BMI and morbidity in relation to body composition: a cross-sectional study of a rural community in North-East India

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This paper deals with BMI and morbidity in relation to body-fat mass (BFM) and fat-free mass (FFM). The analysis was based on cross-sectional data concerning the age, household income, anthropometry and morbidity of 575 males aged 18–59 years from a rural community in North-East India. Data on morbidity were based on the self-reported morbidity (SRM) of the subjects during the last 4 weeks before the survey, whereas data on BMI and body composition were estimated from anthropometry. It was found that SRM was significantly associated with age and income. However, the relationship between BMI and SRM was not significant after adjusting for age and income. Separating the BMI into body-fat mass index (BFMI being BFM in kg divided by height squared in metres) and fat-free mass index (FFMI being FFM in kg divided by height squared in metres), it was found that BFMI was significantly associated with SRM after adjusting for age, income and FFMI. The subjects with a low (<2.9 kg/m²) BFMI were about 4.7 times (odds ratio 4.7, 95% CI 2.6, 8.6) more likely to become sick than those with a normal (2.9–5.0 kg/m²) BFMI. In addition, the risk of becoming sick in Asian populations was higher in the subjects with a high (odds ratio 5.0, 95% CI 2.0, 13.0) more likely to become sick than those with a normal (2.9–5.0 kg/m²) BFMI. In addition, the risk of becoming sick in Asian populations (WHO, 2000) indicated that a low BMI was associated with morbidity, especially in developing countries. Studies of dietary-induced weight loss revealed that both body fat mass (BFM) and fat-free mass (FFM) decreased, but to different extents (Keys et al. 1950). Empirical evidence from Asian populations indicated that a low BMI was associated with a low BFM and FFM, although there were differences in the proportion of BFM and FFM (Ferro-Luzzi et al. 1997; Strickland & Tuffrey, 1997). It has also been observed that BMI is higher in Asian than Caucasian subjects at the same BMI (Deurenberg-Yap et al. 2000), possibly due to differences in leg length (Norgan, 1994; Deurenberg & Deurenberg-Yap, 2003). Some studies of the relationship between low BMI and morbidity in developing countries have, of course, produced inconsistent results (Garcia & Kennedy, 1994), despite certain evidence of a curvilinear relationship (de Vanconcellos, 1994). Thus, the purpose of the present paper is to understand the relationship between BMI and self-reported morbidity (SRM) in relation to body composition as estimated from the anthropometry of adult males in a rural population from North-East India.

Materials and methods

Subjects

This study was based on a cross-sectional sample of 575 War Khasi males aged 18–59 years as reported elsewhere for a rural community in North-East India.
different purpose (Khongsdier, 2002). The study was conducted among the rural War Khasis in the East Khasi Hills district of the state of Meghalaya in North-East India. The War Khasis are one of the sub-groups of the Khasi tribe, who speak the Mon-khmer language of the Austro-Asiatic group. They have been following the matrilineal system of society. Their main occupation is agriculture, and rice is their staple food. Data were collected from 366 households (95 %) in five villages (3 %) selected by means of a systematic random sampling of the listed villages in the study area. No statistical sampling of individuals was applied for the collection of anthropometric data due to operational difficulties in the field. However, all adult males (aged 18–59 years) who were willing to cooperate in the study were included in our sample.

**Measurements**

Data on anthropometric measurements included body weight and height as well as biceps, triceps, sub-scapular and supra-iliac skinfold thickness. A beam-balance scale (100 g precision; Galaxy Informatics Ltd, New Delhi, India) was used to weigh the subject barefoot, wearing light apparel. The balance was checked against a standard weight after weighing each subject. The height was measured with a Harpenden anthropometer (1 mm precision; Galaxy Informatics Ltd) and the skinfold thickness with Holtain skinfold calipers (0.1 mm precision; Holtain, Crymych, UK), following the methods described by Weiner & Lourie (1981).

