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Original Article

CORRELATION OF BODY HEIGHT BY FOOT LENGTH AND KNEE HEIGHT MEASUREMENTS IN POPULATION OF NORTH INDIA

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ABSTRACT

Background: The body height measurement plays an important role in personal and medico legal identification and has become invaluable aid to scientific research in Anatomy, especially anthropological anthropometry. This study is conducted to find the correlation between body height and foot length & knee height measurements in both the sexes and to determine accurate and best predictor of height from above two parameters using Correlation Coefficient.

Methods: Asymptomatic, healthy 1000 subjects (500 males and 500 females), residents of Teerthanker Mahaveer University of cosmopolitan origin age over 18 years old were studied. Their body height, Foot lengths and knee height were measured and all the readings were subjected to Statistical Analysis using mean ± standard deviation, Pearson's correlation coefficients and linear regression analyses.

Result: In present study, correlation coefficients (r) values between body height, foot lengths and knee height were found to be statistically significant and positive in both males, females and in combined data, with highest 'r' value of knee height followed by foot lengths. Regression equations for estimating body height were developed for each of these parameters by Linear Regression.

Conclusion: The study suggests the Knee height to be the best body height indicator developed for estimation of body height according to gender including age as a predictor variable in order to reduce the inherent problem of sample specificity and enhance accuracy confidence in the estimation.

KEY WORDS: Body height, Foot length, Knee height, Correlation Coefficient, Linear Regression Analysis.

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INTRODUCTION

"I am invisible; understand, simply because people refuse to see me" - Ralph Ellison

In today's world we are all living with risk. There is no such thing as "ZERO RISK" to individuals, society or the environment.

"Everyone has the right to recognition everywhere as a person before the LAW"[1].

In recent times many accidents, natural mass disaster like earthquake, tsunamis and man-

made disaster like bomb blast, wars, plane crashes etc. require special attention where bodies are found in mutilated states. These cases justify "**The Universal Old Age Truth**"- Which states the forensic experts that although there is one way in which to be born, there are many ways in which to die [2].

Stature is an important key feature of identification of biological profile of an individual. Foot dimensions have not been frequently used though sparing of foot is usually seen in most of the crime scenes as well as in cases of mass disaster as people are often shoe-clad. Hence feet can be excellent clue regarding personal identity [3]. Rutishauser [4] for the first time showed that the reliability of prediction of height from foot print was as high as that from long bones as ossification and maturation in foot occurs earlier than the long bones [5].

Accurate indirect methods are needed to assess the nutritional status of older people.[6]In such cases height has to be estimated as surrogate since the length of the long bones in arms and legs does not reduce with age, arm span and knee height has being used as surrogate measure of heights in older people where reliability was carefully controlled [7]. Arm span has also being used, but may be less satisfactory then the knee height because of joints stiffness in older people, which could reduce the accuracy of the measurement [8,9].

No study till now in India validated recumbent height measurements against standing height measurements among adults or elderly individuals without any ambulatory or debilitated conditions that cause inaccuracy of the measurements.Therefore present study is aimed to predict the best body height indicator and to develop a nationally representative prediction equation for estimation of stature according to gender including age as a predictor variable in order to reduce the inherent problem of sample specificity and enhance accuracy confidence in the estimation.

MATERIALS AND METHODS

For present study, total 1000(500 males and 500 females) asymptomatic, healthy adults, residing in Teerthanker Mahaveer University of cosmopolitan origin with age over 18 years old with no diagnosed history of knee arthropathy and spinal deformity and a written informed consent was taken from the subjects. The measurements were taken between 2 to 5 p.m. to eliminate the discrepancies due to diurnal variations.

No Objection Certificate was obtained from the college Ethical Research Committee.

Sampling Method: Purposive and Judgement sampling methods. These samplings are best when we are studying a particular set of groups.

Study design: Evaluative study.

METHOD

Body Height (B. H.) was measured with an anthropometer/Stadiometer and was taken from the vertex to the floor with the person standing barefoot in the anatomical position and with the head in Frankfurt plane (Martin, Saller, 1957) in centimetres.

Foot length (FL) was measured as the distance from the most posterior point of the heel (**pternion)** to the most anterior point of the longest toe-first or the second (**acropodion**) in centimetres by spreading calipers (Hrdlicka type) [10].

