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Clinical Study

Community-Specific BMI Cutoff Points for South Indian Females

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Objective. To analyze multiparameters related to total body composition, with specific emphasis on obesity in South Indian females, in order to derive community-specific BMI cutoff points. *Patients and Methods*. A total number of 87 females (of age 37.33 ± 13.12 years) from South Indian Chennai urban population participated in this clinical study. Body composition analysis and anthropometric measurements were acquired after conducting careful clinical examination. *Results*. BMI demonstrated high significance when normal group (21.02 ± 1.47 kg/m^2) was compared with obese group (29.31 ± 3.95 kg/m^2), $P < 0.0001$. BFM displayed high significance when normal group (14.92 ± 4.28 kg) was compared with obese group (29.94 ± 8.1 kg), $P < 0.0001$. *Conclusion*. Community-specific BMI cutoffs are necessary to assess obesity in different ethnic groups, and relying on WHO-based universal BMI cutoff points would be a wrong strategy.

1. Introduction

Obesity is a pathology which signifies excess body fat directly related to reduced life expectancy. Obesity has been considered as one of the major epidemics faced in the present century. Totally 5% of the Indian population has been affected by obesity. Indian BMI standards were used for categorization into three groups [1, 2]. Almost for 200 years, BMI has been considered as the main index of obesity, but witnessed to have exhibited compromising accuracy in body fat assessment [3]. Measurement of BMI in conjunction with waist circumference aided in the diagnosis of negative effects of vascular disability [4]. Argument still prevails as to how capable BMI is to assess obesity, though BMI has been the most popularly adopted means of obesity assessment [5]. WHO-based BMI cutoff points would consider only height and weight; therefore there could be improper fat or obesity assessment [6]. Hence community-specific cutoff points would be more appropriate, especially in south Indian female population, taking into consideration energy-rich spicy south Indian food.

2. Patients and Methods

2.1. Study Design and Population. A free obesity awareness camp was conducted at SRM Hospital and Research Centre, Kattankulathur, Tamilnadu, India from the 3rd to 5th of August 2010 for the South Indian females. All the data were acquired in one stretch. This was not a follow-up study. A total number of 87 females who belonged to Chennai urban population of South India from different professions participated in this clinical study. Their mean age was 37.33 ± 13.12 years. They were categorized into 3 groups based on BMI as an index of obesity (Indian BMI standards [1, 2]) as follows: normal (18.5–22.9), at risk (23–24.9), and obese (≥25). Females were divided into three groups based on BMI as an index of obesity. Group-I: normal, $N = 26$, age = 37.35 ± 16.3 years; Group-II: at risk, $N = 16$, age = 32.56 ± 11.87 years; Group-III: obesity, $N = 45$, age = 39.02 ± 11.25 years. The health assessment questionnaire test was administered to each patient. The functional status in activities of daily living of each participant was noted carefully. Apart from understanding physiological basis of obesity, identifying suitable BMI cut-off points pertaining to specific community as that of South Indian females considered in the present clinical study is the need of the hour, owing to the fact that the body constitution varies in different ethnic groups, races, and so forth. due to different culture, food habits, and work routine schedule. Device used in this clinical study is bioelectric impedance analysis-based body composition analyzer (Slim Manager N40, AIIA, Communications, Inc., South Korea). After obtaining informed

Table 1

(a) Analysis of anthropometric and body composition characteristics between groups (normal, at risk, and obese) and chi-Square.

