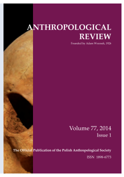
Anthropological Review • Vol. 79 (1), 47–57 (2016)

DE GRUYTER OPEN

Anthropological Review
Available online at: https://doi.org/10.1515/anre-2016-0004



Predictive equations for height estimation using knee height of older Bengalees of Purba Medinipur, West Bengal, India

Binoy Kuiti, Kaushik Bose

Department of Anthropology, Vidyasagar University, West Bengal, India

Abstract: For nutritional assessment work for older population, it is important to be able to estimate body height based on knee height. The present report describes three equations for height estimation among older Bengalees based on knee height and compares the results with knee height based formulae developed for several other populations. Anthropometric measurements were analyzed from 114 (62 men and 52 women) older subjects aged >= 55 years. The subjects were randomly selected from two blocks (Contai I and Ramnagar I), at coastal area of Purba Medinipur District in West Bengal, India. A population specific formula for height was created based on knee height of the subjects. These estimated formulae from the present study and fourteen other previously reported formulae were also applied to these older population and the mean estimation errors were statistically compared. Analysis indicated that our derived formulae gave accurate estimation of height among the subjects.

Key words: Bengalees, height estimation, knee height

Introduction

Anthropometric values are closely related to nutrition, genetic makeup, environmental characteristics, social and cultural condition, lifestyle, functional status and health. Anthropometric evaluation is an essential feature of geriatric nutritional evaluation for determining malnutrition, being overweight, obesity, muscular mass loss, fat mass gain and adipose tissue redistribution. Anthropometric indicators are used to evaluate the prognosis of chronic and acute diseases, and to guide medical intervention in the elderly (Grinker et al. 2000; Froster et al. 2005; Villareal et al. 2005). The biological aging process is characterized by a progressive decline in functional capacity in all tissue and organs of the body, as well as by a decrease in the ability to respond and adjust to environmental changes (Adams

Original Article Received: July 7, 2015; Accepted for publication: November 30, 2015
DOI: 10.1515/anre-2016-0004

and Whith 2004). Height is an important anthropometric measurement for the assessment of health conditions in people. Ideal body weight is based on height. Body mass index (BMI), which is calculated from height and weight (expressed in kg/m^2) (Shetty and James 1994; WHO 1997) is used to judge the level of obesity and under-nutrition. Energy expenditure is measured from resting metabolic rate (RMR), which is estimated from the WHO equation; RMR= (15.4xWeight) + (0.27xHeight) +717. Creatinine height index (Wasler 1987), which is representing the nutritional status of individual, also requires a measurement of height. However, there are difficulties in obtaining an accurate measurement of height in elderly subjects. Because in this ending stage of human life span, both aged men and women suffer with several physiological, psychological and biological changes, including body composition, such as an increase in body fat and a decrease in lean body mass and also progressive decline in bone density. This can lead to changes in body posture and flattening of the vertebrae, reduction in inter-vertebral disc thickness, dorsal kyphosis, scoltosis, bowing of the legs which can contribute to a reduction in height. Difficulties for biological deformities and several conditions such as infectious diseases, osteoporosis, paralysis and amputation (Cockram et al. 1990; Bermudez et al. 1999) standing height may not be a reliable indicator for correct estimated stature in elderly population. Thus, many researchers have sought to develop methods to estimate body height from specific measures of body segments. Knee height is one of the reliable measurements that can predict proxy height by statistical regression method due to its high relation (Chumlea et al. 1994). Knee height is accepted as an independent method because it is not affected by different factors like the weakness of erector spine muscle and reduction of water content within the inter-vertebral disk. For this reason, when height cannot be measured accurately, knee height can be used for the estimation of body height (Chumlea et al. 1985; Haboubie et al. 1990; Roubenoff and Wilson 1993; Han and Lean 1996). In our present study, we attempted to derive stature-predicted equations using age, weight, knee height and sex among elderly Bengalees of Purba Medinipur, West Bengal. We then compared with other knee-length-based previously derived equations (Chumlea et al. 1985; Chumlea and Guo 1992; Bermudez et al. 1999; Donini 2000; Knous 2002; Lera 2005; Cereda et al. 2010; Mathew et al. 2014).

