Human Biology Review (ISSN 2277 4424) 5 (1) 2016
Original Scientific Paper (Kuiti and Bose pp 34-52)
Revised and Accepted on October 24, 2015
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Predicted weight with different body segments and its use in nutritional assessment among older Bengalees of Purba Medinipur District, West Bengal

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Citation: Kuiti B and Bose K. 2016. Predicted weight with different body segments and its use in nutritional assessment among older Bengalees of Purba Medinipur District, West Bengal. Human Biology Review, 5 (1), 34-52.

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ABSTRACT

The aim of this study was to assess the applicability of alternative versus direct anthropometric measurements for evaluating of nutritional status among older Bengalees. We conducted a cross-sectional survey in a coastal area of Purba Medinipur District, West Bengal. We measured weight, height, knee height, waist, hip and mid-upper-arm circumferences of 114 older individuals. Correlations between the different methods for calculating body mass index (BMI; using direct or alternative measurements) were evaluated by Passing-Bablok regression method; agreement in the allocation of participants to the same risk category was assessed by squared weighted kappa statistic and indicators of internal relative validity. Using the Passing-Bablok regression method, the best agreement was found in fourth model (height + WC + HC) for men and in women, the best agreement was found in the second model (height + MUAC). The agreement between this classification and that obtained using BMI calculated by alternative measurements was "fair-good."

When it is not possible to determine nutritional status risk category by using weight, we suggest that for older Bengalees, it may be appropriate to use the alternative measurements to predict weight and BMI.

Key words: Predicted Weight, Predicted BMI, Bengalees.

INTRODUCTION:

Most nutritional assessment tools rely on body mass index (BMI) and require accurate weight and height measurements. Among researchers and doctors of hospitals, nursing homes and rural primary health centers, these measurements are sometimes difficult to obtain. Thus often there is a need to estimate body weight of older people. The nature of difficulty depends on immobility, trauma, burns, and non ambulatory, emergency and critically ill patients and the lack of availability of measuring scales or intravascular lines that may easily become dislodged. In such cases, a special instrument is required for indirect weight measurement in these older people.

Various indirect methods have been developed to estimate weight in previous studies (Chumlea 1988, Donini 1998, Jung 2004, Miyatake 2007, Crandall 2009, Lin 2009, Fawzy 2010 and Bernal-Orozco 2010). These investigations utilized various body segments to derive ethnic-specific predictive equations in different ethnic groups worldwide. The different body segment parameters used in these formulae could be divided into three groups: circumferences, skin fold thickness and length measurements. Some studies have utilized mid-upper arm circumference (MUAC) (Lin 2009, Crandall 2009, Bernal-Orozco 2010, Chumlea 1988, Donini 1998 and Jung 2004), calf circumference (CC) (Bernal-Orozco 2010, Chumlea 1988 and Donini 1998) while others have used waist circumference) WC (Miyatake et al 2007) and hip circumference (HC) (Lorenz et al, 2007). Others have used subscapular skinfold (SST) (Chumlea 1988 and Donini 1998) and triceps skin fold thickness (TSF) (Bernal-Orozco 2010) as proposed predictive covariates. Height (Miyatake et al, 2007), knee height (KH) (Lin 2009, Bernal-Orozco 2010, Chumlea 1988, Donini 1998 and Jung 2004) were length measurement parameters used in body weight prediction in various formulae in some previous studies. All of proposed equations were sex-specific. The importance of these studies are that body weight and BMI are important measures for the evaluation nutritional status.

Hitherto, ethnic-specific equations for the prediction of weight among Bengalees are lacking. In view of this, in our present study, we attempted to derive weight-predicted equations using age, height, knee height (KH), waist (WC), hip (HC) and mid upper-arm circumference (MUAC) and also tried to assess the applicability of alternative versus direct anthropometric measurements for evaluating the nutritional status assessment among elderly Bengalees of Purba Medinipur, West Bengal. To the best of our knowledge, this is the first study which reports ethnic-specific equations for the prediction of weight among older Bengalees.

MATERIAL AND METHODS*:*

The cut-off point of 55 years was taken in the 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 minimum number of subjects required was calculated following the standard sample size estimation method procedures (Lwanga and Lemeshow, 1991). 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). Standard precautions for taking height among older individuals were undertaken following Ghose et al. (2001). Measurements were recorded to the nearest 0.1 cm. Classification of nutritional status was based on the WHO Asia-Pacific guidelines (2004).

Data were analyzed using the Statistical Package for Social Sciences (SPSS, Version 16) and Med Calc (Version 14). Sex differences were studied using the t-test. Multiple regression analyses were performed to generate weight predictive equations using age, height, knee height, waist (WC), hip (HC) and mid-upper arm circumference (MUAC) as independent variables.

We formed four models of regression method for the prediction of stature using the following parameters: KH, age, height, WC, HC and MUAC as follows:

Weight (kg) = $a^i + b^1$* (knee height in cm) +b^2*(MUAC in cm)………………. (1)

Weight (kg) = $a^i + b^1$* (height in cm) +b^2*(MUAC in cm)……………………. (2)

Weight (kg)= a^i +b^1*(knee height in cm)+b^2*(Age in years)+b^3*(MUAC in cm) (3)

Weight (kg)= a^i + b^1*(height in cm) +b^2*(WC in cm) +b^3*(HC in cm)……… (4)

Weight was the dependent variable and independent variables were knee height, age, height, WC, HC and MUAC. Thus, a^i was the intercept, and b^1, b^2, b^3 represented the regression coefficients (slopes) of knee height, age, height, WC, HC and MUAC respectively. The R^2, which is the coefficient of determination is interpreted as the proportion of the total variation in weight accounted for by factors (factors "explains" R^2 of the variability of weight).

Passing Bablok Regression (Passing et al. 1983) calculates a regression equation ($y = a + bx$) including 95% CIs for the constant (*a*) and proportional bias (*b*). This procedure requires continuous variables and a linear relationship between the 2 methods. We tested the assumption of linearity by using the cumulative sum linearity test (cusum linearity test). The cusum test is used to assess whether residuals are randomly scattered above and below the regression line and do not exhibit any distinct trend. A p value <0.05 indicates a significant deviation from linearity. Agreement in the allocation of participants to the same risk category was assessed by squared weighted kappa statistic and indicators of internal relative validity.

