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ESTIMATION OF STATURE FROM HAND AND FOOT DIMENSIONS AMONG UNIVERSITY GIRL-STUDENTS IN BILASPUR, CHHATTISGARH, INDIA

ABSTRACT: Theoretical development of the inter-relationship between stature and other body dimensions is important in forensic investigation and cases of hospitalized patients with physical disabilities. Principal aim of the study was to estimate stature from bilateral measurements of hands and feet (length and breadth). Participants were 135 girl students, aged 18–22 years in a University in Bilaspur, Chhattisgarh, India. Ordinary least squares (OLS) and multiplication factor (MF) analyses were used to estimate stature. The differences in stature (actual stature minus estimated stature) were compared between two methods. Mean stature was 155.51 cm. Mean values of estimated stature and difference from the actual stature was recorded from: left hand length (OLS: 155.17 cm, difference 0.34 cm; MF: 155.65cm, difference -0.14 cm), left hand breadth (OLS: 156.16 cm, difference -0.66 cm; MF: 155.77 cm, difference -0.26 cm), right hand breadth (OLS: 155.69 cm, difference -0.18 cm; MF: 155.80 cm, difference -0.29 cm), left foot length (OLS: 153.98 cm, difference 1.53 cm; MF: 155.67cm, difference -0.16 cm), and left foot breadth (OLS: 155.38 cm, difference 0.13 cm; MF: 156.38 cm, difference -0.87 cm). The estimated stature from MF consistently overestimated the actual stature except left foot breadth whereas the regression analysis marginally underestimated it except hand breadth. The OLS more precisely estimated stature than MF.

KEY WORDS: Hand – Foot – Asymmetry – Stature estimation – Regression – Multiplication factor

INTRODUCTION

Estimation of stature from anthropometric measurements of different body segments in adult humans has been undertaken since long (Jarzem, Gledhill 1993, Ozaslan *et al.* 2003, 2006). Studies reported precise estimation of stature from hand and foot dimensions that included young adult University students in: Mauritius (Agnihotri *et al.* 2007, 2008), Turkey (Sanli *et al.* 2005), Nigeria (Barnabas, Elupko

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2008), and Maharashtra, India (Khanapurkar, Radke 2012). Other studies from North Indian samples included estimation of stature from foot among girls aged 13–18 years (Krishan *et al.* 2011a) and young women aged 18–22 years (Rani *et al.* 2011). Stature was estimated also from hand and foot dimensions among 17–20 year-old young females of North India (Krishan *et al.* 2011b, Krishan, Sharma 2007).

Studies have reported positive correlation between stature and hand length among young individuals aged 20–23 years in Sri Lanka (Ilayperuma *et al.* 2009). Multiple regression analysis using parameters (Foot length, hand length and head length) to estimate stature was found to have better precision than simple linear regression equation using a single parameter (Krishan *et al.* 2011a). Hand length (Right and left) and hand breadth (Right and left) estimated stature; and left hand length was found to have significant effect in the regression models among 18–30 year-old University students in Mauritius (Agnihotri *et al.* 2008). In the same sample, a study on the relationship between foot length and stature, right foot length explained highest variations in stature (Agnihotri *et al.* 2007). Multiple regression equation was also designed to estimate stature from hand dimension regardless of side among University students in Egypt (Abdel-Malek *et al.* 1990).

As discussed above, estimation of stature from hand and foot dimensions among young adult females have been reported from India and abroad. However, study on errors of estimation of stature through regression analysis and multiplication factors has not been yet reported precisely except a few (Krishan *et al.* 2012). Considering that issue, there was need for further research to elucidate estimation of stature from hands and feet. Therefore, objectives of the present study among adult females were to:

1) Estimate stature from length and breadth of hands and feet.
2) Calculate and compare the differences in stature estimation (Actual stature minus estimated stature) by two methods (Regression analysis and multiplications factors).

MATERIAL AND METHODS

The present study was cross-sectional in nature. As a part of a study on anthropometric characteristics and nutritional status of young adult women, the participants were 135 girl students, aged 18–22 years, at Guru Ghasidas Vishwavidyalaya, a University in Bilaspur, Chhattisgarh, India. A sample was drawn from the list of the registered students in the University. Measurements of stature (cm), length (mm) and breadth (mm) of hands and feet were recorded following standard international protocols (Lee, Nieman 2007, Lohman *et al.* 1988). Stature (Height vertex) was measured using standard Martin's anthropometer and bilateral hand and foot dimensions (Length and breadth) were measured using a standard sliding caliper to the nearest tenth of a centimeter. Measurements were taken by the properly trained postgraduate student (MG) in the University Department and one of the co-authors (SD). Each trait was measured twice and the average of the two repeated measures was then used. Technical error of measurements (TEM) validated the measurement quality and consistency for repeating measurements (Intra-examiner and inter-examiner). Test-retest reliability was computed using intra-class correlation coefficients (ICC, repeated measures) with 95% confidence intervals (mean difference ± 1.96 SD) (Bland, Altman 1986); all anthropometric measurement ICC values were above 0.85 (Altman 1999). Stature, hand length, hand breadth, foot length, and foot breadth were normally distributed following assumptions (Shapiro-Wilk test, $p > 0.05$).