Material and Methods

The cut-off point of 55 years was taken in present study to define elderly subjects following Ghose et al. (2001). The sample size consisted of 62 men and 52 women of Contai I and Ramnagar I blocks, located in Coastal area of Purba Medinipur district, in West Bengal, India. A random sampling procedure was followed to select the subjects. The socio-economic information including name, address and age of the randomly selected individual were collected from the voter identity card. This study was approved by the relevant Ethics Committee.

All anthropometric measurements were made by one investigator (BK) using standard anthropometric technique (Lohman et al. 1988). Measurements were recorded to the nearest 0.1 cm.

Data were analyzed using the Statistical Package for Social Sciences (SPSS, Version 16). Sex differences were studied using the t-test. Multiple regression analyses were performed to generate stature predictive equations using age, weight and knee height as independent variables.

We formed three models of regression method for the prediction of stature using the following parameters: knee height, age and weight as follows:

$$\text{Stature (m)} = a^i + b^1 * \text{(knee height in cm)} \quad (1)$$

$$\text{Stature (m)} = a^i + b^1 * \text{(knee height in cm)} + b^2 * \text{(Age in years)} \quad (2)$$

$$\text{Stature (m)} = a^i + b^1 * \text{(knee height in cm)} + b^2 * \text{(Age in years)} + b^3 * \text{(weight in kg)} \quad (3)$$

Stature was the dependent variable and independent variables were knee height, age and weight. Thus, a^i was the intercept, and b^1, b^2, b^3 represented the regression coefficients (slopes) of knee height, age, weight and sex, respectively. The R^2 which is the coefficient of determination is interpreted as the proportion of the total variation in height accounted for by factors (factors "explains" R^2 of the variability of stature). $ICC_{2,1}$ intraclass correlation coefficient two-way random effect model (absolute agreement definition) was utilized to determine the degree of agreement between means.

Results

The characteristics of the subjects are presented in Table 1. Mean age of males (64.5±9.65) and females (62.35±7.93) were similar. There was a significant sex difference in mean height (men=1.61meter, SD=0.05; women=1.46 meter, SD=0.06). Similarly, significant sex differences existed in mean height and weight.

Taller men and women had higher knee height. The Pearson's correlation coefficient (r) was 0.724 ($p<0.001$) for men and 0.534 ($p<0.001$) for women. In both cases, the Pearson's correlation coefficient (r) results were significantly ($p<0.05$) negative (men=–0.183) and women (–0.315). The Pearson's correlation coefficient (r) was 0.479 ($p<0.001$) for men and r=0.322 ($p<0.05$ respectively) for women.

Multi linear regression model derived in our study are shown in Table 2. In men, proxy stature could be predicted by three models using knee height, age and weight; in all equations. In all cases F-values were statistically significant ($p<0.0001$). In men R^2 for knee height was 0.524 (t=8.133, $p<0.001$), for knee height and age R^2 was 0.557 (knee height: t=8.352, $p<0.001$; age:

Table 1. Characteristics of the subjects.

Variable	Males (n=62)		Females (n=52)		*p*-value
	Mean±SD	Range	Mean±SD	Range	
Age (years)	64.50±9.65	55.0–110.0	62.35±7.93	55.0–84.0	NS
Height (m)	1.61±0.95	1.48–1.77	1.46±0.06	1.32–1.64	<.001
Weight (kg)	54.40±10.24	35.0–85.0	43.83±7.53	29.0–61.0	<.001
Knee height (cm)	50.49±2.54	44.0–57.5	45.20±2.33	40.4–49.7	<.001

$p<.001$ (unpaired Student's *t* test) between men and women in each physical variable.
NS = Not Significant.

t=–2.088, $p<0.05$). In regression model with knee height, age and weight, R^2 was 0.664 (knee height: t=8.630, p<0.001; age: t=–1.225, n.s. and weight: t=4.308, $p<0.001$). In women for knee height R^2 was 0.285 (t=4.469, $p<0.001$). For knee height and age, R^2 was 0.386 (knee height: t=4.781, $p<0.001$; age: t=–2.828, $p<0.01$). In regression model with knee height, age and weight, R2 was 0.412 (knee height: t=4.196, $p<0.001$; age: t=–2.809, $p<0.01$ and weight: t=1.469, n.s.).