RESULTS:

The characteristics of the subjects are presented in *Table 1*. Mean age of males (64.5 years ± 9.65) and females (62.35 years ± 7.93) were similar. There was a significant sex difference in mean height (men =161.39 cm, SD = 5.49; women = 146.45cm, SD = 5.56). Similarly, significant sex difference existed in mean weight (men =54.40 kg, SD = 10.24; women = 43.83kg, SD = 7.53).

The Pearson's correlation coefficient (r) of weight with height with weight was 0.479 (p < 0.001) in men and 0.322 (p < 0.05) in women. In the correlation between weight and MUAC, r was significantly (p < 0.001) positive in both sexes (men = 0.761) and women (0.853). In the relation of weight with WC and HC, r values were 0.904 and 0.915 respectively (p<0.001) for men. For women, these values were 0.716 and 0.668, respectively (p<0.001. Correlation between weight and knee height, result was not significant for men. In women it was significant, r = 0.292 (p<0.05).

Multi linear regression model derived in our study are shown in *Table 2*. In men, proxy weight could be predicted by four models using knee height, age, and height, MUAC, HC and WC in all equations. In all cases F-values were statistically significant (p < 0.0001). In men R^2 for knee height and MUAC was 0.593 (knee height t=1.377, n.s and MUAC = 9.045, p<0.001), for height and MUAC, R^2 was 0.653 (height: t = 3.540, p < 0.05; MUAC: t = 8.496, p<0.001). In regression model with knee height, age and MUAC, R^2 was 0.593 (knee height: t = 1.366, n.s; age: t = -0.049, n.s and MUAC: t = 8.472, p<0.001). In the last regression model with height, WC and HC, R^2 was 0.902 (height: t = 1.974, n.s; WC: t = 6.136, p<0.001 and HC: t = 4.899, p<0.001).). In women R^2 for knee height and MUAC was 0.771 (knee height t=3.049, <0.05 and MUAC = 12.101, p<0.001), for height and MUAC, R^2 was 0.763 (height: t = 2.701, p < 0.05; MUAC: t = 11.661, p<0.001). In regression model with knee height, age and MUAC, R^2 was 0.774 (knee height: t = 3.026, <0.05; age: t = 0.789, n.s and MUAC: t = 12.071, p<0.001). In the last regression model with height, WC and HC, R^2 was 0.561 (height: t = 2.153, <0.05; WC: t = 2.840, p<0.05 and HC: t = 0.579, n.s).

Figures 1 (a), (b), (c) and (d) display the Passing-Bablok regression analyses illustrating the agreement between two methods, the measured weight method and four weight predicted methods in men. The intercepts (slope) were -19.3582 (1.3786); -12.5683 (1.2434); -19.3897 (1.3801) and -2.9806 (1.0572), respectively. The best agreement was found in the fourth model (height + WC + HC). *Figures 2 (a), (b), (c) and (d)* display the Passing-Bablok regression analysis in women. The intercepts (slope) were 0.7039 (1.1399); -6.4113 (1.1310); -6.4585 (1.1373) and -28.7206 (1.6202), respectively. The best agreement was found in the second model (height + MUAC). In all agreement analysis, in both sexes, the cusum test for linear model validity was not significant ($p > 0.05$).

Table 3 outlines the descriptive analysis of height, measured weight and predicted weight of older men and women. The mean (sd) and the quartile values are presented.

Table 4 displays the results of the Kappa analysis for relative risk assessment (nutritional status based on Asia-Pacific BMI cut-off points), demonstrated by inter-rater agreement between measured weight, height, BMI and predicted weight and predicted BMI. The Kappa (95% CI) for men were 0.572 (0.392-0.753); 0.525 (0.338-0.711); 0.572 (0.392-0.753) and 0.687 (0.562-0.847), respectively. All agreement for relative risk analysis represented intermediate to good agreement (0.40-0.75) but the computed BMI by fourth predicted weight model (height + WC + HC) showed "fair-good" agreement with measured weight BMI. In women, the Kappa results were 0.201 (0.023-0.380); 0.640 (0.459-0.822); 0.548 (0.350-0.746) and 0.386 (0.168-0.604), respectively. For relative risk analysis computed BMI by first and fourth predicted weight model showed "poor-agreement" but computed BMI by second model (height + MUAC) showed better "fair-good" agreement than the third model (knee height, age and MUAC).

DISCUSSION:

One of the major limitations of our study is the small sample size. Nevertheless, our findings clearly suggest that there is a need for population specific predictive formulae. When we used equations based on other populations to estimate weight in our subjects, the lowest underestimation was -0.0027 kg for men, -0.0051 kg for women and highest observation was 0.0668 kg for men and 6.4787 kg for women. In contrast, the new population-specific formula for men (height, WC and HC) that we devised yielded a mean overestimation of 0.0668 kg, this difference from actual height was not statistically significant. In women, specific formula for predicted weight (height and MUAC) also devised yielded a mean overestimation of -0.0572 kg.

The results of our study showed that the use of alternative measures for estimating weight and BMI may be useful in predicting the nutritional status of older Bengalees. Thus, similar studies are required among non-older Bengalees as till now no predictive equations (using body segments) for weight and BMI exist. More importantly, since India is a land of vast ethnic heterogeneity similar studies should be undertaken on other populations so as to derive ethnic-specific equations using body segments for predicted BMI. Since linear measurements like height, WC, HC and MUAC are much more easily determined compared to weight, these predictive equations for BMI would have immense health implications with regard to nutritional surveillance, monitoring and intervention programmes. Since a country like India, where the prevalence of undernutrition is very high, particularly among vulnerable groups like tribals, these equations would be of much practical value.