Knee Height (K H) defined as the distance from the heel of the foot to the top of the patella, (most anterior surface of the femoral condyles of the thigh, medial being more anterior), with the ankle and knee each flexed to a 90^0 angle, measured by Ross's Knee height Calipers. All the readings were tabulated & subjected to statistical analysis using mean ± standard deviation of data and computing the correlation coefficient(-1 to +1) with excel on window professional 2007. Associations were considered statistically significant at the $p<0.05$ and <0.01 level evaluated with Z-test. Derivation of Linear regression equations was done to calculate height from foot length and knee height of an individual. All measurements were recorded by the same person in order to avoid interobserver bas employed.

Standardized anthropometric instruments used in all studies, yet there is lack of uniformity between methods and the degree of measurement error associated. This is significant because high amounts of measurement

error can invalidate statistical results. Targets for anthropometric assessment have been put forward by Zerfas,[11]using a repeat- measures protocol. In present study, intraobserver precision estimates for measures of body height, foot lengths & Knee height measurements were evaluated from two repeated measures on 50 subjects and then mean of two was taken. From this replicate data, three precision estimates were calculated: the technical error of measurement (TEM), the relative technical error of measurement (rTEM), and the coefficient of reliability (R),[11]for reliability analysis.

Technical error of measurement (TEM) is a measure of error variability that carries the same measurement units as the variable measured. Its interpretation is that differences between replicate measurements will be within± the value of TEM two-thirds of the time.[12]Similarly, 95% of the differences between replicate measurements are expected to be within±/2_/ TEM, [13]which is referred to as the 95% precision margin. Intra-observer TEM is estimated from differences between replicate measurements taken by one observer, while interobserver TEM is estimated from single measurements taken by two or more observers. From TEM, the coefficient of reliability(R) can be determined, which ranges from 0 (not reliable) to 1 (complete reliability) although there are no recommended values for R, Ulijaszek and Kerr (1999)[14]suggested that a cut-off of 0.95 be used (i.e. a human measurement error of up to 5%). So a reduction in error indicates improvement in measurement technique between observers, and greater quality control.

RESULTS AND OBSERVATIONS

Table 1: Mean± Standard values of Body Height, Foot Length & Knee Height in both Males and Females.

	MALE	FEMALE	BOTH GENDERS
HEIGHT	168.14±7.708	157.68±7.068	162.91±9.056
RIGHT FOOT LENGTH	24.949±1.376	22.937±1.157	23.943±1.621
LEFT FOOT LENGTH	24.935±1.389	22.913±1.199	23.924±1.645
KNEE HEIGHT	51.6±3.21	47.7±2.26	49.6±3.40

Table 2: Descriptive Statistics of Parameters in both males and females.

PARAMETERS	MALE	FEMALE	BOTH GENDERS
CORRELATION COEFFICIENT (r)HEIGHT & RT.FOOT LENGTH	0.7025**	0.4846**	0.7471**
CORRELATION COEFFICIENT (r)HEIGHT & LT.FOOT LENGTH	0.7027**	0.3885**	0.7434**
REGRESSION COEFFICIENT(b) HEIGHT & RT.FOOT LENGTH	3.933	2.9585	4.172
REGRESSION COEFFICIENT(b) HEIGHT & LT.FOOT LENGTH	3.898	2.8153	4.092
VALUE OF CONSTANT(a) HEIGHT & RT.FOOT LENGTH	69.99	89.82	63
VALUE OF CONSTANT(a) HEIGHT & LT.FOOT LENGTH	70.93	93.17	64.99
CORRELATION COEFFICIENT (r)HEIGHT & KNEE LENGTH	0.7477**	0.5111**	0.7829**
REGRESSION COEFFICIENT(b)	1.792	1.797	2.085
VALUE OF CONSTANT(a)	75.62	71.92	59.36

**Strongly Significant as p-value < 0.01

Table 3: Linear Regression Formulae for Body Height (cms) from Foot Lengths and Knee Height.

