Association between Body Composition and Body Mass Index in Young Japanese Women

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Summary The National Nutrition Survey of Japan indicated a trend toward a decreasing body mass index (BMI; kg/m²) among young Japanese women. Current studies suggest that not-high BMI often does not correlate with not-high body fat percentage. Recently, the classification of BMI in adult Asians was proposed by the International Obesity Task Force. The addition of an “at risk of overweight” category, BMI as 23.0–24.9, was intended to prevent chronic diseases. We investigated the association between body fat percentage (BF%) and BMI to evaluate the screening performance of BMI focused on individual preventive medicine. The subjects consisted of 605 female college students. The subjects’ ages (y), heights (cm), body weights (kg), BMIs, and BF percents with underwater weighing expressed as the means±SD were 19.6±0.5, 158.7±5.6, 53.8±7.2, 21.3±2.4, and 24.9±4.9, respectively. We defined high BF% as ≥85th percentile of BF% (29.8%). High-BF% individuals are often not classified into BMI≥23.0 because their BMI readings are very broad (18.4–31.7). In comparison to the screening performances (specificity and sensitivity), BMI≥23.0 (85.3% and 52.1%, respectively), rather than BMI≥25.0 (96.7% and 29.8%, respectively), is recommended for the mass evaluation of fatness. For this reason, the BMI “at risk of overweight” category is characterized as the threshold of increasing the appearance ratio of high-BF% individuals. In conclusion, the BMI 25.0kg/m² category is determined as high BF%, regardless of body composition measurement for mass evaluation as a result of quite high specificity. Even so, body composition measurement is necessitated by the individual evaluation of fatness focused on preventive medicine because BMI performed a poor representation of body composition, especially BMI<25.0 kg/m² individuals.

Key Words body composition, body mass index, screening performance, young Japanese obese women, underwater weighing

Body weight consists of both body fat mass (BFM) and fat free mass (FFM) and is regulated by the balance between food consumption and energy expenditure. The metabolic effects of excess BFM are thought to underlie the morbidity and mortality associated with obesity, though increased FFM is not associated with an increased risk of chronic diseases (1).

Conventionally, it is assumed that an excess body fat percentage (BF%) defines obesity (1–7). Numerous reports have shown that body mass index (BMI) is a reasonable indicator of fatness (7–9) because overweight (high-BMI) subjects are also defined as obese (high-BF%). This situation indicates that changes in body weight are a suitable reflection of alterations in BFM rather than in FFM.

A decreasing BMI trend is evident among young Japanese women (10–13). However, our previous studies (14, 15) suggest that the ratio of young high-BF% women, who are not screened by BMI cutoff in Japanese (≥25.0 kg/m²) (10, 11), is increasing. This phenomenon is commonly observed in young Japanese (16–18) and is referred to as “masked obesity.” This observation indicates that not-high BMI often does not correlate with not-high BF%.

Recently, the classification of body weight based on BMI in adult Asians to prevent chronic diseases was proposed by the International Obesity Task Force (9). An “at risk of overweight” category, BMI of 23.0–24.9 kg/m², was added to the “in Japanese” classification. Literature documenting the association between body composition and BMI is sparse. Moreover, the screening performance of “at risk of overweight” and the classification of BMI of high-BF% individuals in young Japanese women are not found. Therefore we investigated the association between body composition and BMI in young Japanese women.

SUBJECTS AND METHODS

Study subjects and body composition measurement. The present study was conducted from 1994 to 1999. The subjects were recruited only after being informed of

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Table 1. Physical characteristics of study subjects.