Conclusion:

In conclusion, our study demonstrated that the Lornez equation (Lornez et al., 2007) and Crandall equation (Crandall et al., 2009), which are currently used for the assessment of nutritional status and anthropometric variance for older men and women worldwide, may not be accurate and appropriate for estimation among older Bengalees. We stress that our formulae could be used for estimating weight based on height, MUAC, WC and HC among older Bengalee individuals. However, further studies are needed with a much larger sample size to validate our findings. Moreover, similar studies should be undertaken among other ethnic populations in India to determine ethnic-specific equations. This is of paramount importance since India has immense ethnic variability. These investigations would generate much valuable information which could be utilized for nutritional status assessment and subsequent planning of appropriate ethnic-specific health promotion and intervention programmes.

Acknowledgements:

Department of Anthropology, Vidyasagar University, is acknowledged for support for the present research. The subjects are also thanked for their cooperation.

Authors' contribution:

BK and KB conceptualized and designed the paper, performed *the* 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 declared that there is no conflict of interest.

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Table 1: Characteristics of the Subjects

ANTHROPOMETRIC MEASUREMENT	**Older Men (n=62)**		**Older Women (n=52)**		***'t'* value**
	Mean	S.D	Mean	S.D	
Height (cm)	161.39	5.49	146.45	5.56	14.38*
Weight (Kg)	54.40	10.24	43.83	7.53	6.18*
Age (year)	64.50	9.65	62.35	7.93	1.29^{NS}
MUAC (cm)	24.72	3.18	22.45	2.61	4.10*
Knee Height (cm)	50.49	2.54	45.20	2.33	11.50*
Waist Circumference (cm)	81.96	10.91	78.82	11.95	1.47^{NS}
Hip Circumference (cm)	83.95	6.95	82.22	9.71	1.11^{NS}

*p < .001,

N.S = Not Significant.

Table 2: Regression table

		MUAC		Knee Height		Height		Age		Waist Circumference		Hip Circumference		R^2
	Intercept	Coefficient	S.E	Coefficient	S.E	Coefficient	S.E	Coefficient	S.E	Coefficient	S.E	Coefficient	S.E	
Men (n =62)														
MUAC +K.H	-28.811	2.423^{*}	0.268	$0.462^{n.s}$	0.335									0.593
MUAC + Ht	-84.976	2.187^{*}	0.257			0.529^{**}	0.149							0.653
K.H + MUAC + Age	-28.419	2.419^{*}	0.286	$0.462^{n.s}$	0.338			$-0.005^{n.s}$	0.094					0.593
Ht +W.C +H.C	-68.286					$0.184^{n.s}$	0.093			0.468^{*}	0.076	0.650^{*}	0.133	0.902
Women (n=52)														
MUAC +K.H	-40.627	2.397^{*}	0.198	0.678^{**}	0.222									0.771
MUAC + Ht	-47.112	2.370^{*}	0.203			0.258^{**}	0.095							0.763
K.H + MUAC + Age	-44.108	2.414^{*}	0.200	0.676^{**}	0.223			0.052 n.s	0.066					0.774
Ht +W.C +H.	-33.948					0.283^{**}	0.132			0.365^{**}	0.128	$0.092^{n.s}$	0.159	0.561

C

Ht = height, MUAC = mid-upper arm-circumference, WC = waist circumference, HC = hip circumference and age.
*= <0.001; ** = <0.05; n.s = not significant.

Table 3: Descriptive analysis of Height, Weight and Predicted Weight.

	Older Men (n=62)						Older Women (n=52)					
	Height	Measured Weight	Predicted weight by KH+ MUAC	Predicted weight by MUAC +Ht	Predicted weight by KH+ MUAC +Age	Predicted weight by Ht+ WC+ HC	Height	Measuring Weight	Predicted weight by KH+ MUAC	Predicted weight by MUAC +Ht	Predicted weight by KH+ MUAC +Age	Predicted weight by Ht+ WC+ HC
Mean+S.D	161.39+5.49	54.40 +10.24	54.41+7.89	54.46+8.28	54.38+7.89	54.34+9.72	146.5+5.56	54.40+7.53	54.41+6.61	54.46+6.58	54.38+6.62	54.34+5.64
Quartiles												
25	157.10	47.75	48.39	48.40	48.31	48.42	143.30	40.00	32.36	38.59	38.55	40.22
50	160.60	53.00	53.13	53.59	53.14	53.74	145.80	42.25	37.62	45.15	44.06	43.24
75	164.53	60.50	60.18	60.90	60.13	59.34	149.08	48.63	42.42	48.52	49.34	47.54

Figure 1(a): Passing-Bablok Regression scatter plot for men.