Factors	Total dataset		Normal ($n = 26$)		At-risk ($n = 16$)		Obesity ($n = 45$)		Significance	Chi-square	Asymp.sig
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	P		
Age	37.33	13.12	37.35	16.30	32.56	11.82	39.02	11.25	0.175 (NS)	18.56	0.001
Ht	159.06	9.93	158.65	11.40	161.75	9.31	158.33	9.28	0.488 (NS)	29.07	0.663
Wt	65.48	13.13	53.02	7.65	63.33	7.21	73.45	11.30	0.000 (HS)	2.79	1.000
BMI	25.88	4.75	21.02	1.47	24.14	0.53	29.31	3.95	0.000 (HS)	15.18	1.000
ICF	20.63	4.91	18.79	4.68	21.56	4.84	21.36	4.88	0.072 (LS)	11.48	1.000
ECF	10.04	2.41	8.98	2.49	10.47	2.15	10.49	2.29	0.2 (LS)	17.89	1.000
Body fat mess	23.55	9.34	14.92	4.28	19.60	3.07	29.94	8.10	0.000 (HS)	9.49	1.000
Body water	27.26	5.55	25.78	4.45	26.61	5.66	28.34	5.94	0.151 (NS)	15.18	1.000
Muscle mass	34.71	7.06	32.82	5.68	33.89	7.21	36.09	7.56	0.149 (NS)	11.74	1.000
Fat-free-mass	37.24	7.58	35.21	6.08	36.37	7.73	38.73	8.12	0.149 (NS)	9.82	1.000
SMM	19.63	4.49	18.39	3.56	19.16	4.51	20.50	4.84	0.145 (NS)	18.87	1.000
RA	1.78	0.54	1.64	0.49	1.71	0.53	1.88	0.56	0.179 (NS)	11.17	1.000
LA	1.77	0.54	1.65	0.49	1.71	0.52	1.87	0.57	0.212 (NS)	18.10	1.000
Trunk	16.85	3.45	16.06	2.94	16.51	3.63	17.44	3.63	0.248 (NS)	28.96	0.999
PBF	40.33	8.58	42.92	7.81	41.68	7.63	38.35	8.98	0.047 (LS)	7.7	1.000
WHR	0.90	0.06	0.90	0.07	0.90	0.06	0.90	0.06	0.912 (NS)	40.29	0.020
VFA	98.52	41.83	98.43	43.64	103.44	40.54	96.83	42.02	0.866 (NS)	1.9	1.000
Edema	0.33	0.01	0.33	0.01	0.33	0.00	0.33	0.01	0.642 (NS)	46.77	0.001
Fat control	−10.78	11.57	−1.76	9.89	−8.32	2.57	−16.86	10.76	0.000 (HS)	12.13	1.000
Muscle control	2.21	2.61	5.03	2.55	1.39	1.63	0.86	1.37	0.000 (HS)	467.67	0.000
Basal metabolic rate	1282.13	213.87	1204.42	209.08	1332.56	207.72	1309.09	211.22	0.079 (LS)	2.79	1.000
Obesity degree	120.75	20.19	122.69	24.62	119.69	13.98	120.00	19.56	0.844 (NS)	30.9	0.946
Abdomen circumference	87.91	13.76	87.93	15.61	87.28	12.20	88.12	13.45	0.979 (NS)	6.52	1.000

NS: not significant, LS: less significant, HS: high significant.

(b) Tests of normality.

	Kolmogorov-Smirnov[a]			Shapiro-Wilk		
	Statistic	Df	Sig	Statistic	Df	Sig
WT	.096	77	.079	.980	77	.270
BMI	.105	77	.036	.925	77	.000
ICF	.073	77	.200*	.984	77	.469
ECF	.095	77	.083	.982	77	.331
Body fat mass (BFM)	.110	77	.022	.944	77	.002
Fat control	.059	77	.200*	.991	77	.869
Muscle control	.200	77	.000	.827	77	.000

* This is a lower bound of the true significance.
[a] Lilliefor's significance correction.

consent from each participant and following the standard technical protocol (age, height, and weight of each individual was recorded and fed to the device. The participant is asked to stand on foot rest design of the device, where the probes are placed and the participant is asked to hold two other probes attached to the device. Then by incorporating multiple frequencies (500 Hz, 50 KHz, 500 KHz) and tetra polar 8 and point tactile impedance method; by maintaining the room temperature between 10°C to 40°C and maintaining humidity within 90%; applying low current which is less than 100 μA) multi parameters such as BMI, ICF (intra cellular fluid), ECF (extra cellular fluid), BFM (body fat mass), BW (body water), MM (muscle mass), FFM (fat free mass), SMM (skeletal muscle mass), PBF (percent body fat), WHR (wais-to-hip ratio), VFA (visceral fat area), Edema, Fat Control, Muscle Control, BMR (basal metabolic rate), OD (obesity degree), and AC (abdominal circumference) considered in this clinical study were measured and displayed on LCD monitor and a printout was taken. Time taken for the procedure for each participant was approximately 1 min 30 sec.