Data on morbidity were based on the ‘self-reported illness experience’ of a subject as generally adopted in surveys, which did not involve a clinician (Strickland & Uljiaszek, 1993; Garcia & Kennedy, 1994; Strickland & Tuffrey, 1997). SRM is also more preferable from the point of view that a clinical diagnosis involves much time, cost and technical expertise, which are not always possible when carrying out community-based studies in developing countries, including India. Despite its limitations (Sadana, 2000), SRM might be considered to be the second alternative proxy for assessing the morbidity status of populations in developing countries. Nevertheless, the term ‘morbidity’ in this study was defined simply in terms of the number of ‘days ill’ and/or ‘days unable to work’ in the last 4 weeks before the survey. Each subject included in the study was asked whether or not he had been ill at any time in the past 4 weeks. If the answer was yes, he was asked how many days had he been in bed or unable to work due to illness. A subject who reported at least 2 d ill was classified as being ‘ill’. No attempt was made to determine the prevalence of a specific disease or symptom. Of 575 subjects included in the study, 137 (23.8 %) reported that they had experienced illness for at least 2 d in the 4 weeks before the survey. This proportion included those who were still unable to go for work at the time of survey because of illness for the previous 4 weeks.

Data on household income were also collected directly from the heads of households after developing a rapport through a prolonged stay in the field; these were cross-checked, taking into consideration some aspects of socio-economic conditions such as housing conditions, types of occupation, land-holding and monthly expenditure. Three economic groups were arbitrarily classified following the interval estimation based on the standard deviation of the average monthly per capita income of households, as described elsewhere (Khongsdier, 2002).

With a view to understanding the relationship between body composition and SRM, the BMI was separated into two components: body fat mass index (BFMI = BFM in kg divided by height squared in metres) and fat-free mass index (FFMI = FFM in kg divided by height squared in metres). BFM and FFMI were estimated using the predicted equations of Durnin & Womersley (1974) and Siri (1961). On the basis of data on 2986 Caucasian men aged 18–98 years, Schutz et al. (2002) and Kyle et al. (2003) have proposed a normal range of 16.7–19.8 kg/m² for FFMI and 1.8–5.2 kg/m² for BFM for a normal range of BMI of 18.5–25.0 kg/m². These Caucasian subjects had a mean height of about 175 cm and weight of 74 kg compared with a mean height of 158 cm and weight of 49 kg for the subjects in the current study. Considering these massive differences in weight and height between the two ethnic groups, as well as the negative relationship between BMI and longer hospital stay (Pichard et al. 2004), the cut-off for the lower range of FFMI was adjusted as follows:

\[
16.7 \times 158 \text{ cm} = 15.1
\]

Therefore, the subjects with FFMI < 15.1, 15.1–18.0 and > 18.0 kg/m² were arbitrarily categorised as having low, normal and high FFMI, respectively. On the other hand, the normal range for BMI was adjusted to 18.0–23.0 kg/m², taking into consideration the recommended cut-off point of 23.0 kg/m² for the upper range of normal BMI in Asian populations (WHO, 2000). Thus, the subjects with BFM < 2.9, 2.9–5.0 and > 5.0 kg/m² were arbitrarily grouped into low, normal and high BFMI categories, respectively.

**Statistical analyses**

Statistical analyses were carried out using the Statistical Package for Social Sciences (Version 10.0; SPSS Inc., Chicago, USA) for Windows, in which the level of significance was set at 5 %. The characteristics of the subjects taken in this study are given in Table 1 according to the different categories used for statistical analyses. The analysis was first carried out to present the age-income-adjusted means of anthropometric measurements and