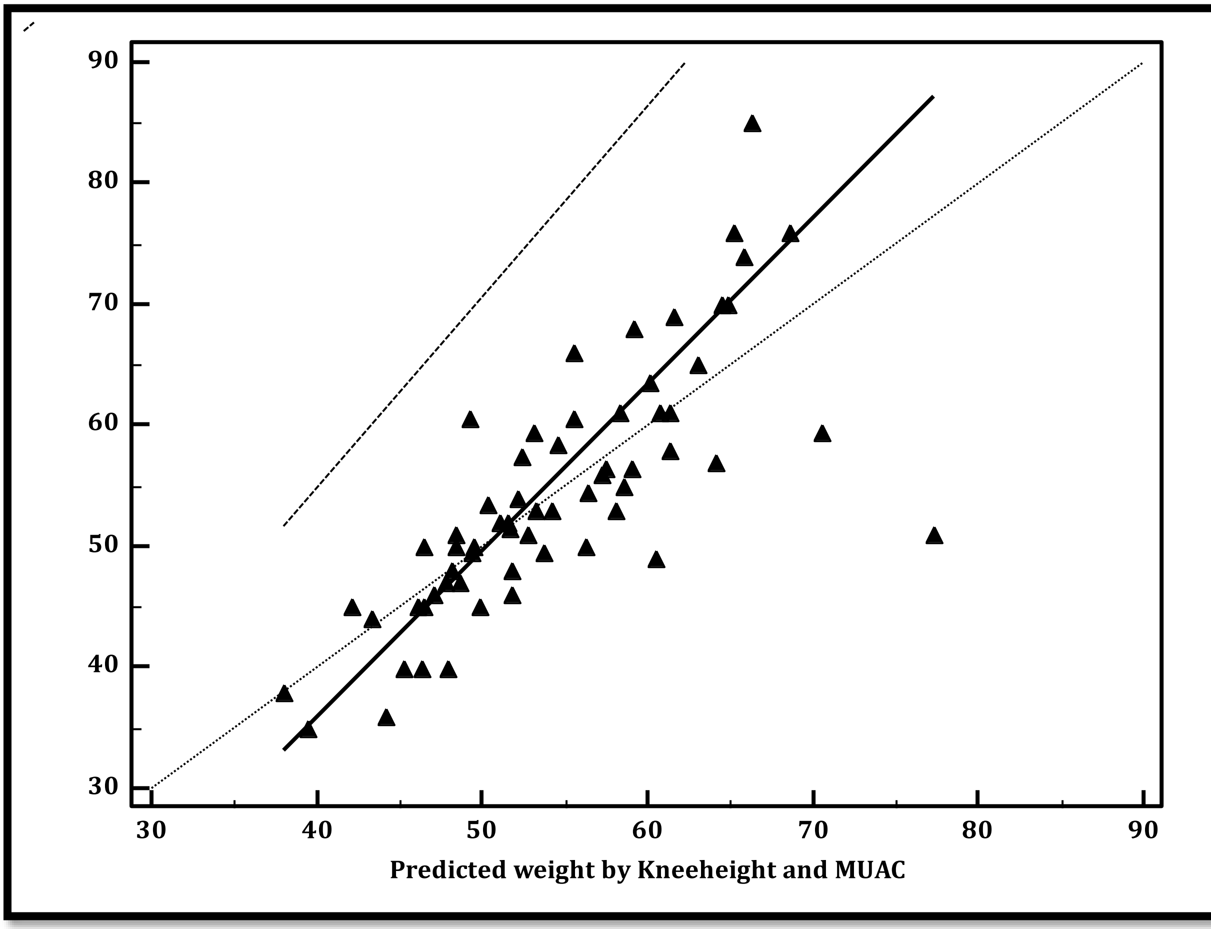

Figure 1(b): Passing-Bablok Regression scatter plot for men.

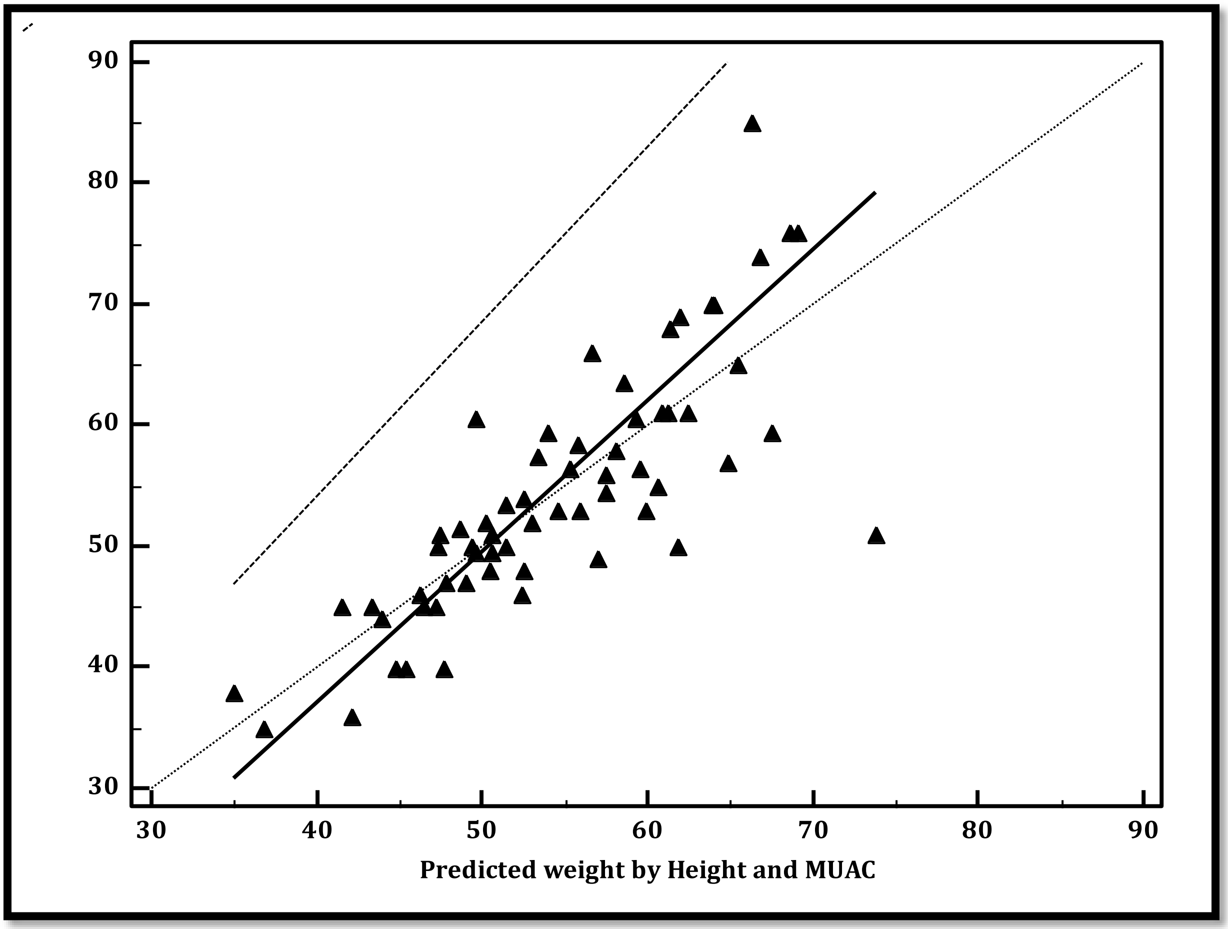

Figure 1(c): Passing-Bablok Regression scatter plot for men.