We would like to provide the definition of all variables considered in this clinical study for better understanding BMI: A standardized estimate of an individual's relative body fat calculated from a person's height and weight [7], unit of measurement in Kg/mt^2. BFM (body fat mass): This is the total amount of fat in the body (adipose tissue) and also is the difference between body weight and fat free mass [8], unit of measurement in Kg. FFM (fat free mass): difference between mass of body and fat [8], unit of measurement in Kg. PBF (percent body fat): this is the percentage of fat contained by our body [8], unit of measurement in percentage (%). FC (fat control): this is the parameter that has an inverse relationship with obesity [9], unit of measurement in Kg. MC (muscle control): this is the mechanism that involves flexing and relaxing the muscles individually and in groups [9], unit of measurement in Kg. BW (body water): this is all the water within the body, including intracellular fluid, extracellular fluid, and water in gastrointestinal and urinary tracts [10], unit of measurement in litre. VFA (visceral fat area): fat located in peritoneal cavity (abdominal area) that surrounds body's internal organs [11], unit of measurement in Cm^2. WHR (waist-to-hip ratio): this is a measurement that compares the size of waist in inches to that of hips. Risk for developing heart disease is typically measured by WHR. Also, WHR is the dominant risk factor for developing cardiovascular disorders in Australia [12], unit of measurement in constant. Abdomen circumference: the distance around entire abdomen/waist [11], unit of measurement in Cm. Obesity degree: this is the percentage above or below the ideal weight [13], unit of measurement in percentage (%). BMR (basal metabolic rate): this is the number of calories the body burns at rest to maintain normal body functions [14], unit of measurement in calories. Edema: an accumulation of an excessive amount of watery fluid in cells or intracellular tissues [15], unit of measurement in litre.

2.2. Statistical Analysis. Data analysis has been done by SPSS Software package version 10.0 (SPSS Inc. Chicago, USA). The measured mean BMI, BFM, FC, MC in normal, at-risk, and obese groups were compared using a one-way descriptive statistics test. Then ANOVA test was administered to find out the significance between groups (normal, at risk, and obese) in each parameter. Then post hoc test (Tukey HSD) was performed to find out the significant value when normal (control group) was compared against at-risk and obese groups in each parameter. The partial correlation analysis was used to find out the correlation between BMI, and FC, BMI and MC, BMI, and BFM. Kolmogorov-Smirnov and Shapiro-Wilk tests of normality were performed to test the normality of weight, BMI, ICF, ECF, BFM, FC, and MC. Stem and leaf plot, normal, detrended normal plots of BMI, BFM, were plotted. Test statistics was used to calculate chi-square. Age groups were categorized in cross-tabulation format.

3. Results

Table 1(a) categorizes the anthropometric as well as body composition parameters Vs normal, at-risk, obese, and overall female population. We can find the significance value between groups, with respect to each parameter. Table 2 deciphers the significance value of each parameter, when normal group was compared with at-risk and obese groups. There was high statistical significant difference in weight, BMI, BFM, FC, and MC parameters. There was less significant difference in ICF, ECF, PBF, and BMR (Table 1(a)). Statistical significance was nil in age, height, BW, MM, FFM, SMM, RA, LA, Trunk, WHR, VFA, Edema, OD, and AC (Table 1(a)). Asymptotic significance was prominent in muscle control, edema, and age group (Table 1(a)). (Table 1(b)) details the following facts: Kolmogorov test exhibits higher significance with respect to muscle control, ICF and fat control (lower bound of true significance), Wt, BMI, ECF, and BFM exhibit moderate significances; Shapiro-Wilk test exhibits higher significance with respect to BMI, MC, and BFM, lesser significance with respect to Wt, ICF, ECF and FC.

Table 2: Significance of each parameter with normal group as the basis against all obesity groups in South Indian female population (at risk, obese).

Sl. No.	Parameter	Normal versus at risk	Normal versus obese
1	Wt (Kg)	0.003 MS	0.000 HS
2	BMI (Kg/m^2)	0.004 MS	0.000 HS
3	ICF (L)	0.173 NS	0.083 LS
4	ECF (L)	0.118 MS	0.028 LS
5	BFM (Kg)	0.063 LS	0.000 HS
6	FC (Kg)	0.083 LS	0.000 HS
7	MC (Kg)	0.000 HS	0.000 HS

MS: moderate significant.
LS: Less significant.
HS: High significant.