<table>
<thead>
<tr>
<th></th>
<th>Total (n=605)</th>
<th>Not-high BF% (n=511)</th>
<th>High BF% (n=94)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mean±SD</td>
<td>Range</td>
<td>Mean±SD</td>
</tr>
<tr>
<td>Age (y)</td>
<td>19.6±0.5</td>
<td>19.0–21.8</td>
<td>19.5±0.5</td>
</tr>
<tr>
<td>Height (cm)</td>
<td>158.7±5.6</td>
<td>142.0–178.0</td>
<td>158.6±5.6</td>
</tr>
<tr>
<td>Weight (kg)</td>
<td>53.8±7.2</td>
<td>37.9–82.6</td>
<td>52.6±6.2</td>
</tr>
<tr>
<td>BMI² (kg/m²)</td>
<td>21.3±2.4</td>
<td>15.9–31.7</td>
<td>20.9±2.0</td>
</tr>
<tr>
<td>Body fat percentage (%)</td>
<td>24.9±4.9</td>
<td>7.9–39.5</td>
<td>23.5±3.8</td>
</tr>
</tbody>
</table>

1 BF%, body fat percentage.
2 BMI, body mass index.
3 Body fat percentage was estimated by the underwater weighing method.

RESULTS

The physical characteristics are presented in Table 1. Figure 1 shows the histograms of both BMI (A) and BF% (B), respectively. The distribution of BMI was not normal; however, BF% illustrated normal distribution. The BF% cutoff point (85th percentile) was indicated at 29.8% (Table 1). Figure 2 presents the fit line (solid line) and the 95% confidence interval (CI) area (dot area) of total subjects between BF% and BMI. Furthermore, Fig. 2 includes the 95% mahalanobis distance ellipses and fit lines (broken lines) for both not-high-BF% and high-BF% subjects, respectively. Intercepts and slopes of these fit lines appear distinctly. Further, the range of 95% CI for the prediction of BF% employing BMI and for BMI
BMI and Body Composition in Young Japanese Women

Fig. 2. Relationships between body mass index (BMI) and body fat percentage (BF%). Fit lines indicate total subjects (solid line) and classified subjects (broken lines). The dot area indicates 95% confidence interval of total subjects. Ellipses indicate 95% mahalanobis distance of classified subjects (see Table 1).

Using BF% were very broad (approximately 20 kg/m² and 15%, respectively). On the other hand, it is clear that nearly the entire ellipse of not-high-BF% subjects was at BF%<85th and BMI<25.0 kg/m². In contrast, that of high-BF% subjects covered a wide BMI range from <18.5 to ≈30.0 kg/m².

On the other hand, relationships among each BMI class were significantly correlated, with the exception of BMI<18.5 kg/m², presented in Table 2. The strongest relationship (r=0.573) was found in BMI≥25.0 kg/m². The correlations of BMI 23.0–24.9 kg/m² and BMI 18.5–22.9 kg/m² were low (r=0.331 and 0.385, respectively).

The appearance and distribution of high-BF% subjects and the categorized number of subjects within each BMI class are presented in Fig. 3. Reasonable results were obtained in the case of appearances; high-BF% subject appearances increased with increased BMI class. False-positive (not-high BF%, but higher BMI) subjects within BMI≥25.0 and 23.0–24.9 kg/m² categories were 37.8% and 73.4%, respectively. In distributions, false-negative (high BF%, but BMI<23.0 kg/m²) readings were observed in 47.9% of the high-BF% subjects. In particular, 10% of BMI 18.5–22.9 kg/m² sub-

Table 2. Relationships of body mass index with body fat percentage by body mass index classes.1

<table>
<thead>
<tr>
<th>Class</th>
<th>Range (kg/m²)</th>
<th>n</th>
<th>r</th>
<th>p</th>
<th>95% confidence interval</th>
</tr>
</thead>
<tbody>
<tr>
<td>Obese</td>
<td>25≤</td>
<td>45</td>
<td>0.573</td>
<td>&lt;0.01</td>
<td>0.335–0.741</td>
</tr>
<tr>
<td>At risk</td>
<td>23–24.9</td>
<td>79</td>
<td>0.331</td>
<td>&lt;0.01</td>
<td>0.118–0.514</td>
</tr>
<tr>
<td>Normal range</td>
<td>18.5–22.9</td>
<td>421</td>
<td>0.385</td>
<td>&lt;0.01</td>
<td>0.301–0.464</td>
</tr>
<tr>
<td>Underweight</td>
<td>&lt;18.5</td>
<td>60</td>
<td>0.179</td>
<td>0.17</td>
<td>–0.078–0.415</td>
</tr>
</tbody>
</table>