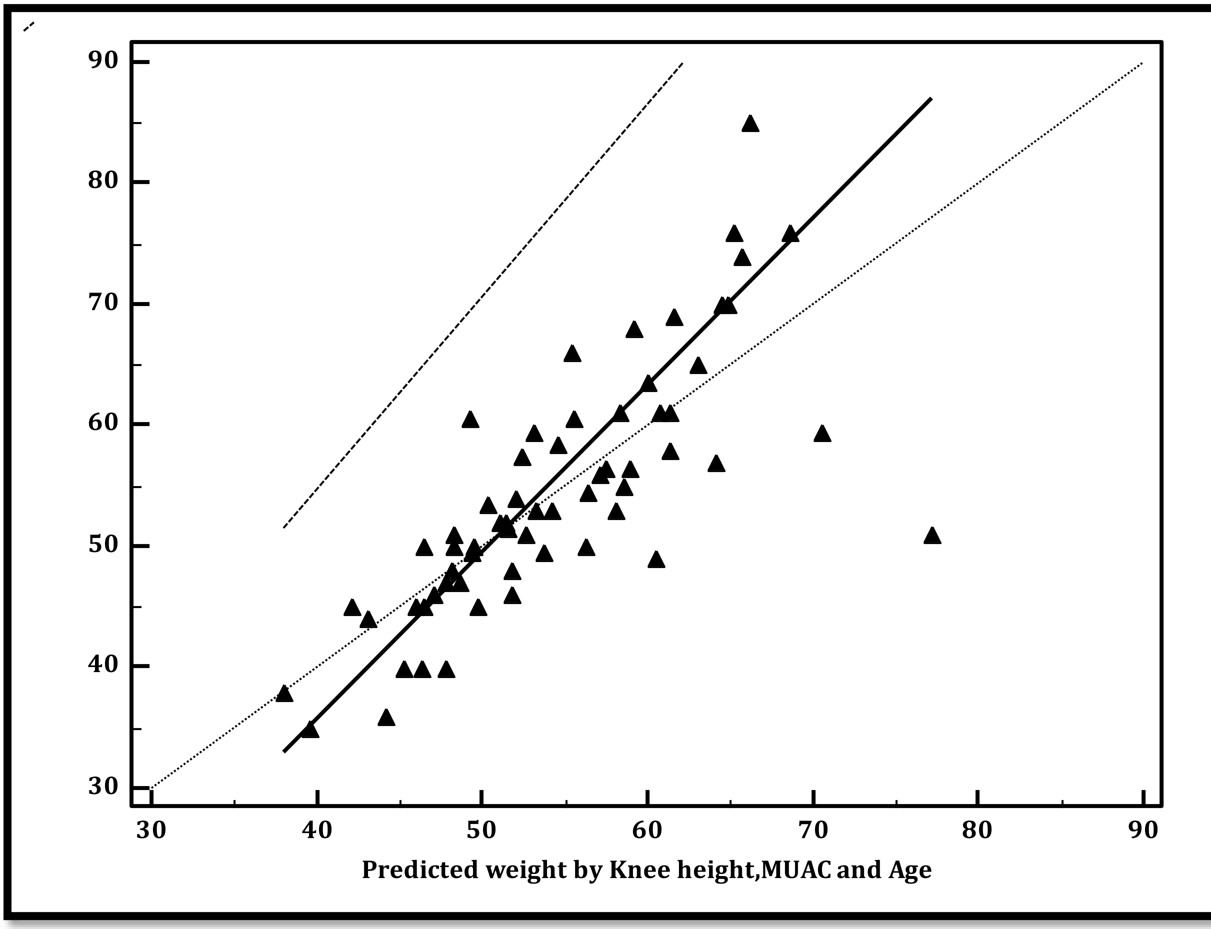

Figure 1(d): Passing-Bablok Regression scatter plot for men.