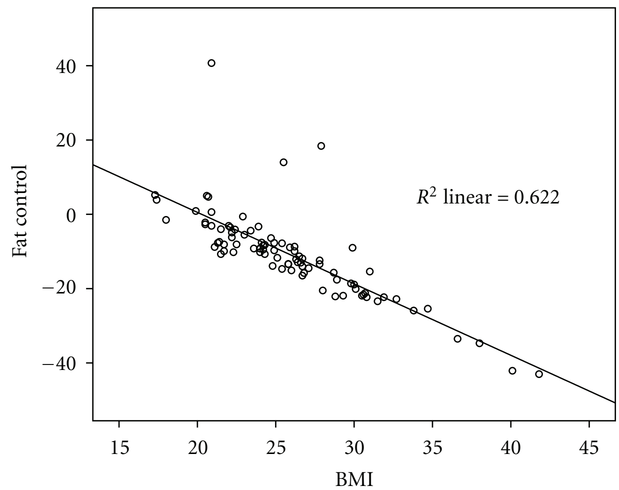

Figure 1: Plot of BMI versus fat control

When normal group was compared with at-risk group, we noticed that the variable with high statistical significance is MC; variables those are moderately significant are weight and BMI. The rest parameters are nonsignificant. Similarly when normal group was compared against obese group, parameters that exhibited high significance were weight, BMI, BFM, FC, and MC; factors with least significance were ICF and ECF (Table 2). Table 3 enumerates the following

Table 3: Age group * BMI range cross tabulation.

			BMI range Normal	At risk	Obese	Total
Age group	18–29	Count	11	9	9	29
		% within age group	37.9%	31.0%	31.0%	100.0%
		% within BMI range	42.3%	56.3%	20.0%	33.3%
		% of total	12.6%	10.3%	10.3%	33.3%
	30–39	Count	3	4	17	24
		% within age group	12.5%	16.7%	70.8%	100.0%
		% within BMI range	11.5%	25.0%	37.8%	27.6%
		% of total	3.4%	4.6%	19.5%	27.6%
	40–49	Count	5	1	10	16
		% within age group	31.3%	6.3%	62.5%	100.0%
		% within BMI range	19.2%	6.3%	22.2%	18.4%
		% of total	5.7%	1.1%	11.5%	18.4%
	50–59	Count	4	1	5	10
		% within age group	40.0%	10.0%	50.0%	100.0%
		% within BMI range	15.4%	6.3%	11.1%	11.5%
		% of total	4.6%	1.1%	5.7%	11.5%
	60–69	Count	3	1	4	8
		% within age group	37.5%	12.5%	50.0%	100.0%
		% within BMI range	11.5%	6.3%	8.9%	9.2%
		% of total	3.4%	1.1%	4.6%	9.2%
Total		Count	26	16	45	87
		% within age group	29.9%	18.4%	51.7%	100.0%
		% within BMI range	100.0%	100.0%	100.0%	100.0%
		% of total	29.9%	18.4%	51.7%	100.0%

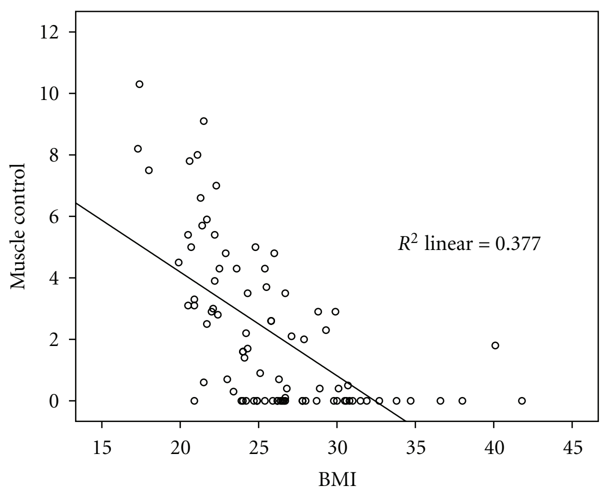

Figure 2: Plot of BMI versus muscle control.

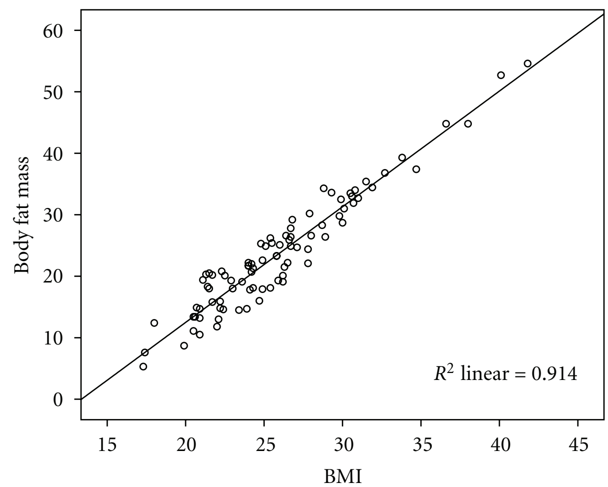

Figure 3: Plot of BMI versus BFM.