A multiplication factor (MF) for estimation of stature was derived by dividing stature by hand and foot dimensions (Length and breadth) (Brandt 2009, Krishan *et al.* 2012). It was decided that depending on the magnitude and significance of paired difference between the measurements of right and left sides of hand and foot dimensions (length and breadth), the MF and regression analysis would be done for both sides separately (when $p < 0.05$) or only one side (when $p > 0.05$) (Preferably the left one). Hierarchical linear regression models of predicting stature after controlling for age were computed, separately taking hand and foot dimensions as the predictors. The difference of estimate (Actual stature minus estimated stature) was calculated. A p-value < 0.05 was considered statistically significant. Ethical approval was obtained from the appropriate authority before the commencement of the study. Informed consent was obtained from the participants. All statistical analyses were done using the SPSS statistical package (version 13.0).

RESULTS

The sample represented young adult women (Mean age 20.15 yrs ± 1.24 SD or standard deviation). Mean

stature was 155.51 cm ± 5.59 SD (*Table 1*). Separate measurements of two sides indicated marginal differences in mean values without statistical significance for hand and foot dimensions except hand breadth. Hand length was 1.55 mm higher in left side and hand breadth was 0.32 mm higher in right side. In case of foot length and breadth, mean values of the measurements of right side were marginally bigger. Paired difference between two sides though marginal, was significant only for hand breadth (t = 2.03, $p < 0.05$). In the circumstances, hand and foot measurements of left side only were considered except hand breadth (Both sides) to calculate multiplication factor (MF). The MFs of hand length (9.24 ± 0.38) and hand breadth (Right: 18.03 ± 0.89, left: 18.10 ± 0.87) give an overall estimate of relation between height and these two measurements. The MF indicating relation with stature was 6.64 (± 0.23) for foot length and 18.31 (± 1.60) for foot breadth (*Table 1*).

Stature prediction through linear regression analysis (After controlling for age, in hierarchical regression models) from the measurements of the left sides of hand and foot dimensions (length and breadth) and both sides for hand breadth, displayed significant relationships (*Table 2*). In all cases, models were statistically significant (F-values in ANOVA with $p < 0.0001$). Regression models therefore, in all cases showed that hand and foot measurements remarkably predicted stature. Age was not found to have any significant relation with estimation of stature in any regression model. Regression coefficient for left hand breadth was highest (0.56) compared to the lowest value for left foot breadth (0.29). In five models, standardized coefficient beta exhibited high significance ($p < 0.001$). Therefore, the null hypothesis was not accepted and regression coefficients indicated reliability in estimation of stature from hand and foot dimensions. The standard error of estimate (SEE) predicted the deviation of estimated stature from the

TABLE 1. Descriptive statistics of age, stature, bilateral paired differences and multiplication factor (MF) with stature for hand and foot dimensions in University girl students (n = 135) at Bilaspur, Chhattisgarh, India. SD, Standard deviation; Min, Minimum value; Max, Maximum value; MF,: Multiplication factor.

Variables	Mean (SD)	Min	Max	t (paired)	*p*
Age (years)	20.15 (1.24)	18.50	22.50	---	---
Stature (cm)	155.51 (5.59)	141.10	172.90	---	---
Hand length-right (mm)	168.30 (7.32)	151.00	190.00	---	---
Hand length-left (mm)	168.45 (7.43)	152.00	191.00	---	---
Hand length difference (right-left) (mm)	-1.55 (2.51)	-8.00	5.00	-0.72	0.47
MF (left hand length)	9.24 (0.38)	8.27	10.53	---	---
Hand breadth-right (mm)	86.38 (4.18)	75.00	97.00	---	---
Hand breadth-left (mm)	86.06 (4.23)	75.00	98.00	---	---
Hand breadth difference (right-left) (mm)	0.32 (1.82)	-4.00	5.00	2.03	0.04
MF (right hand breadth)	18.03 (0.89)	15.42	21.54	---	---
MF (left hand breadth)	18.10 (0.87)	16.26	21.01	---	---
Foot length-right (mm)	234.48 (10.28)	211.00	274.00	---	---
Foot length-left (mm)	234.44 (9.63)	214.00	260.00	---	---
Foot length difference (right-left) (mm)	0.04 (4.07)	-10.00	32.00	0.13	0.90
MF (left foot length)	6.64 (0.23)	5.95	7.34	---	---
Foot breadth-right (mm)	85.52 (5.27)	69.00	99.00	---	---
Foot breadth-left (mm)	85.41 (6.11)	51.00	101.00	---	---
Foot breadth difference (right-left) (mm)	0.11 (3.5)	-6.00	34.00	0.37	0.71
MF (left foot breadth)	18.31 (1.60)	15.75	31.22	---	---