Following equations were obtained:

Equations	R^2
Y = 82.52 + (1.56xKH) for men	0.52
Y = 88.75 + (1.28xKH) for women	0.29
Y = 89.20 + (1.56xKH) – (0.10xage) for men	0.56
Y = 102.48 + (1.30xKH) – (0.22xage) for women	0.39
Y = 82.33 + (1.44xKH) – (0.06xage) + (0.18xWt) for men	0.66
Y = 102.10 + (1.16xKH) – (0.22xage) + (0.13xWt) for women	0.41

Figures 1 (a), (b) and (c) display the Bland-Altman diagrams for the three methods in men. The mean agreement (upper-lower limits) were 0.0001 (0.0743 to –0.0741); 0.0002 (–0.0071) and –0.0000 (±0.062), respectively. The best agreement was found in the third model (knee height + age + weight). Fisher Z-transformation results revealed that z values between the first and second models was 2.0923 while that between the second and third models was 1.5636. It was 1.4124 between the first and third models. Figures 2 (a), (b) and (c) display the Bland-Altman diagrams for the three methods in women. The mean agreement (upper-lower limits) were –0.0001 (±0.092); 0.0001 (0.0086 to – 0.085) and –0.0005 (0.0831 to – 0.0841), respectively. As with men, the best agreement was found in the third model (knee height + age + weight). Fisher Z-transformation results revealed that z values between the first and second models was 1.2933 while that between the second and third models was 2.0439. It was 1.1946 between the first and third models.

In the present study, knee height measurement successfully estimated stature in both sexes. There are many equations for estimating stature from knee height, which have been reported by Chumlea et al. 1985; Roubenoff and Wilson 1993; Haboubi et al. 1990; Han and Lean 1996 etc. from various countries (Table 3). The reliability of height measurements (both estimated and actual) has been confirmed by calculating the

Table 2. Regression Models.

Model		Knee Height		Age		Weight		
	Intercept	Beta	SE	Beta	SE	Beta	SE	R^2
1. Only knee height	82.52	1.562[1]	0.192					0.52
2. Knee height + Age	89.20	1.561[1]	0.187	–0.103[3]	0.049			0.56
3. Knee height + Age + Weight	82.33	1.438[1]	0.167	–0.055[NS]	0.045	0.184[1]	0.043	0.66
4. Only knee height	88.75	1.277[1]	0.286					0.29
5. Knee height + Age	102.48	1.279[1]	0.268	–0.222[2]	0.079			0.39
6. Knee height + Age + Weight	102.10	1.161[1]	0.277	–0.218[2]	0.078	0.126[NS]	0.086	0.41

SE – Standard Error; NS – Not Significant. The first three models (1,2 and 3) refer to men while the last three models (4,5 and 6) refer to women.
[1]$p\leq.001$; [2]$p\leq.01$; [3]$p\leq.05$.

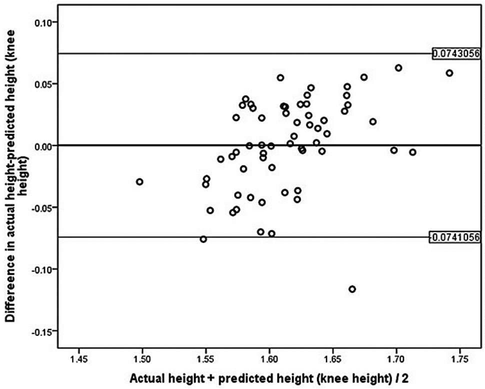


Fig. 1(a) Bland-Altman plot for men (knee height).