<table>
<thead>
<tr>
<th>Table 1. Characteristics of study sample (n 575)</th>
<th>Frequency (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Characteristics</strong></td>
<td><strong>Age group (years)</strong></td>
</tr>
<tr>
<td></td>
<td>18–31 (n 159)</td>
</tr>
<tr>
<td></td>
<td>32–45 (n 202)</td>
</tr>
<tr>
<td></td>
<td>46–59 (n 154)</td>
</tr>
<tr>
<td><strong>Income group</strong></td>
<td></td>
</tr>
<tr>
<td>Low (n 224)</td>
<td>38-96</td>
</tr>
<tr>
<td>Middle (n 193)</td>
<td>33-57</td>
</tr>
<tr>
<td>High (n 158)</td>
<td>27-48</td>
</tr>
<tr>
<td><strong>BFM category</strong></td>
<td></td>
</tr>
<tr>
<td>&lt; 18.0 (n 150)</td>
<td>26-09</td>
</tr>
<tr>
<td>18.0–23.0 (n 358)</td>
<td>62-26</td>
</tr>
<tr>
<td>&gt; 23.0 (n 67)</td>
<td>11-65</td>
</tr>
<tr>
<td><strong>FFM category</strong></td>
<td></td>
</tr>
<tr>
<td>&lt; 2.9 (n 329)</td>
<td>57-22</td>
</tr>
<tr>
<td>2.9–5.0 (n 221)</td>
<td>38-43</td>
</tr>
<tr>
<td>&gt; 5.0 (n 25)</td>
<td>4-35</td>
</tr>
<tr>
<td><strong>Reporting and not reporting illness</strong></td>
<td></td>
</tr>
<tr>
<td>Yes (n 137)</td>
<td>23-83</td>
</tr>
<tr>
<td>No (n 438)</td>
<td>76-17</td>
</tr>
</tbody>
</table>
indicators using the one-way analysis of co-variance for both the subjects reporting and not reporting illness. The risk estimates with 95% CI for morbidity relative to age, income, BMI, BFMI and FFMI categories were computed using odds ratios and regression coefficients from logistic regression models. The morbidity dummy was 1 for the subjects reporting illness and 0 for those subjects not reporting illness. The income variable was expressed in terms of individual score, according to whether a given subject belonged to the low-income, middle-income or high-income group, which were graded as 1, 2 and 3, respectively. The low, high and normal categories of BMI, BFMI and FFMI were coded as 1, 2 and 3, respectively. The curve of the relationship between BFMI and percentage SRM was also fitted using the second-degree polynomial model, and the significance of departure from linearity was tested following the method suggested by Snedecor & Cochran (1967).

### Results

**Prevalence of chronic energy deficiency and self-reported morbidity**

Table 1 shows the percentage distribution of the study subjects according to age, income and body composition. About 26%, 62% and 12% of the subjects were in the BMI categories of <18·0, 18·0–23·0 and >23·0 kg/m², respectively. The prevalence of CED, as defined by a BMI <18·0 kg/m² (26%), was about 54% less than that measured by a BFMI <2·9 kg/m² (57%). Nevertheless, it indicates that CED was still a major nutritional problem in the study population. In addition, about 24% of men reported having experienced illness for at least 2 d during the 4 weeks before the survey, and about 39% of them belonged to the low-income group. It may thus be theoretically expected that SRM in this population should be associated with low body composition and poor socio-economic conditions, besides other factors including individual age.

**Subjects of reporting and non-reporting illness**

Table 2 gives the means of anthropometric measurements and indices for the subjects reporting and not reporting illness after adjusting for individual age and household income. According to the analysis of co-variance test, the subjects reporting illness were taller than were the subjects not reporting illness (F-ratio 5·69; degrees of freedom DF 1, 571; P=0·017), despite the absence of a significant difference between them with respect to body weight. Overall, anthropometric measurements and indices relative to body fat composition, for example skinfold thickness, BFMI, percentage BFMI and BFMI, were significantly lower in the subjects reporting illness than in those not reporting illness. There was, however, no significant difference between the two groups with respect to BMI. In this regard, it may be noted that BMI is simply a composite measure of body mass in terms of BFMI and FFMI relative to height. The significant difference between the subjects reporting and not reporting illness with respect to BFMI (F-ratio 7·73; (DF 1, 571; P=0·006) was indicative of the same trend that anthropometric measurements and indices relative to body fat composition were significantly lower in the former than in the latter (Table 2).

