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/m²) was compared with obese group (29.31 ± 3.95 kg/m²), P < 0.0001. BMI 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. Tot ally 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 P |
|---------------------|---------------|-----------------|------------------|------------------|--------------|------------|-------------|
|                     | Mean          | SD              | Mean             | SD               | Significance | Chi-square | Asymp.sig 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 mass       | 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            | 18.79            | 4.68             | 21.56        | 4.84       | 21.36       | 4.88        | 0.072 (LS)  | 11.48 | 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-Smirnova | Shapio-Wilk       |
|------------------|----------------------|-------------------|
|                  | Statistic Df Sig     | Statistic Df Sig  |
| WT               | 0.096 77 .079 .980   | 77 .270           |
| BMI              | 0.105 77 .036 .925   | 77 .000           |
| ICF              | 0.073 77 .200* .984  | 77 .469           |
| ECF              | 0.095 77 .083 .982   | 77 .331           |
| Body fat mass    | 0.110 77 .022 .944   | 77 .002           |
| Fat control      | 0.059 77 .200* .991  | 77 .869           |
| Muscle control   | 0.000 77 .827 .000   | 77 .000           |

aThis is a lower bound of the true significance.

Lilliefors 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 (waist-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/m². 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 percent (%). MC (muscle control): this is parameter that has an inverse relationship with obesity [9], unit of measurement in percentage (%). FC (fat control): this is the percentage above or below the ideal weight [13], unit of measurement in Cm. Obesity degree: this is the percentage above or below the ideal weight [13], unit of measurement in percent (%). 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 deciphered 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 BMI (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.

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.

| Age group | Count | Normal | At risk | Obese | Total |
|-----------|-------|--------|---------|-------|-------|
| 18–29     | 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     | 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     | 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     | 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     | 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     | 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
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) decipher 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 ($21.02 \pm 1.47 \text{ kg/m}^2$) against at-risk group ($24.14 \pm 0.53 \text{ kg/m}^2$), $P < 0.004$ and was highly significant with normal group.
Against obese group (29.31 ± 3.95 kg/m²), \( P < 0.001 \). 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, obese = 24.1–30, and severely 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/m² 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 within the range of 25–35 kg/m² 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 cut-off 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
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 BMI cutoff points concluded for the studied South Indian female population.

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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