TABLE 2. Hierarchical Linear regression models predicting stature from hand and foot dimensions in University girl students (n = 135) at Bilaspur, Chhattisgarh, India. Regression equation is y = a + bx. Dependent variable (y) = Stature (cm); Independent variable (x) = HL, Hand length (mm); HB, Hand breadth (mm); FL, Foot length (mm); FB, Foot breadth (mm). In the equation, a= constant and b = regression coefficient for the predictors. 'Se' refers to standard error of the regression coefficient. 'Beta' refers to standardized regression coefficient. Standard error of estimate (SEE).

Model	Estimated equation	SE	Beta	*t*	*p*-value	95% CI for B		Adj R^2	SEE	R^2 Change	F Change	*p*-value
						Lower Bound	Upper Bound					
1	89.47 + (0.39 x LHL)	0.06	0.49	6.48	<0.0001	0.26	0.48	0.23	4.90	0.24	41.99	<0.0001
2	107.97 + (0.56 x LHB)	0.10	0.42	5.35	<0.0001	0.35	0.76	0.17	5.10	0.18	28.64	<0.0001
3	109.91 + (0.53 x RHB)	0.11	0.36	4.42	<0.0001	0.26	0.69	0.16	5.25	0.13	19.50	<0.0001
4	69.58 + (0.36 x LFL)	0.04	0.61	8.76	<0.0001	0.27	0.43	0.36	4.47	0.37	76.70	<0.0001
5	130.61 + (0.29 x LFB)	0.08	0.27	3.25	<0.0001	0.10	0.40	0.10	5.41	0.07	10.53	<0.0001

hand and foot measurements. The SEE of estimates was found to be small (Minimum 4.47 for left foot length and maximum 5.41 for left foot breadth). Residuals showed no pattern and were at random (*Table 2*).

Mean values of estimated stature from either regression analysis or multiplication factors (MF) for hand and foot dimensions (Length and breadth), in all cases were found to be very close to the actual stature (155.51 ± 5.59 cm) and did not show any significant differences between them (*Table 3*). The estimated stature from MF consistently overestimated the actual stature except left foot breadth whereas the regression analysis underestimated it except hand breadth. However, the ranges of minimum and maximum values of the estimated stature were pretty wide and that was more evident in case of MF analysis than regression analysis. When compared with actual stature, the range of minimum and maximum values of estimated stature was relatively narrower in case of regression analysis. The standard deviation of estimated stature from hand and foot dimensions through MF consistently exceeded the standard deviation of actual stature, whereas the estimated stature from regression analysis had standard deviations lower than the actual stature (*Table 3*).

DISCUSSION

To summarize, hand and foot measurements (Length and breadth) successfully estimated stature in young adult women University students. Length and breadth as co-predictors in the regression models of either hand or foot were not significant to estimate stature. Foot breadth estimated stature with marginally lower error in comparison with foot length through regression analysis.

The results varied from that recorded among 18–30 year-old University women-students in Nigeria (Ibeachu *et al.* 2011). Bilateral difference was observed in hand length (Right 17.62 ± 0.07 cm, left 17.69 ± 0.07 cm) and hand breadth (Right 7.69 ± 0.03 cm, left 7.58 ± 0.03 cm) in that Nigerian sample. In that study, left hand length was higher than the right hand length while in the breadth there was a reverse. In the present study also the women had larger right hand breadth and longer left hand length. Average hand length (168.40 ± 0.73 mm) and hand breadth (86.20 ± 0.41 mm) of Indian women indicated shorter hand length and broader hand breadth than Nigerian women. Another study among Nigerian women (>18 years) reported mean values for: foot length (Right 25.00 ± 1.33 cm, left 24.75 ± 0.17 cm) and foot breadth (Right 9.14 ± 0.58 cm, left 8.92 ± 0.08 cm) (Bob-Manuel, Didia 2008). Whereas in the present study in Indian sample, foot length (Right 234.48 ± 10.28 mm, left 234.44 ± 9.63 mm) and foot breadth (Right 85.52 ± 5.27 mm, left 85.41 ± 6.11 mm) showed smaller foot size (either length or breadth) compared to the Nigerian women.