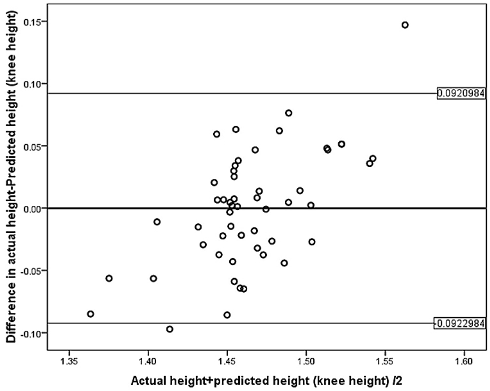


Fig. 2(a) Bland-Altman plot for women (knee height).

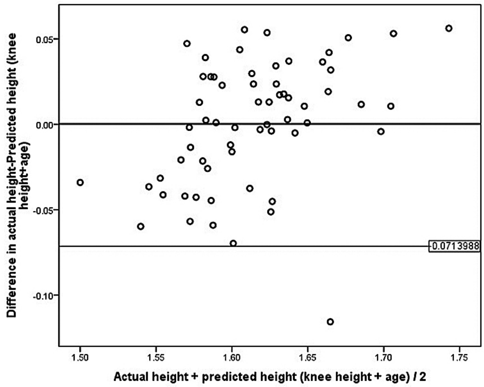


Fig. 1(b) Bland-Altman plot for men (knee height and age).

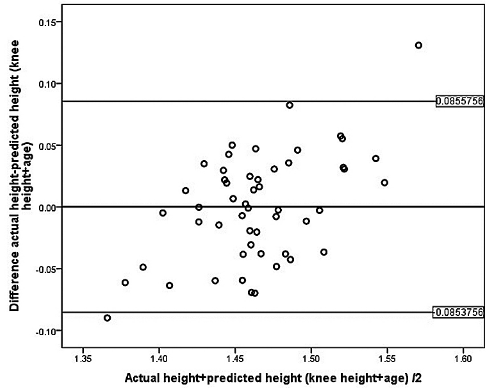


Fig. 2(b) Bland-Altman plot for women (knee height and age).

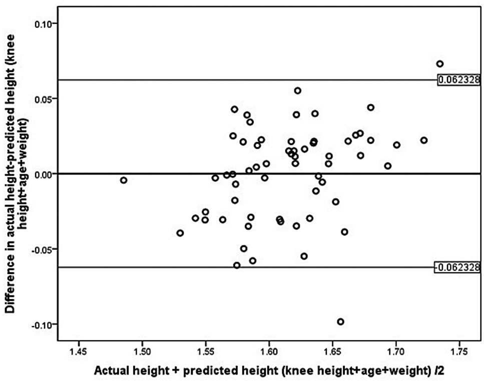


Fig. 1(c) Bland-Altman plot for men (knee height, age and weight).

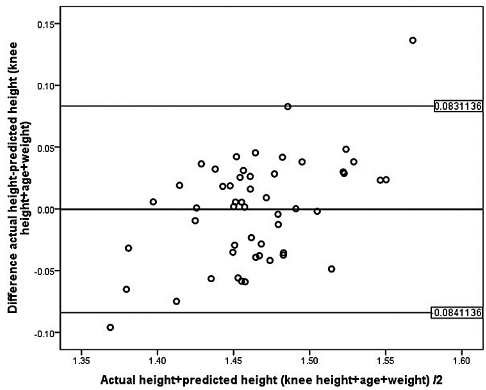


Fig. 2(c) Bland-Altman plot for women (knee height, age and weight).

Table 3. Regression equations developed to estimate the predicted body height based on knee height in various elderly populations.