SEX	VARIABLES	EQUATIONS	S.E.E. (cms)	COEFFICIENT OF DETERMINATION (r^2)	ADJUSTED (R^2)	p Value
Male	RT.FOOT LENGTH	B.H.=69.99+3.93(FL)	0.13	0.49	0.01	<0.01
	LT. FOOT LENGTH	B.H.=70.93+3.89(FL)	0.24	0.49	0.05	<0.01
	KNEE HEIGHT	B.H.=75.62+1.79(KH)	0.12	0.54	0.01	<0.01
	KNEE HEIGHT WITH AGE	**B.H.=80.62+1.79(KH)-0.18(AGE)**	0.45	0.0001	0.2	<0.01
Females	RT.FOOT LENGTH	B.H.=89.82+2.95(FL)	0.21	0.23	0.04	<0.01
	LT. FOOT LENGTH	B.H.=93.17+2.81(FL)	0.13	0.14	0.01	<0.01
	KNEE HEIGHT	B.H.=71.92+1.79(KH)	0.37	0.26	0.13	<0.01
	KNEE HEIGHT WITH AGE	**B.H.=72+1.79(KH)-0.0002(AGE)**	0.31	0.0001	0.09	<0.01
Both Genders	RT.FOOT LENGTH	B.H.=63.00+4.17(FL)	0.08	0.54	0.006	<0.01
	LT. FOOT LENGTH	B.H.=64.99+4.09(FL)	0.08	0.54	0.006	<0.01
	KNEE HEIGHT	B.H.=59.36+2.08(KH)	0.25	0.6	0.06	<0.01
	KNEE HEIGHT WITH AGE	**B.H.=59.4+2.08(KH)-0.001(AGE)**	0.37	0.0004	0.13	<0.01

P<0.01, strongly significant

The technical error of measurement (TEM) can be determined which is an accuracy index and measures the standard deviation between repeated measures. The formulation of TEM depends on how many observers have taken the measurement. If the same observers has measured on two occasions (a measure of intra-TEM) or two observers have measured the same, then the formula for TEM is where D is the difference between the two measurements, and N is the sample size, as shown in Table 4.

$$\sqrt{\frac{\sum D^2}{2N}}$$

It is also possible to compute the relative TEM (%TEM), which provides an estimate of the error magnitude relative to the size of the measurement (expressed as a percentage) and is analogous to the coefficient of variation (see below).

$$\%TEM = \frac{TEM}{\bar{X}} * 100$$

From TEM, the coefficient of reliability (R) can be determined, which ranges from 0 (not reliable) to 1 (complete reliability), where SD is the standard deviation of all measurements.

$$1 - \left(\frac{(TEM)^2}{SD^2} \right)$$

Table 4: Three precision estimates of reliability as TEM, rTEM and R for different.

Parameters	TEM (cm)	rTEM (%)	R
Body Height	< 0.5	< 0.84	> 0.98
RT. Foot length	< 0.5	< 0.84	> 0.98
LT. Foot length	< 0.5	< 0.84	> 0.98
Knee Height	< 0.5	< 0.84	> 0.98

DISCUSSION

There are various methods to estimate stature from bones but the earliest and reliable method is by regression analysis[15]. Correlation Coefficient between body height, both right and left foot lengths & knee height in both the genders and combined data were found to be statistically significant ($p < 0.01$) and positive indicating a strong relationship between parameters. As Knee Height showed the highest degree of correlation (r=0.7477 in males, r=0.5111 in females, r=0.7829 in both genders) followed by foot lengths (Right foot length = r=0.7025 in males, r=0.4846 in females, r=0.7471 in both genders) (Left foot length = r= 0.7027in males, r=0.3885 in females, r=0.7434 in both genders), with least standard error of estimate of 0.12 in males followed by0.37 in females in comparison to foot lengths(Table2), suggesting Knee height is best and accurate parameter in estimating body height. Within the long bone measurements, the estimation from knee height is highly correlated to stature than other long bone measurements. There are many equations for estimating stature from knee height, which has been reported by Chumlea[13], Lera[16], Chumlea[17], Han[18], Chumlea[19], Palloni [20], Donini[21], Zhang[22], Mayers[23], Shahar[24], Cockram[25], Knous[26] in various countries.

CONCLUSION

Intraobserver reliability of the measurement, differences between replicate measurements taken by one observer was<0.5cm & relative TEM as <0.84%. And even so, coefficients of reliabilities above 0.95 are indicative of good quality control. These results suggest that Body height, foot length and knee height are sufficiently precise for anthropometric research application. Thus, the present study suggests the Knee height to be the best body height indicator for estimation of body height according to gender including age as a predictor variable in order to reduce the inherent problem of sample specificity and enhance accuracy confidence in the estimation.

List of Abbreviations:

Max.: Maximum,

Min.: Minimum,

B.H.: Body Height,

S.E.E.: Standard Error Estimate.

Conflicts of Interests: None

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