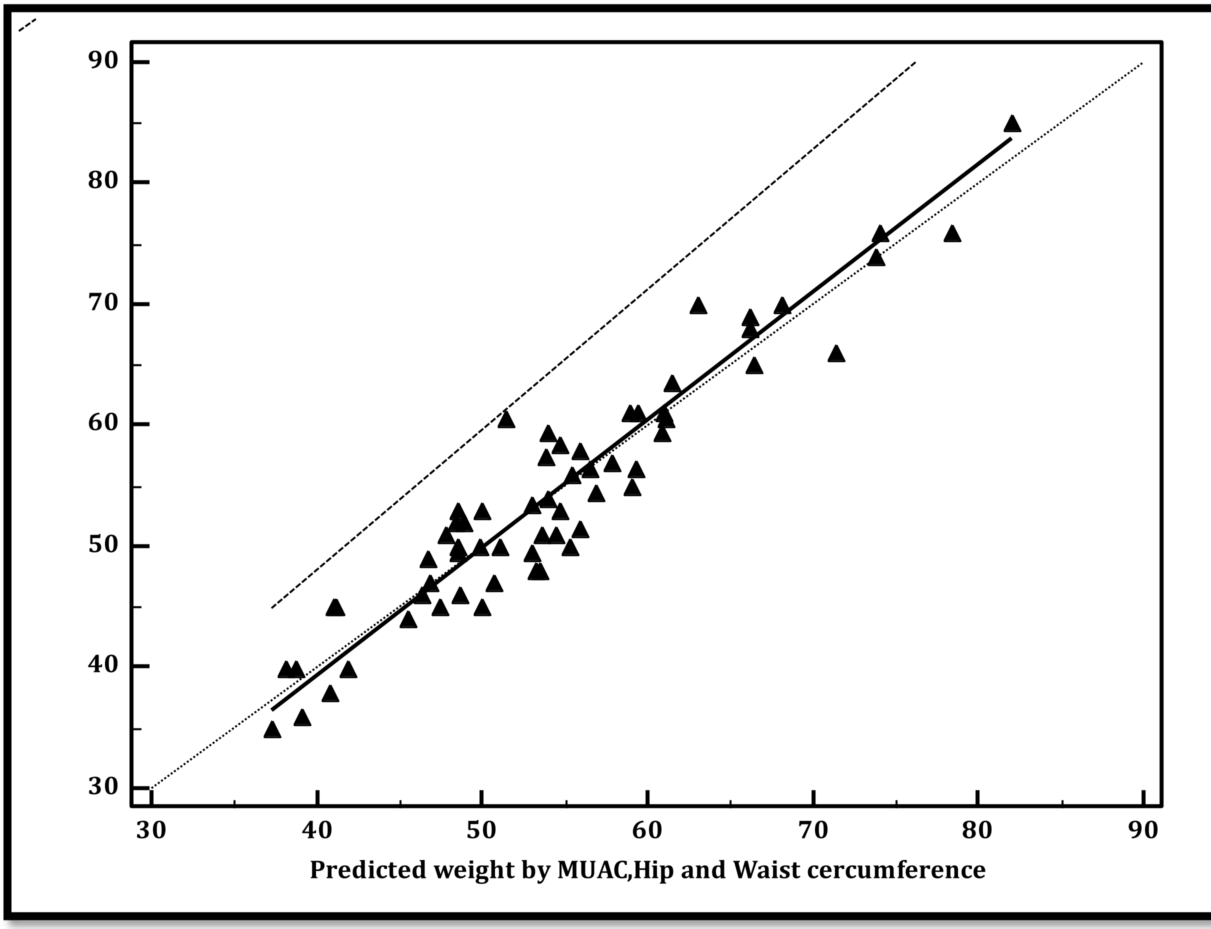

Figure 2(a): Passing-Bablok Regression scatter plot for women.

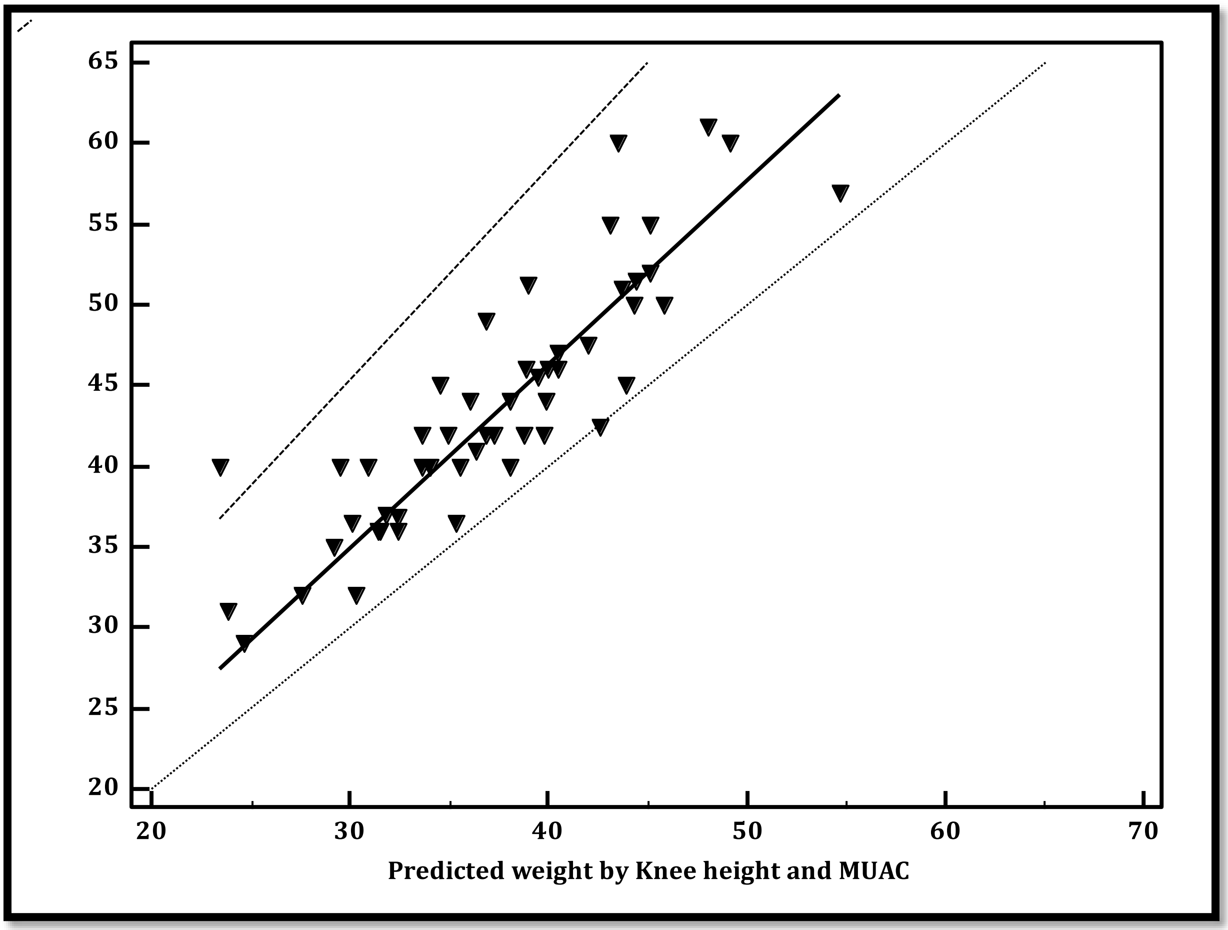

Figure 2(b): Passing-Bablok Regression scatter plot for women.