#### Table 2. Actual and adjusted means of anthropometric measurements and indices for subjects reporting and not reporting illness

<table>
<thead>
<tr>
<th>Variables</th>
<th>Reporting illness (n 137)</th>
<th>Not reporting illness (n 438)</th>
<th>Analysis of co-variance tests</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Actual</td>
<td>Adjusted</td>
<td>Actual</td>
</tr>
<tr>
<td>Height (cm)</td>
<td>158.81</td>
<td>4.93</td>
<td>158.8</td>
</tr>
<tr>
<td>Weight (kg)</td>
<td>48·24</td>
<td>6·65</td>
<td>49·00</td>
</tr>
<tr>
<td>Log 4 ST</td>
<td>1·43</td>
<td>0·13</td>
<td>1·44</td>
</tr>
<tr>
<td>BMI (kg/m²)</td>
<td>19·21</td>
<td>2·66</td>
<td>19·50</td>
</tr>
<tr>
<td>Body fat mass (kg)</td>
<td>6·29</td>
<td>3·24</td>
<td>6·67</td>
</tr>
<tr>
<td>Body fat mass (%)</td>
<td>12·57</td>
<td>4·16</td>
<td>12·89</td>
</tr>
<tr>
<td>Fat-free mass (kg)</td>
<td>41·95</td>
<td>3·98</td>
<td>42·42</td>
</tr>
<tr>
<td>Fat-free mass index (kg/m²)</td>
<td>16·64</td>
<td>1·49</td>
<td>16·83</td>
</tr>
<tr>
<td>Body fat mass index (kg/m²)</td>
<td>2·50</td>
<td>1·31</td>
<td>2·61</td>
</tr>
</tbody>
</table>

ST, skinfold thicknesses (biceps - triceps - sub-scapular - supra-iliac).
and BFMI. As with BMI, there was no significant relationship between FFMI and SRM. Age, income level and FFMI were adjusted in the fifth model. The subjects with a low BFMI (<2·9 kg/m²) were about 4·7 times (95 % CI 2·6, 8·6; \( b_{1·547} (SE 0·307); P_{0·0001} \)) more likely to become sick than those with a normal BFMI (2·3–5·0 kg/m²). Also, the risk of getting sick was about four times higher in the subjects with a high BFMI (>5·0 kg/m²) than those with a normal BFMI (95 % CI 1·3, 9·8; \( b_{1·372} (SE 0·557); P_{0·014} \)).

Figure 1 shows the prevalence of SRM (%) according to BFMI categories of 1·5, 1·6–2·0, 2·1–2·5, 2·6–3·0, 3·1–3·5, 3·6–4·0, 4·1–5·0 and >5 kg/m². The means of these BFMI groups were 1·44, 1·78, 2·30, 2·79, 3·27, 3·76, 4·43 and 6·2 kg/m², respectively, as indicated in the figure by the eight data points with 95 % CI error bars. The curve was fitted using the second-degree polynomial model. It was found that the nature of relationship between BFMI and SRM was U-shaped. The significance of a departure from linearity was tested as described by Snedecor & Cochran (1967), this being found to be significant (\( F\)-ratio = curvilinearity of regression divided by mean squares of deviations from quadratic regression \( = 583·39/62·46 = 9·34; DF 1, 5; P_{0·05} \)). The polynomial equation was derived as follows:

\[
SRM(\%) = 89·199 + (−2·370)\times BFMI + 4·432\times BFMI^2
\]

The summary of logistic regression of SRM on BFMI in relation to age, income and BFMI is given in Table 4. Overall, the results showed that there was a negatively significant relationship between BFMI and SRM (\( b_{= −0·456 (SE 0·149); P_{<0·002} \) bootstraping the present study.}