facts and figures: females, who were within the age group of 18–29 years, had comparatively more normal people than at-risk and obese group. Females categorized in 30–39 years age group had maximum percentage of obese people than other two categories. Females of 40–49 age groups had comparatively higher percentage of obese people than other two categories. Females who belonged to 50–59 years age group had slightly higher percentage of obese people than normal people; percentage of people who belonged to at risk group was too small, however. Female participants 60–69 years-age

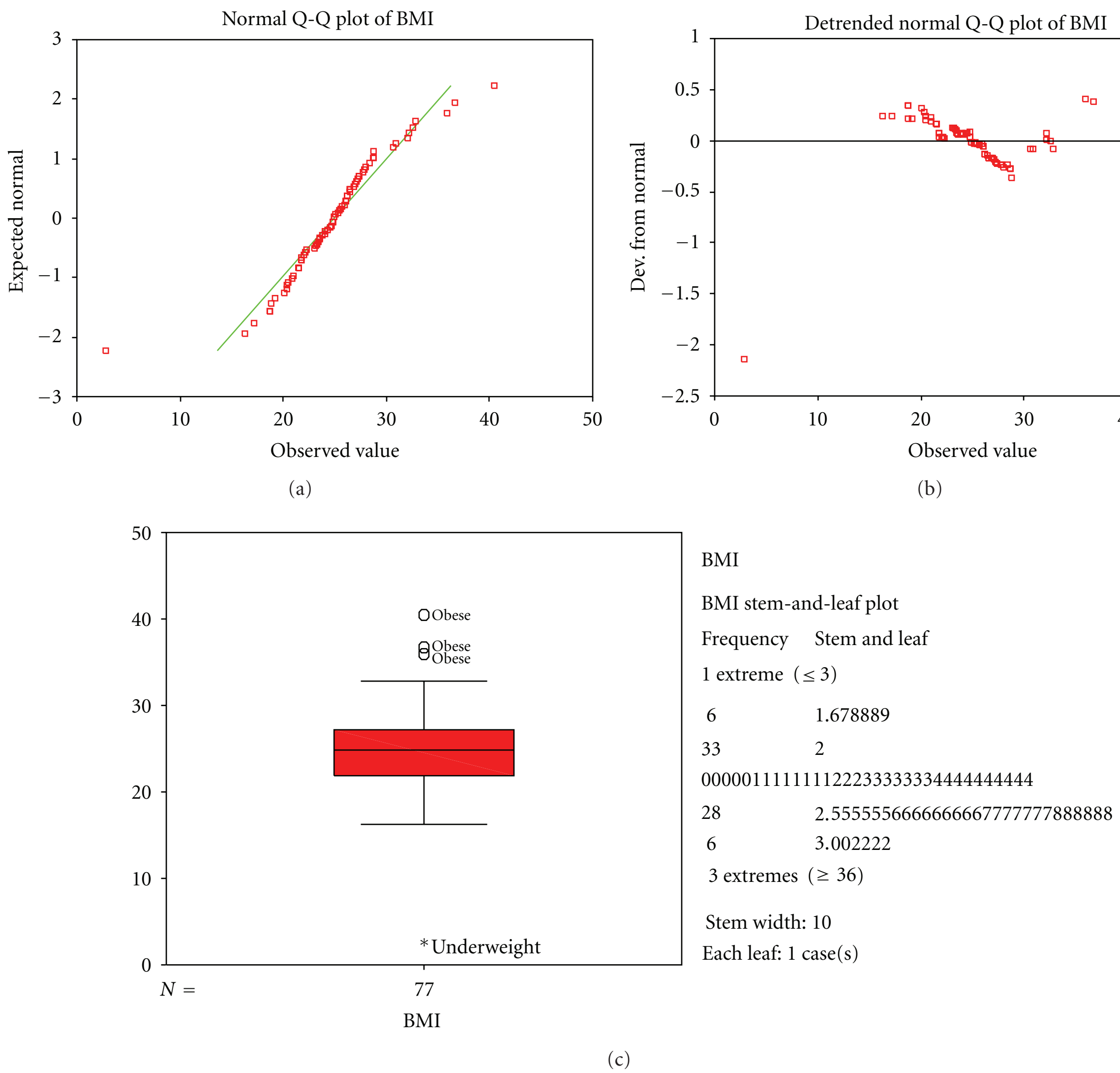

Figure 4: (a) Normal Q-Q plot of BMI, (b) detrended normal Q-Q plot of BMI, and (c) stem-leaf plot of BMI.

group had similar higher concentration of obese people than their normal counterparts; again, percentage of people who belonged to at-risk group was small.

