260-266, 2009.
[29] A. K. Agnihotri, S. Kachhwaha, V. Jowaheer, and A. P. Singh, "Estimating stature from percutaneous length of tibia and ulna in Indo-Mauritian population," *Forensic Science International*, vol. 187, no. 1-3, pp. 109.e1-109.e3, 2009.
[30] A. Ozaslan, S. Koc, I. Ozaslan, and H. Tugcu, "Estimation of stature from upper extremity," *Mil. Med.*, vol. 171, no. 4, pp. 288-291, 2006.
[31] T. Kanchan, R. G. Menezes, R. Moudgil, R. Kaur, M. S. Kotian, and R. K. Garg, "Stature estimation from foot dimensions," *Forensic Science International*, vol. 179, no. 2-3, pp. 241.e1-241.e5, 2008.
[32] S. Reel, S. Rouse, W. V. Obe, and P. Doherty, "Estimation of stature from static and dynamic footprints," *Forensic Science International*, vol. 219, no. 1-3, 283.e1-283.e5, 2012.
[33] T. Kanchan, K. Krishan, S. ShyamSundar, K. R. Aparna, and S. Jaiswal, "Analysis of footprint and its parts for stature estimation in Indian population," *The foot*, vol. 22, no. 3, pp. 175-180, 2012.
[34] N. Ahemad, and R. Purkait, "Estimation of stature from hand impression: a nonconventional approach," *Journal of Forensic Sciences*, vol. 56, no. 3, pp. 706-709, 2011.
[35] N. K. Mohanty, "Prediction of height from percutaneous tibial length amongst Oriya population," *Forensic Science International*, vol. 98, no. 3, pp. 137-141, 1998.
[36] M. Akhlaghi, M. Hajibeygi, N. Zamani, and B. Moradi, "Estimation of stature from upper limb anthropometry in Iranian population," *Journal of Forensic and Legal Medicine*, vol. 19, no. 5, pp. 280-284, 2012.
[37] I. Y. Anas, U. G. Esomonu, and A. D. Zagga, "Prediction of stature of Hausa ethnic group using hand length and breath," *Journal of medicine in the tropics*, vol. 12, no. 1, pp. 30-32, 2010.
[38] S. Hossain, J. A. Begum, M. L. A. Banu, F. Rahman, and Z. Akhter, "Prediction of stature from hand length and breadth - An Anthropometric study on Christian Gara tribal Bangladeshi females," *Bangladesh Journal of Anatomy*, vol. 8, no. 1, pp. 21-27, 2010.
[39] I. Ilayperuma, G. Nanayakkara, and N. Palahepitiya, "Prediction of personal stature based on the hand length," *Galle Medical Journal*, vol. 14, no. 1, pp. 15-18, 2009.
[40] O. P. Jasuja, and G. Singh, "Estimation of stature from hand and phalange length," *Journal of Indian Association of Forensic Medicine*, vol. 26, no. 3, pp. 100-106.
[41] P. Rastogi, K. R. Nagesh, and K. Yoganarasimha, "Estimation of stature from hand dimensions of North and South Indians," *Legal medicine*, vol. 10, no. 4, pp. 185-189, 2008.
[42] International Organization for Standardization (ISO), General requirements for establishing anthropometric databases, ISO 15535, 2006.
[43] A. Chandra, P. Chandna, and S. Deswal, "Hand Anthropometric Survey of Male Industrial Workers of Haryana State (India)," *International Journal of Industrial and Systems Engineering*, vol. 9, no. 1, pp. 98-120, 2011.
[44] National Aeronautics and Space Administration. "Anthropometric Source Book - A Handbook of Anthropometric Data," (Report No. NASA RP-1024). *National Technical Information Service*, (1978).
[45] A. Chandra, P. Chandna, and S. Deswal, "Analysis of hand anthropometric dimensions of male industrial workers of Haryana state," *International Journal of Engineering*, vol. 5, no. 3, pp. 242-256, 2011.
[46] A. Choksi, G. R. Babu, and M. S. Dahiya, "Study on the primary characteristics of identification: estimation of stature from palm length among the native Guajarati population," *NHL Journal of Medical Sciences*, vol. 3, no. 2, pp. 13-17, 2014.
[47] A. Chandra, P. Chandna, and S. Deswal, "Estimation of hand index for male industrial workers of Haryana State (India)," *International Journal of Engineering, Science and Technology*, vol. 5, no. 1, pp. 55-65, 2013.
[48] A. H. Shivkumar, G. M. Raju, and V. Vijaynath, "Prediction of stature by right middle finger length of males among south Indian population," *Journal of Pharamaceutical and Scientific Innovation*, vol. 2, no. 1, pp. 31-33, 2013.
[49] C. R. Khothari, "Research Methodology: Methods and Techniques," New Age International, New Delhi, 2004.
[50] P. Chandna, S. Deswal, and A. Chandra, "An anthropometric survey of industrial workers of the northern region of India," *International Journal of Industrial and Systems Engineering*, vol. 6, no. 1, pp. 110-128, 2010.
[51] A. Chandra, P. Chandna, S. Deswal, and R. Kumar, "Ergonomics in the office environment: a review," *in Proceedings of International Conference on Energy and Environment*, Chandigarh, 2009, pp. 913-919.
[52] T. Kanchan, and K. Krishan, "Anthropometry of hand in sex determination of dismembered remains - a review of literature," *Journal of Forensic and Legal Medicine*, vol. 18, no. 1, pp. 14-17, 2011.
[53] K. Krishan, T. Kanchan, R. G. Menezes, and A. Ghosh, "Forensic anthropology case work essential methodological considerations in stature estimation," *Journal of Forensic Nursing*, vol. 8, no. 1, pp. 45-50, 2012.
[54] A. K. Abdel-Malek, A. M. Ahmed, S. A. E. A. E. Sharkawi, and N. A. E. M. A. E. Hamid, "Prediction of stature from hand measurements," *Forensic Science International*, vol. 46, no. 3, pp. 181-187, 1990.