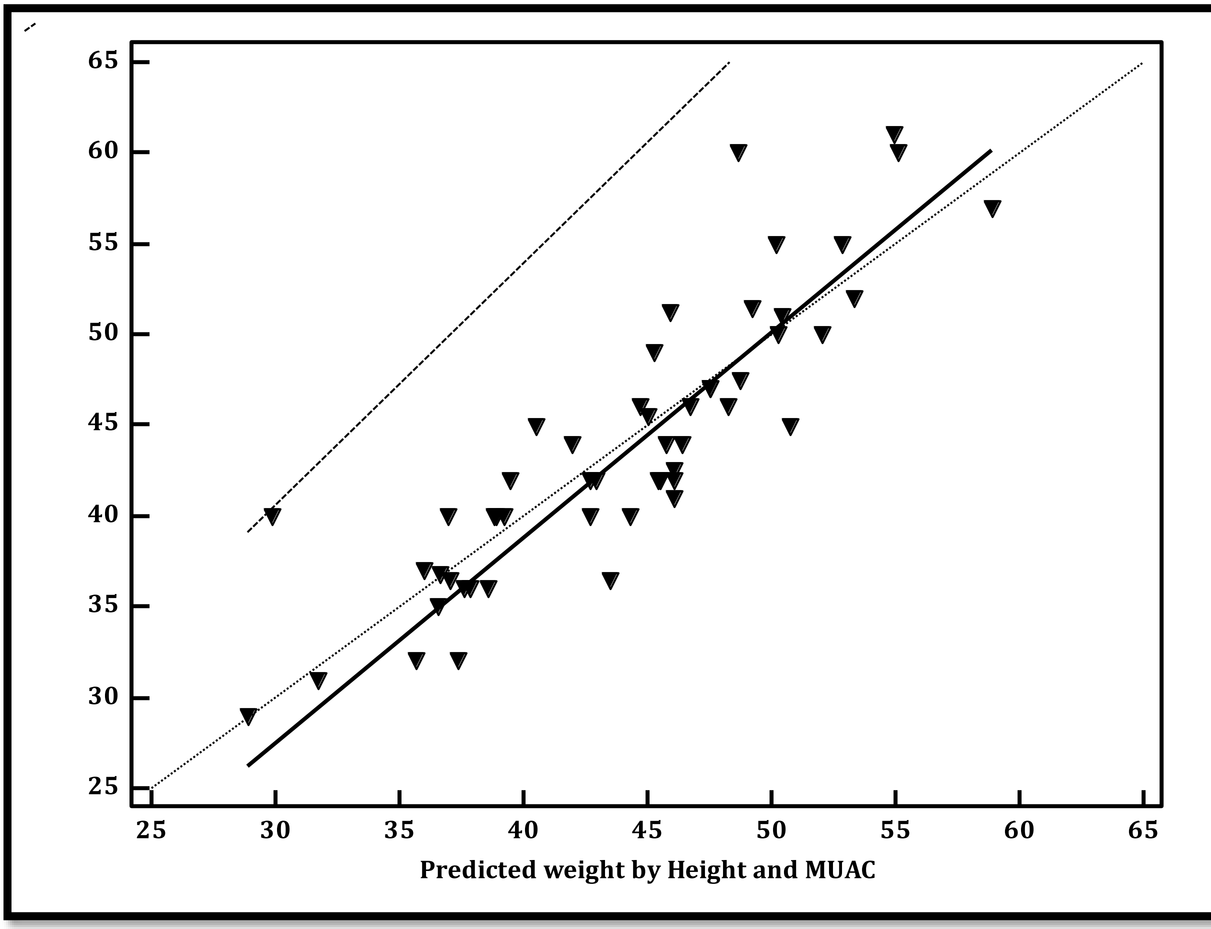

Figure 2(c): Passing-Bablok Regression scatter plot for women.

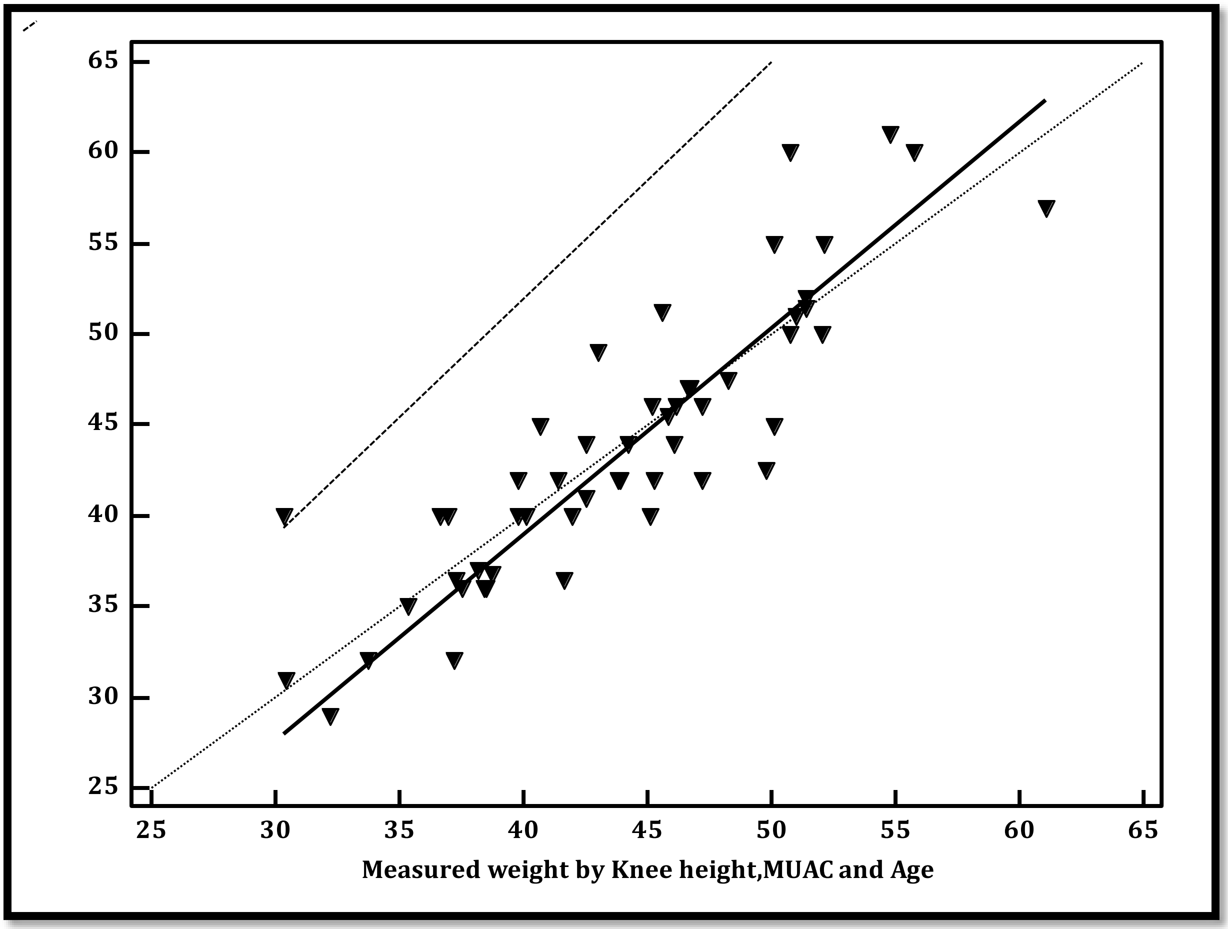

Figure 2(d): Passing-Bablok Regression scatter plot for women.