Hand length and foot length had significant correlation ($p < 0.05$) with stature in 19–22 year-old

TABLE 3. Estimated stature from hand and foot dimensions and differences with actual stature* in University girl students (n = 135) at Bilaspur, Chhattisgarh, India. * Actual stature = 155.51 cm ± 5.59 SD (Min: 141.1 cm, Max: 172.9 cm); OLS, Ordinary Least Squares or regression analysis; MF, Multiplication Factor; Min, Minimum (Underestimation); Max, Maximum (Overestimation); SD, Standard deviation.

	Estimated stature through OLS			Estimated stature through MF		
Anthropometric parameters	Mean (SD)	Min	Max	Mean (SD)	Min	Max
Estimated stature (cm) from left hand length	155.17 (2.90)	148.75	163.96	155.65 (6.87)	140.45	176.48
Difference of stature (cm) (based on left hand length)	0.34 (4.88)	-12.71	17.55	-0.14 (6.39)	-17.64	20.52
Estimated stature (cm) from left hand breadth	156.16 (2.37)	149.97	162.85	155.77 (7.65)	135.75	177.38
Difference of stature (cm) (based on left hand breadth)	-0.66 (5.08)	-15.03	16.87	-0.26 (7.35)	-16.89	23.59
Estimated stature (cm) from right hand breadth	155.69 (2.22)	149.66	161.32	155.80 (7.42)	135.53	174.58
Difference of stature (cm) (based on right hand breadth)	-0.18 (5.23)	-14.39	18.42	-0.29 (7.63)	-25.64	21.16
Estimated stature (cm) from left foot length	153.98 (3.47)	146.62	163.18	155.67 (6.39)	142.10	172.64
Difference of stature (cm) (based on left foot length)	1.53 (4.47)	-13.76	17.1	-0.16 (5.40)	-16.53	16.15
Estimated stature (cm) from left foot breadth	155.38 (1.77)	145.4	159.9	156.38 (11.20)	93.38	184.93
Difference of stature (cm) (based on foot breadth)	0.13 (5.41)	-13.47	15.61	-0.87 (11.15)	-24.34	65.82

students in Maharashtra, India (Khanapurkar, Radke 2012). In that study, stature was estimated from hand length (in cm) (Stature = 84.9 + 4.30*Hand length) and foot length (in cm) (Stature = 72.8 + 3.70*Foot length). In the present study, regression coefficient estimating stature from left hand length (in mm) (89.47 + 0.39*Left Hand length) and left foot length (in mm) (69.58 + 0.36*Foot length) were lower than that estimated in the Maharashtrian sample.

Bilateral correlation for foot length was higher than foot width and stature was estimated in adults (18 to 44 years) in Turkey (Zeybek *et al.* 2008). Foot length had significant difference between sides among 13–18 year-old young female participants from northern India (Krishan *et al.* 2011a). In that study, foot length estimated stature with greater accuracy than foot breadth. Correlation coefficients between stature and foot dimensions were found to be positive and statistically significant ($p < 0.05$) among young college students aged 18 to 22 years of Delhi, India and the foot length had shown highest accuracy in estimating stature (Rani *et al.* 2011). In a sample of 17–20 years old individuals from Rajput community in Himachal Pradesh, India, correlation coefficients between stature and all the measurements of hands and feet (length and breadth) were positive and statistically significant ($p < 0.05$). In the present study, correlation between bilateral measurements of hands and feet (Length and breadth) was significant ($p < 0.05$), except significant ($p < 0.05$) paired difference of bilateral hand breadth. Hand and foot dimensions estimated stature with marginal difference from actual stature.

CONCLUSION

In the present study, hand and foot length and breadth could successfully estimate actual stature in young adult women. The regression analysis was observed to be more precise compared to the multiplication factors of the measurements to estimate stature. However, regression models were specific for the sample and that needs further verifications from other studies in India. Another study among subjects from North India aged between 17 and 20 years, also evidenced that regression analysis was better than multiplication factor in stature estimation from anthropometric measurements of hand length, hand breadth, foot length and foot breadth (Krishan *et al.*

2012). The present study therefore, contributes an important idea in stature estimation from hand and foot dimensions that might be useful in 1) theoretical development of inter-relationship between stature and other body dimensions (hands and feet); 2) forensic sciences and investigations, personal identification; and also 3) as a good alternative measurement to estimate stature, especially providing convenience in recording among the hospitalized elderly patients with physical disabilities. Similar studies with reference to different ethnic backgrounds by age and sex are necessary to be carried out in a country like India where morphometric variations in human populations are diverse in correspondence with environmental settings and genetic affinities.

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