Figure 1 demonstrate the negative correlation between BMI and FC ($r = -0.789$, $P < 0.001$). Figure 2 depicts the negative correlation between BMI and MC ($r = -0.614$, $P < 0.001$). Figure 3 displays the positive correlation between BMI and BFM ($r = 0.956$, $P < 0.001$); age being the controlling variable in all the three cases. Figure 4 provides the Q-Q plots that have been utilized to plot the quintile of BMI's distribution against test distribution. Figure 4(a) displays clustering of points around straight line (between 20 and 30 of observed value). Figure 4(b) depicts the comparison between observed value and detrended normal value. Figure 4(c) shows the stem and leaf plot that has been plotted to exhibit frequency. A majority of cases (33 + 28 = 61) are clustered around 20 and 30. Figure 5(a) deciphers the clustering of points around straight line (between 12 and 22 of observed value). Figure 5(b) details the comparison between observed and detrended normal value. Figure 5(c) displays stem and leaf plot that signifies the following facts: majority of cases (20 + 16 = 36) are clustered around 10 and 24. Figure 6 and (error bar) informs one of the following facts. (i) Weight: Incremented drastically from normal to at-risk to obese category. (ii) BMI: Incremented progressively from normal to at-risk to obese category. (iii) ICF: comparatively at higher threshold in at risk group than normal and obese groups. (iv) ECF: slightly at higher threshold than normal and obese groups. (v) BFM: progressive increment from normal to at risk; drastic jump from at risk to obese. (vi) Fat control (FC): depiction of severe deterioration from normal to at-risk to obese category. (vii) Muscle control (MC): slight decrementation witnessed from normal to at-risk to obese group.

Among the females who participated in this study, BMI was moderately significant with normal group ($21.02 \pm 1.47\,kg/m^2$) against at-risk group ($24.14 \pm 0.53\,kg/m^2$), $P < 0.004$ and was highly significant with normal group