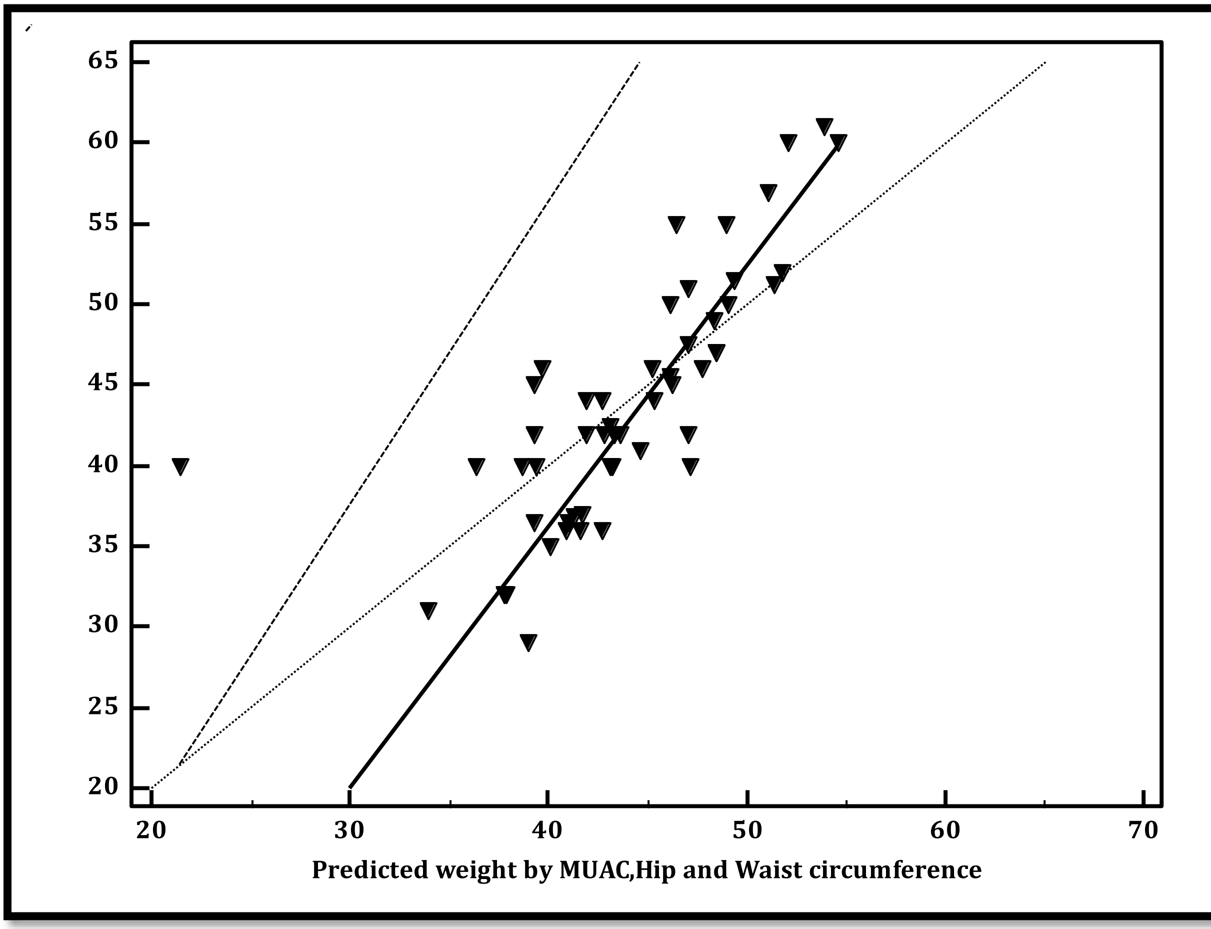

Table: 4: Classification by BMI category

Type of alternative measurements	Asia Pacific BMI category calculated by measured weight for men			
	Underweight n=16 (%)	Normal n=30 (%)	Overweight n=16 (%)	Kappa (95% CI)
BMI calculated by knee height and MUAC	11 (17.7%)	38 (61.3%)	13 (21.0%)	0.572 (0.392-0.753)
BMI calculated by height and MUAC	10 (16.1%)	36 (58.1%)	16 (25.8%)	0.525 (0.338-0.711)
BMI calculated by knee height, age and MUAC	11 (17.7%)	38 (61.3%)	13 (21.0%)	0.572 (0.392-0.753)
BMI calculated by height, WC and HC	13 (21.0%)	38 (54.8%)	13 (24.2%)	0.687 (0.526-0.847)
	Asia Pacific BMI category calculated by measured weight for women			
	Underweight n=14 (26.9%)	Normal n=25 (48.1%)	Overweight n=13 (25.0%)	Kappa (95% CI)
BMI calculated by knee height and MUAC	30 (57.7%)	20 (38.5%)	2 (3.8%)	0.201 (0.023-0.380)
BMI calculated by height and MUAC	17 (32.7%)	23 (44.2%)	16 (23.1%)	0.640 (0.459-0.822)
BMI calculated by knee height, age and MUAC	15 (28.8%)	24 (46.2%)	13 (25.0%)	0.548 (0.350-0.746)
BMI calculated by height, WC and HC	11 (21.2%)	34 (65.4%)	7 (13.5%)	0.386 (0.168-0.604)