Reference (year of publication)	Subjects	Sample size	Age (years)	Proxy indicator of body height	Equations	R^2
Present study	West Bengal, India	Men=62 Women=52	55–110	KH, Age	Y=89.20+(1.561xKH)–(0.103xAge) (M)	0.56
					Y=102.48+(1.28xKH)–(0.22xAge) (W)	0.39
				KH	Y=82.52+(1.562xKH) (M)	0.52
					Y=88.75+(1.277xKH) (W)	0.29
				KH,Age,Wt	Y=82.33+(1.438xKH)–(0.055xAge)+(0.184xWt) (M)	0.66
					Y=102.1+(1.161xKH)–(0.218xAge)+(0.126xWt) (W)	0.41
Chumlea et al. (1985)	American	Men=106 Women=130	65–104	KH, Age	Y=60.65+(2.04xKH) (M)	–
					Y=84.88+(1.83xKH)–(0.24xAge) (W)	0.85
Chumlea and Guo (1992)	White and Black	–	–	KH, Age	Y= 59.01+(2.08xKH) (M)	–
					Y=75.00+(1.91xKH)–(0.17xAge) (W)	–
Li et al. (2000)	Chinese	Men=89 Women=164	62–88 64–97	KH	Y= 51.16+(2.24xKH) (M)	0.63
					Y=46.11+(2.46xKH)–(0.12xAge) (W)	0.67
Bermudez et al. (1999)	Hispanic (America)	Men=128 Women=166	60–92	KH	Y=70.28+(1.81xKH) (M)	0.72
					Y=59.29+(1.92xKH) (W)	0.71
				KH, Age	Y=76.02+(1.79xKH)–(0.07xAge) (M)	0.72
					Y=68.68+(1.90xKH)–(0.123xAge) (W)	0.73
	Puerto-Rican	Men=81 Women=87	60–92	KH	Y=53.42+(2.13xKH) (M)	0.77
					Y=55.98+(1.99xKH) (W)	0.68
				KH, Age	Y=52.95+(2.13xKH)+(0.006xAge) (M)	0.77
					Y=66.80+(1.94xKH)–(0.123xAge) (W)	0.70

Hwang et al. (2009)	Korea	Men=2532 Women=2531	20-69	KH, Age	Y=74.63–(0.09xAge)+(1.95xKH) (M) Y=70.87–(0.14xage)+(1.96xKH) (W postmenop.)	0.72 0.69
	San Paulo, Brazil	Men=245 Women=505	Mean 73.3 M 72.1 W	KH, Age	Y=67.2+(1.96xKH)–(0.08xAge) (M) Y=69.87+(1.85xKH)–(0.11xAge) (W)	0.68 0.59
Lera et al. (2005)	Santiago, Chile	Men=389 Women=615	Mean 70.6 M 71.3 W	KH, Age	Y=64.88+(2.09xKH)–(0.10xAge) (M) Y=75.17+(1.78xKH)–(0.10xAge) (W)	0.70 0.54
	Mexico city	Men=388 Women=607	Mean 69.5 M 70.0 W	KH, Age	Y=63.88+(1.99xKH)–(0.06xAge) (M) Y=73.09+(1.87xKH)–(0.19xAge) (W)	0.67 0.59
Knous and Arisawa (2002)	Joetsu city, Japan	Men=40 Women=39	Mean 69.5 M 70.0 W	KH, Age	Y=71.16+(2.61xKH)–(0.56xAge) (M) Y=64.19+(2.02xKH)–(0.04xAge) (W)	0.84 0.73
Donini et al. (2002)	Italian	Men=113 Women=172	65-74 M 65-75 W	KH, Age	Y=99.67+(1.58xKH)–(0.23xAge) (M) Y=94.87+(1.58xKH)–(0.23xAge) (W)	0.75 0.75
Mathew et al. (2014)	Punjab, India	184	Mean 72.79 M 70.41 W	KH, Age	Y=48.732+(2.274xKH)–(0.063xAge) (M) Y=74.503+(1.728xKH)–(0.145xAge) (W)	

KH – Knee Height in cm; M – Men; W – Women; Age in years; Y= predictive height in cm; R^2= multiple correlation coefficient of determination.

Table 4. Estimation of the predicted body height based on knee height: intra-class correlation coefficient (ICC) values obtained in the present and comparative studies.