### Table 3. Prevalence of self-reported morbidity (SRM) by age, income, BMI and its components

<table>
<thead>
<tr>
<th>Categories</th>
<th>n</th>
<th>Prevalence of SRM (%)</th>
<th>Odds ratio (95 % CI)</th>
<th>( b )</th>
<th>se ( b )</th>
<th>P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age groups (years)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>18–31</td>
<td>179</td>
<td>15·64</td>
<td>1·00</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>32–45</td>
<td>202</td>
<td>24·26</td>
<td>1·74 (1·04–2·93)$^*$</td>
<td>0·555</td>
<td>0·265</td>
<td>0·036</td>
</tr>
<tr>
<td>46–59</td>
<td>194</td>
<td>30·93</td>
<td>2·36 (1·42–3·92)$^*$</td>
<td>0·858</td>
<td>0·259</td>
<td>0·001</td>
</tr>
<tr>
<td>Income groups</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>High</td>
<td>158</td>
<td>15·19</td>
<td>1·00</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Middle</td>
<td>193</td>
<td>25·91</td>
<td>1·91 (1·10–3·30)$^\dagger$</td>
<td>0·645</td>
<td>0·280</td>
<td>0·021</td>
</tr>
<tr>
<td>Low</td>
<td>224</td>
<td>28·13</td>
<td>2·06 (1·21–3·51)$^\dagger$</td>
<td>0·725</td>
<td>0·271</td>
<td>0·007</td>
</tr>
<tr>
<td>BMI categories</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>18·0–23·0</td>
<td>358</td>
<td>22·07</td>
<td>1·00</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>&lt;18·0</td>
<td>150</td>
<td>33·33</td>
<td>1·39 (0·89–2·15)$^\dagger$</td>
<td>0·326</td>
<td>0·225</td>
<td>0·147</td>
</tr>
<tr>
<td>&gt;23·0</td>
<td>67</td>
<td>11·94</td>
<td>0·58 (0·26–1·29)$^\dagger$</td>
<td>−0·542</td>
<td>0·405</td>
<td>0·181</td>
</tr>
<tr>
<td>Fat-free mass index categories</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>15·1–18·0</td>
<td>391</td>
<td>24·55</td>
<td>1·00</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>&lt;15·1</td>
<td>58</td>
<td>32·76</td>
<td>0·90 (0·47–1·71)$^\ddagger$</td>
<td>−0·108</td>
<td>0·328</td>
<td>0·743</td>
</tr>
<tr>
<td>&gt;18·0</td>
<td>126</td>
<td>17·46</td>
<td>1·54 (0·79–3·01)$^\ddagger$</td>
<td>0·430</td>
<td>0·343</td>
<td>0·210</td>
</tr>
<tr>
<td>Body-fat mass index categories</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2·9–5·0</td>
<td>221</td>
<td>9·50</td>
<td>1·00</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>&lt;2·9</td>
<td>329</td>
<td>32·83</td>
<td>4·71 (2·57–8·58)$^</td>
<td></td>
<td>$</td>
<td>1·547</td>
</tr>
<tr>
<td>&gt;5·0</td>
<td>25</td>
<td>32·00</td>
<td>3·94 (1·32–9·75)$^</td>
<td></td>
<td>$</td>
<td>1·372</td>
</tr>
</tbody>
</table>

* Adjusted for income.
† Adjusted for age.
‡ Adjusted for age and income.
§ Adjusted for age, income and BFMI.
\(k\) Adjusted for age, income and fat-free mass index.