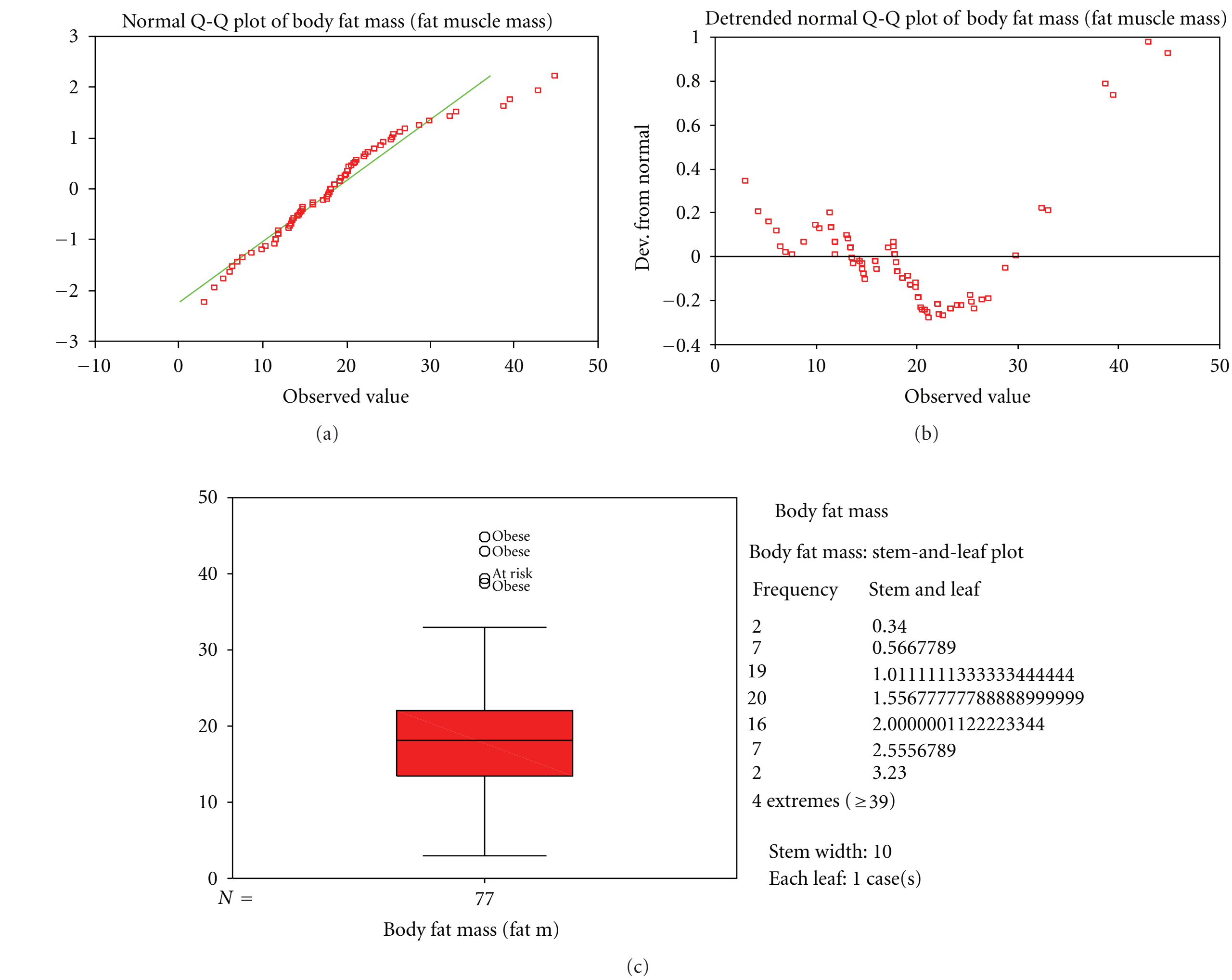

Figure 5: (a) Normal Q-Q plot of BFM, (b) detrended normal Q-Q plot of BFM, and (c) stem-leaf plot of BFM.

against obese group ($29.31 \pm 3.95\,kg/m^2$), $P < 0.001$. BFM was statistically less significant with normal group (14.92 ± 4.28 kg) against at-risk group (19.6 ± 3.07 kg), $P < 0.063$ and was highly significant with normal group against obese group (29.94 ± 8.1 kg), $P < 0.001$. FC was another significant variable considered in our study, which displayed the following information: it was statistically less significant with normal group (-1.76 ± 9.89 kg) against at-risk group (-8.32 ± 2.57 kg), $P < 0.083$, and exhibited high significance with normal group against obese group (-16.86 ± 10.76 kg), $P < 0.001$. Present study details MC to have exhibited considerable significance when normal was compared with at-risk and obese group, $P < 0.001$. Values of MC with respect to normal, at-risk, and obese groups were 5.03 ± 2.55 kg, 1.39 ± 1.63 kg, and 0.86 ± 1.37 kg, respectively. We would like to suggest the following cut-off points for South Indian female community, as universal and Indian BMI standards were not found suitable to assess obesity, as unique culture had its specific impact on obesity in this community: normal = 18.5–21, at risk = 21.1–24.0obese = 24.1–30, and severey obese >30 (Table 1(a)).

4. Discussion

The current paper is an attempt to derive suitable threshold values for BMI for South Indian female community, because WHO-accepted universal BMI criterion has been providing contradictory results (e.g., body builders who have more BMI have low PBF [6]). In Thai population where middle-aged people were considered, WC of 84 cm for men and 80 cm for women was proposed and a BMI of $23\,kg/m^2$ was considered for both genders [16]. In Fiji, a study was conducted to witness the distribution and sociodemographic association of BMI among Melanesians and Indian Fijians aged ≥40 years. Melanesians had the BMI with in the range of $25–35\,kg/m^2$ and above [17]. In our study, females had BMI within the range of 21.02 and 29.31. So comparatively Indian female population has fewer tendencies to put on weight compared to Melanesian population, including women. In Malay subjects, 80 cm WC cutoff point was concluded for females for weight management purpose instead of BMI [18]. In Dzong village, Nepal, it was found that the mean BMI was less than 21 for both the genders, but mean PBF