	Mean±SD (in meter)	Mean Δ	% Δ mean (range)	*p*-value	ICC (95% CI)
			Present study		
Men	1.6137±.0409	.0002	–.0355	NS	0.83 (0.73–0.90)
Women	1.4644±.0345	.0001	–.0791	NS	0.72 (0.51–0.84)
			Present study		
Men	1.6143±.0400	–.0004	–.0780	NS	0.82 (0.70–0.89)
Women	1.4647±.0297	–.0001	–.1085	NS	0.62 (0.33–0.78)
			Present study		
Men	1.6139±.0447	0	–.0383	NS	0.89 (0.82–0.93)
Women	1.4650±.0357	–.0005	–.1139	NS	0.74 (0.55–0.85)
			Chumlea et al. (1985)		
Men	1.6365±.0529	–.0225	–1.4339	<.0001	0.80 (0.57–0.90)
Women	1.5263±.0466	–.0617	–4.2881	<.0001	0.52 (–0.22–0.80)
			Chumlea and Guo (1992)		
Men	1.6403±.0529	–.0263	–1.6678	<.0001	0.79 (0.49–0.90)
Women	1.5073±.0464	–.0427	–2.9907	<.0001	0.61 (0.00–0.83)
			Li et al. (2000)		
Men	1.6425±.0569	–.0286	–1.8034	<.0001	0.78 (0.45–0.90)
Women	1.4981±.0580	–.0336	–2.3508	<.0001	0.66 (0.28–0.83)
			Bermudez et al.(1999)		
Men	1.6166±.0560	–.0027	–.2129	NS	0.83 (0.73–0.90)
Women	1.4607±.0447	.0039	.1847	NS	0.69 (0.46–0.82)
			Bermudez et al.(1999)		
Men	1.6188±.0461	–.0049	–.3446	NS	0.85 (0.74–0.91)
Women	1.4688±.0453	–.0043	–.3671	NS	0.73 (0.54–0.85)
			Bermudez et al.(1999)		
Men	1.6096±.0542	.0043	.2356	NS	0.84 (0.74–0.90)
Women	1.4592±.0463	.0053	.2870	NS	0.69 (0.46–0.82)

intra-class correlation coefficient (ICC) which is presented in table 4.

In our present study, in case of estimated stature calculated from three equation model (Knee height – 1, knee height + age – 2, knee height + age + weight – 3), there was no significant difference between actual measured stature and predicted stature in both older men [t value=0.052(1), –0.082(2), 0.002(3)] and women[t value=0.018(1), –0.018(2), –0.077(3)]. The reliability of predicted height measurement, knee height with age and weight (equation number – 3) was the most predictable equation [mean differences=0.0000 (–0.0383%)] for measuring proxy stature among Bengalee men (ICC value=0.89, 95% CI upper level 0.93 and lower level 0.82). In case of women, the reliability of predicted height measurement of knee height with age and weight (equation number – 3) was the strongest predictable equation [mean differences was –0.0005(–0.1139%)]. The respective results were:

Table 4. cont.