1 According to cutoff points for adult Asians (29).

Fig. 3. Appearances and distribution of high-body fat percentage (High-BF%) subjects of each body mass index (BMI) class. Appearance=High-BF% subjects (n)/total subjects (n) in each BMI class. Distributions=High-BF% subjects in each BMI class (n)/total High-BF% subjects (n=94).
Table 3. Screening performance of body mass index (BMI) ≥ 23.0 kg/m² for high-body-fat percentage (BF%) individuals.

<table>
<thead>
<tr>
<th>Body-fat percentage status</th>
<th>Not-high BF%</th>
<th>High BF%</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Not-screened</td>
<td>436</td>
<td>45</td>
<td>481</td>
</tr>
<tr>
<td>Screened</td>
<td>75</td>
<td>49</td>
<td>124</td>
</tr>
<tr>
<td>Total</td>
<td>511</td>
<td>94</td>
<td>605</td>
</tr>
</tbody>
</table>

1 BF% status was classified by 85th percentile BF% (see Table 1).
2 BMI ≥ 23.0 with high-BF% individuals (n = 49) ratio in total high-BF% individuals (n = 94).
3 BMI < 23.0 with not-high-BF% individuals (n = 436) ratio in total not-high-BF% individuals (n = 511).
4 Kappa measures the degree of agreement.

Table 4. Screening performance of body mass index (BMI) ≥ 25.0 kg/m² for high-body-fat percentage (BF%) individuals.

<table>
<thead>
<tr>
<th>Body-fat percentage status</th>
<th>Not-high BF%</th>
<th>High BF%</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Not-screened</td>
<td>494</td>
<td>66</td>
<td>560</td>
</tr>
<tr>
<td>Screened</td>
<td>17</td>
<td>28</td>
<td>45</td>
</tr>
<tr>
<td>Total</td>
<td>511</td>
<td>94</td>
<td>605</td>
</tr>
</tbody>
</table>

1 BF% status was classified by 85th percentile BF% (see Table 1).
2 BMI ≥ 25.0 with high-BF% individuals (n = 28) ratio in total high-BF% individuals (n = 94).
3 BMI < 25.0 with not-high-BF% individuals (n = 494) ratio in total not-high-BF% individuals (n = 511).
4 Kappa measures the degree of agreement.

Discussion

Obesity is defined as excess BF% (1–7). Previously, many convenient BF% measurement techniques for field studies have been developed (21). For example, bioelectrical impedance analysis (BIA) as a new method is readily applied and useful (9, 14, 21–24). In contrast, skinfold thickness (SFT) measurements as a traditional method can provide a reasonable assessment of body fat (4, 15, 21, 25–31). Moreover, the study of Piers et al. (32) suggests that when equation models for these methods are improved, they can provide more accurate body composition. On the other hand, numerous reports have demonstrated that BMI is a reasonable indicator of fatness (7–9). The relationship between BF% and BMI is different among different ethnic groups (33). In young Japanese women, our results also demonstrated that high BMI (BMI ≥ 25.0 kg/m²) is a good reflection of high BF%.

The International Obesity Task Force recommends “BMI classes in adult Asians” (9), whose cutoffs for “at risk of overweight” (≥ 23.0 kg/m²) and “obesity” (≥ 25.0 kg/m²) are lower than called for in the World Health Organization criteria because morbidity and mortality is occurring in people with lower BMIs and smaller waist circumstances in Asian populations. Our results support the concept of an “at risk of overweight” (BMI 23.0–24.9 kg/m²) category focused on preventive medicine because “at risk of overweight” appears as a threshold of increasing high-BF% individuals’ appearance ratio within classified subjects (Fig. 3). We assume that the newly determined BMI cutoff “in Asians” (BMI ≥ 23.0 kg/m²) is valuable and acceptable for mass evaluation as a fatness indicator in comparison to previous cutoffs “in Japanese” (BMI ≥ 25.0 kg/m²), at least among young women.