### Table 4. Coefficients of logistic regression of self-reported morbidity on body-fat mass index (BFMI) and fat-free mass index (FFMI)

<table>
<thead>
<tr>
<th>Variables</th>
<th>( \beta )</th>
<th>se ( \beta )</th>
<th>Wald test</th>
<th>P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age</td>
<td>0·039</td>
<td>0·009</td>
<td>18·07</td>
<td>0·000</td>
</tr>
<tr>
<td>Income</td>
<td>−0·169</td>
<td>0·136</td>
<td>1·54</td>
<td>0·215</td>
</tr>
<tr>
<td>FFMI</td>
<td>0·158</td>
<td>0·096</td>
<td>2·73</td>
<td>0·099</td>
</tr>
<tr>
<td>BFMI</td>
<td>−0·456</td>
<td>0·149</td>
<td>9·36</td>
<td>0·002</td>
</tr>
</tbody>
</table>

### Discussion

**Chronic energy deficiency and self-reported morbidity in relation to age and economic condition**

In view of the present findings and those reported for some populations in North-East India (Khongsdier, 2001), the prevalence of CED (26 %) in the study population is still a major concern when compared with that of overweight (12 %). Moreover, the subjects show a significant difference in morbidity rate according to age and economic status. The positive correlation between age, income level and SRM indicates that older adults and those with lower income levels are at higher risk of self-reported morbidity. This finding is consistent with previous studies which have shown that older adults and low-income populations have higher rates of morbidity (Khongsdier, 2001). The relationship between BMI and SRM was found to be significant, with higher BMI associated with a higher risk of morbidity. This is consistent with previous research which has shown that individuals with a higher BMI are at greater risk of chronic diseases (Khongsdier, 2001).

The prevalence of self-reported morbidity (SRM) by age, income, BMI and its components is summarized in Table 3. The table shows a significant increase in the prevalence of SRM with age, income level, and BMI categories. The prevalence of SRM was lowest in the age group of 18–31 years and highest in the age group of 46–59 years. Similarly, the prevalence of SRM was lowest in the low-income group and highest in the high-income group. The prevalence of SRM was also found to be significantly higher in the BMI category of 18·0–23·0 kg/m² compared to other BMI categories. This finding is consistent with previous research which has shown that individuals with a BMI in the normal range have a lower risk of morbidity (Khongsdier, 2001).
belonging to the low-income group had about twice the risk of getting sick when compared with those belonging to the high-income group. In addition, the prevalence of SRM in the age group aged 46–59 years was more than twice that of the lower age group of 18–31 years. This indicates the significant role of age and socio-economic status in patterning BMI and morbidity. However, the relationship between BMI and SRM was not significant after adjusting for age and income level. Considering BMI alone, it looks as though SRM in the present population was not associated with low or high BMI, but that it occurred mainly because of poor economic condition compounded by age and other socio-environmental factors (Khongsdier, 2002). Therefore, although BMI is widely considered to be a variable indicating the socio-economic and health status of the population, its relationship with morbidity in the present sample of adult males was not statistically perceptible.

**BMI and its components**

It is obvious from the current analysis that the absence of a significant relationship between BMI and SRM was due not only to the confounding effects of age and income level, but also to the effects of body composition. After separating the BMI into BFMI and FFMI, the results indicated that BFMI was significantly associated with SRM, the relationship being U-shaped after fitting according to the second-degree polynomial model. Thus, the present findings indicate that BMI is actually associated with morbidity in terms of BFMI, but not in terms of both BFMI and FFMI.

The present findings are therefore inconsistent with the general observation that BMI is a good indicator of fatness and associated morbidity and/or mortality, especially in developed countries (Garrow, 1988; Allison et al. 1999; Must et al. 1999; Himes, 2000; Barbagallo et al. 2001; Farrell et al. 2002; Krueger et al. 2004). It may be noted that BMI is highly correlated with both BFMI and FFMI (Garn et al. 1986; Norgaard, 1994). Accordingly, it is likely that the respective relationship of these two components of body composition and morbidity is not accounted for by BMI alone. It has been suggested that BMI alone is not a good indicator of the respective contribution of BFMI and FFMI to the body mass of an individual (Garn et al. 1986; Frankenfield et al. 2001; Prentice & Jebb, 2001; Kyle et al. 2003). In their study of rural men and women in Guatemala, Immink et al. (1992) also observed that BMI explained little of the variation in BFMI and FFMI, especially at a low level of BMI. Thus, although BMI is widely used as an indicator of fatness, it does not always provide accurate information about BFMI relative to FFMI and other components of body composition. This may have certain implications for the variation in the responses of BFMI and FFMI to ageing, physical activity, genetic/ethnic factors, etc. (Forbes, 1987, 1999; Guo et al. 1999; Mott et al. 1999; Wagner & Heyward, 2000; Hughes et al. 2002).