	Mean±SD (in meter)	Mean Δ	% Δ mean (range)	*p*-value	ICC (95% CI)
		Bermudez et al. (1999)			
Men	1.6088±.0542	.0052	.2869	NS	0.83 (0.73–0.90)
Women	1.4681±.0462	–.0036	–.3165	NS	0.74 (0.54–0.85)
		Hwang et al. (2009)			
Men	1.6728±.0504	–.0588	–3.6864	<.0001	0.62 (–0.22–0.87)
Women	1.5073±.0469	–.0427	–2.9911	<.0001	0.61 (0.00–0.82)
		Lera et al. (2005)			
Men	1.6100±.0505	.0040	.2092	NS	0.85 (0.75–0.91)
Women	1.4662±.0439	–.0017	–.1922	NS	0.73 (0.53–0.85)
		Lera et al. (2005)			
Men	1.6395±.0541	–.0256	–1.6172	<.0001	0.81 (0.52–0.91)
Women	1.4938±.0422	–.0293	–2.0821	<.0001	0.65 (0.27–0.82)
		Lera et al. (2005)			
Men	1.6048±.0509	.0091	.5293	NS	0.84 (0.74–0.91)
Women	1.4576±.0460	.0069	.4040	NS	0.75 (0.56–0.86)
		Knous and Arisawa (2002)			
Men	1.6682±.0857	–.0542	–3.3575	<.0001	0.65 (0.10–0.84)
Women	1.5299±.0471	–.0654	–4.5452	<.0001	0.47 (–0.22–0.76)
		Donini et al. (2002)			
Men	1.6461±.0459	–.0321	–2.0385	<.0001	0.75 (0.25–0.89)
Women	1.5194±.0410	–.0549	–3.8279	<.0001	0.53 (–0.20–0.80)
		Mathew et al. (2014)			
Men	1.6142±.0394	–.0002	–.0673	<.0001	0.83 (0.71–0.90)
Women	1.6169±.0355	–.1524	–10.5053	<.0001	0.16 (–0.07–0.48)
		Actual Measured Height			
Men	1.6139±.0549				
Women	1.4644±.0556				

ICC value=0.74, 95% CI upper level 0.85 and lower level 0.55).

Discussion

Our findings suggest that there is a need for population specific predictive formulae. When we used equations based on other populations to estimate stature in our subjects, the lowest underestimation was –0.0588m for men, –0.1524m for women and highest observation was 0.0191m for men and 0.0289m for women. In contrast, the new population-specific formula for men (knee height, age and weight) that we devised yielded a mean overestimation of 0.0000 m, and this difference from actual height was not statistically significant. We also found that another Indian population–specific equation derived by Mathew et al. (2014) showed significance difference for stature estimation form our subjects, both in men as well as women. This formula resulted in mean deviation for men (–0.0002 m; –0.0673%) as well as women (–0.1524m; –10.5053%). Although the equation given by Mathew et al. (2014) using knee height and age was not as accurate as our new formulae, it outperformed all other population-based formulae we tested.

Over the years, various authors' stature formulae have been used for anthropometric and nutritional assessment in world. In our present study we used fifteen formulae for predicted height among our subjects. We found that American (Chumlea et al. 1985), White and Black (Chumlea and Guo 1992), Chinese (Li et al. 2000), Korea (Hwang et al. 2009), Chili (Lera 2005), Japan (Knous 2002) Italian (Donini 2000), Punjab, India (Mathew et al. 2014) population based equation model showed statistically significance difference in estimation from our derived equations. In cases of Hispanic (Bermudez et al. 1999), Puerto Rican (Bermudez et al. 1999), Brazil (Lera 2005), Mexico City (Lera 2005) no significant difference was observed. The differences from Mongoloid populations (China, Japan, Korea) and Caucasoid (Italy) and Hispanic and Puerto Rican (America) could be due to the fact that the ratios of various body parts to stature differ from one population to another because of ethnic differences, secular trends (Meadows and Jantz 1995) and even environmental factors, such as socioeconomic and nutritional status also influence body proportions (Malina 1991; Duyar 1997).

Conclusion

In conclusion, our study demonstrated that the Chumlea equation (American) and Chumlea and Guo equation (White and Black population), which are currently used for the assessment of nutritional status and anthropometric variance for older men and women in world, are not accurate for estimation among older Bengalees. We stress that our formulae could be used for estimating stature based on knee height among older Bengalee individuals. Since India is a land of vast ethnic heterogeneity, similar studies should be undertaken among other Indian populations to derive ethnic-specific equations.

Acknowledgements

Department of Anthropology, Vidyasagar University, is acknowledged for ethical and instrumental support for the present research.

Authors' contributions

BK and KB conceptualized and designed the paper, performed present work; BK prepared the manuscript and KB edited the manuscript. Both authors were involved in drafting the manuscript and approved the final manuscript.

Conflict of interest

The authors declare that there are no conflicts of interest.