However, Piers et al. (32) demonstrated that BMI was a poor surrogate for body fatness for individual evaluation. Our results also demonstrated that BMI performs a poor representation of body composition. In BMI ≥ 25.0 kg/m² individuals, it can appear that body composition measurement is not necessitated by the individual evaluation of fatness because BMI ≥ 25.0 kg/m² displayed the strongest relationship (Table 2); moreover, specificity was quite high (Table 3). On the other hand, however, it is clear that the BMI ≥ 25.0 kg/m² category was included in 27.8% of false-positive subjects. Furthermore, we found that approximately 70% of “at risk of overweight” (BMI as 23.0–24.9 kg/m²) individuals were defined as false-positive. Although the sensitivity of BMI ≥ 23.0 kg/m² is improved over that of BMI ≥ 25.0
kg/m², positive individuals are a minority in the category of "at risk of overweight." Furthermore, it appears that they have no health risks because their overweight is caused by increased FFM (1). In contrast, BMI≥23.0 kg/m² overlooked approximately 50% of high-BF% subjects (Fig. 3 and Table 3). The principal limitation of the BMI as a measure of body fat is that it does not distinguish BFM from FFM (4). These false-negative subjects are commonly observed and referred to as "masked obesity" in current young Japanese (16–18). For this reason, it seems difficult for a prediction of BF% using BMI in young Japanese women because the range of 95% CI of predicted BF% derived from BMI was very wide (Fig. 2). This result is consistent with that of Smalley et al. (5). Based on these findings, BMI seems to be more suitable for mass evaluation than for individual evaluation of fatness.

Norgan (34) suggested that the range of BMI 20.0–25.0 kg/m² is more important than those values in excess of 25.0 kg/m². To our knowledge, however, in comparison with research on high BF% with overweight subjects, little attention has been focused on high BF% with low body weight, relative body weight or BMI, or FFM (1). Liu and Manson (35) reviewed several analyses of morbidity. They found a direct association between "normal range" (BMI 18.5–24.9 kg/m²), the typical 5–10 kg of weight gain that occurs during adulthood in Western populations and increased risk of hypertension, type 2 diabetes mellitus, and myocardial infarct (35). And among women with BMI<25.0 kg/m², the amount of weight gained after age 18 remained a strong predictor of the risk of coronary heart disease (35). Similar results in Japanese adults were also reported (36). Moreover, the National Nutrition Survey of Japan indicated that the lifestyle among Japanese has been Westernized, especially among the younger generation (10, 11, 13, 37). Hara et al. suggested that a Westernized lifestyle induces peripheral insulin resistance and promotes the development of diabetes among Japanese (38). These findings suggest that individual evaluation, rather than mass evaluation, of body fatness seems more important for preventive medicine (39). It appears significant that the classification of an individual as lean, when in fact that individual is truly high BF%, may put the individual at risk for disease associated with obesity and potentially delay possible beneficial therapy (5). Therefore we suggest that body composition measurement is required for individual evaluation, especially BMI<25.0 kg/m² individuals.

Kitano et al. compared three different methods for the evaluation of body composition: dual-energy X-ray absorptiometry (DXA), SFT, and BIA. They also suggest that although different cutoff points to define high BF% for each method are required, SFT and BIA are both suitable for population studies (40). This is consistent with our previous study: compared among underwater weighing, SFT, and BIA. As a result of these findings, though the body composition is measured by field methods (e.g., SFT and BIA), it can provide some beneficial information with respect to the prevention of chronic diseases.

In conclusion, the BMI≥25.0 kg/m² category is determined as high BF% for mass evaluation as a result of quite high specificity. Therefore BMI seems to be a valuable indicator of body fatness for mass evaluation. Even so, body composition measurement is necessitated by the individual evaluation of fatness focused on preventive medicine as a result of the BMI of young Japanese women performing a poor representation of body composition, especially BMI<25.0 kg/m² individuals.

REFERENCES