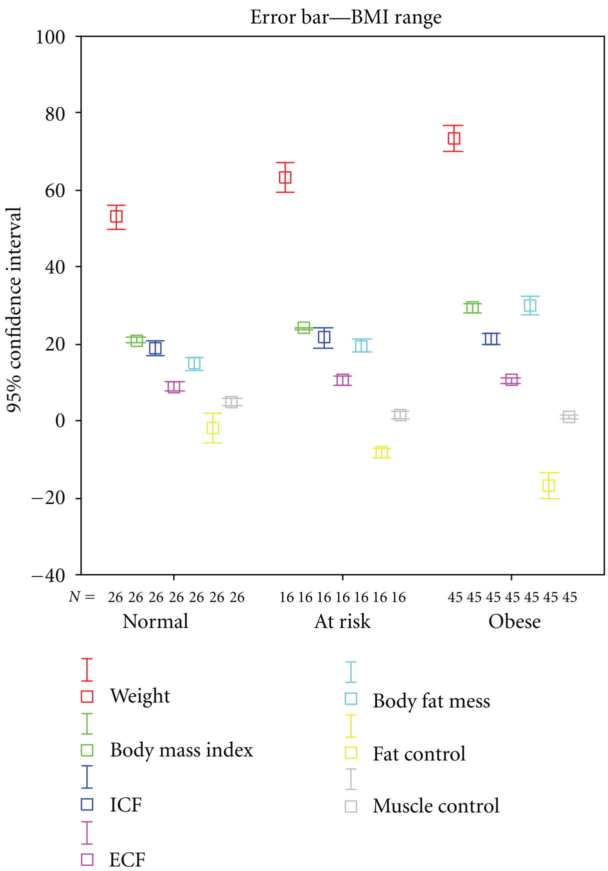

Figure 6: Error bar of BMI range with significance value.

of females ranged from 25.8% to 31% for all age groups [19]. In our study, mean BMI was 25.88 for overall female population and PBF ranged from 42.92% (normal) to at risk (41.65%) to obese (38.35%), so both BMI and PBF were in higher proportions in Indian females compared to their Nepalean counterparts. Wen et al., concluded that different BMI cutoffs are required for Asian Indian as well as Chinese groups and asserted the difference between these Asian ethnic groups and Europeans with respect to PBF-BMI relationship [20]. Present study informs mean values for BMI and PBF to be 25.88 ± 4.75 and $40.33 \pm 8.58\%$, respectively, for the total studied population. BMI was inversely proportional to PBF, signifying the fact that as BMI progressed from normal to obese group, PBF decremented. Rush et al. reported the differentially of PBF and BMI relationship for European, Pacific island, and Asian Indian men [21]. This is due to variation in masculinity and higher degree of fat deposition in abdominal region in Asian Indian people compared to European and Pacific island counterparts. Therefore, universal BMI cut-off points are not suitable for affirming obesity prevalence in these ethnic groups. In the present study as we have witnessed inverse proportionality between BMI and PBF, relying on universal BMI criterion as a main index of adiposity and fat assessment would be an unwise step. Sabanayagam et al. proclaimed the positive correlation between low socioeconomic status and obesity in Malay women, the equation being opposite in Malay men [22]. Our study exhibited negative correlation between low socioeconomic status and obesity (socioeconomic status as depicted from obesity questionnaire [23] and compared with different body composition measurements such as BFM, BMI, PBF, FC, and MC). Barbra et al., recommended public action points for many Asian populations such has 23 kg/m^2 or higher to be included in risk category 27.5 kg/m^2 or higher to be regarded as high-risk category. Henceforth, the following categories were suggested: less then 18.5 kg/m^2 = under weight; 18.5 to 23 kg/m^2 = acceptable risk; 23 to 27.5 kg/m^2 = increased risk; 27.5 kg/m^2 or higher = over risk [7].

5. Limitations

This clinical study has to be extended by taking in consideration different ethnic groups/ races and so forth, health risks have not been clearly predicted with clinical relevance with respect to BMI cutoff points concluded for the studied South Indian female population.

6. Conclusion

The main concern that has lead to the recommendation of community-specific BMI cutoff points is the fact that mean BMI of Asian populations is lower than that of their non-Asian counterparts, even though higher degree of abdominal obesity is witnessed among the Asian populations. The cutoff points have to be utilized taking into account the person's health history and other information such as waist circumference and existences of other risk factors pertaining to health, so that accurate risk assessment can be done efficiently [7]. In our clinical study, the following categorization has been concluded for South Indian female community: normal = 18.5 to 21; at risk = 21.1 to 24; obese = 24.1 to 30; severely obese >30. Being obese (whether women or men) would lead to heart disease and stroke, high blood pressure, diabetes, gall bladder disease, and many other pathologies [24].

Abbreviations

ICF: Intracellular fluid
ECF: Extracellular fluid
BFM: Body fat mass
BW: Body water
MM: Muscle mass
FFM: Fat free mass
PBF: Percent body fat
WHR: Waist-to-hip ratio
VFA: Visceral fat area
BMR: Basal metabolic rate
OD: Obesity degree
AC: Abdominal circumference
FC: Fat control
MC: Muscle control
SW: Standard weight
ED: Edema.

Conflict of Interests

The authors declare no conflict of interests.

Author's Contributions

V. Sapthagiri and M. Anburajan contributed equally to the work.

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