Corresponding author

Kaushik Bose, Department of Anthropology, Vidyasagar University, Midnapore – 721102, West Bengal, India
e-mail address: kaushikbose@cantab.net

References

Adams JM, White M. 2004. Biological aging. Eur J Pub Health 14:331–34.

Bermudez OI, Becker EK, Tucker KL. 1999. Development of sex-specific equations for estimating stature of frail elderly Hispanic living in the North Eastern United States. Am J Clin Nutr 69:992–98.

Cereda E, Bertoli S, Battezzati A. 2010. Height prediction formula for middle-aged (30–55y) Caucasians. Nutrition 26(11–12):1075–81.

Chumlea W, Roche A, Steinbaugh M. 1985. Estimating stature from knee height for persons 60–90 years of age. J Am Geriatr Soc33:116–120. [PubMed: 3968366]

Chumlea WC, Guo S.1992. Equations for predicting stature in white and black elderly individuals. J Gerontol l47(6):M197–203.

Chumlea WC, Guo SS, Steinbaugh ML.1994. Prediction of stature from kneeheight for black and whites adult and children with application to mobility-impaired or handicapped persons. J Am Diet Assoc 94:1385–91.

Cockram DB, Baumgartner RN. 1990. Evaluation of accuracy and reliability of calipers for measuring recumbent knee height in elderly people. Am J Clin Nutr 52:397–400.

Donini LM, de Felice MR, de Bernardini L, Ferrari G, Rosano A, de Medici M, Cannella C. 2000.Prediction of stature in the Italian elderly. J Nutrition, Health and Aging 4:72–6.

Forster S, Gariballa S. 2005. Age as a determinant of nutritional status: a cross sectional study. Nutr J 4:28.

Ghosh A, Bose K, Das Chaudhuri A.B. 2001. Age and sex variation in adiposity and central fat distribution among elderly Bengalee Hindus of Calcutta, India.– Ann Hum Biol 28:616–23.

Grinker JA, Tucker KL, Vokonas PS, Rush D. 2000. Changes in patterns of fatness in adult men in relation to serum indices of cardiovascular risk: the Normative Aging Study. Int J Obes Relat Metab Disord 24:1369–78.

Haboubi NY, Hudson PR, Pathy MS. 1990. Measurement of height in the elderly. J Am Geriatr Soc 38:1008–10. [PubMed: 2212434]

Han TS, Lean ME. 1996. Lower leg length as an index of stature in adults. Int J Obes Relat Metab Disord 20(1):21–7.

Knous BL, Arisawa M. 2002. Estimation of height in elderly Japanese using region-specific knee height equations. Am J Hum Biol 14:300–7.

Lera L, Luis Santos J, Garcia C, Arroyo P, Albala C. 2005. Predictive equations for stature in the elderly: A study in three Latin American cities. Ann Hum Biol 32:773–81.

Lohman TG, Roche AF, Martorell R. 1988. Anthropometric Standarization Reference Mannul. Chicago: Human Kinetics Books.

Mathew AC, Sampath S, Das D, Vijayakumar M, Ramakrishnan N, Ravishankar SL. 2014. Screening for malnutrition in the elderly population: a tool for estimating height from knee height. Asia Pac J Health Sci 1(4S):79–83.

Roubenoff R, Wilson PWF. 1993. Advantage of knee height over height as an index of stature in expression of body composition in adults. Am J Clin Nutr 57:609–13. [PubMed: 8480674]

Shetty PS, James WPT.1994. Body mass index. A measure of chronic deficiency in adults. FAO Food and Nutrition. Paper 56. Rome, Italy.

Villareal DT, Apovian CM, Kushner RF, Klein S. 2005. American Society for Nutrition; NAASO The Obesity Society: Obesity in older adults: technical review and position statement of the American Society for Nutrition and NAASO, The Obesity Society. Am J Clin Nutr 82:923–34.

Wasler M. 1987. Creatinine excretion as a measure of protein nutrition in adults of varying age. J Parenter Enteral Nutr11:73S–78S.