**Low body-fat mass index and self-reported morbidity**

The present findings are also inconsistent with the recent findings that low FFMI, but not low BFMI, in Caucasian patients is associated with a longer length of hospital stay (Pichard et al. 2004). This study was, however, primarily concerned with the risk of becoming sick in the individuals with a low BMI relative to a low BFMI or FFMI at population level. It had little to do with the severity of illness or prolonged hospital stay due to CED or low BMI. Moreover, this study might have missed information on chronic illness that did not cause the subject to report the days of being ill in the 4-week reporting period. Therefore, the relationship between low BMI and morbidity in relation to low BFMI and FFMI warrants more future studies, especially in developing countries where such data are still limited. The present findings, nevertheless, seem to support the hypothesis that low fatness or energy fat stores may have functional and health consequences (James et al. 1988; Shetty & James, 1994; WHO, 1995).

In this study, the adjusted mean of percentage BFMI in the subjects of reporting illness was 12.9%, which was similar to the cut-off point (13%) predicted for the healthy Asian men aged 20–59 years (Gallagher et al. 2000). Whether the percentage BFMI of 13% should be used as the cut-off point for screening the individuals who are likely to become sick with a low BMI is subject to further studies in other Asian populations. It has, however, been suggested that fatness relative to height, rather than fatness relative to body weight, is more appropriate for assessing overweight and obesity (Garrow & Webster, 1985; Frankenfield et al. 2001). In other words, BFMI may be considered more appropriate than percentage BFMI for measuring fatness at both individual and population levels.

**Cut-off points**

It has been proposed that the normal range for BFMI is 1.8–5.2 kg/m² for the normal range of BMI 18.5–25.0 kg/m² (Schutz et al. 2002; Kyle et al. 2003). In this study, the mean BFMI values in the subjects reporting and not reporting illness for the BMI range of 18.5–23.0 kg/m² were 2.68 and 3.19 kg/m², respectively, after allowing for age and income level (F-ratio 31.88; DF 1, 302; P<0.0001). This indicates that the mean BFMI values are in the normal category for both the subjects reporting and not reporting illness. The significant differences between them may, however, be related to the observation that BFMI is higher in Asian than in Caucasian populations (Norgaard, 1990; Gallagher et al. 2000). Indeed, many studies have suggested lower cut-off points for screening the prevalence of overweight and obesity in Asian populations (Deurenberg-Yap et al. 2000; Ko et al. 2001; Lin et al. 2002; Shiwaku et al. 2004). In addition, the WHO Regional Office for Western Pacific Region, in collaboration with the IASO and IOTF, has recommended a BMI of 23.0 kg/m² as the cut-off point for defining overweight in Asian populations (WHO, 2000).

In the present study, the cut-off point for the lower range of normal BMI was also reduced to 18.0 kg/m² for screening the individuals with underweight or CED. Thus, the normal range for BMI was set at 18.0–23.0 kg/m², bearing in mind the recommended cut-off for the upper range (WHO, 2000). It has recently been reported that low FFMI in Caucasian patients is associated with longer hospital stays (Pichard et al. 2004). Considering the lower range for normal FFMI in Caucasian subjects (Schutz et al. 2002; Kyle et al. 2003), the cut-off point of 15.1 kg/m² for low FFMI was obtained after allowing for height. Thus, the normal range for FFMI was adjusted to 15.1–18.0 kg/m². In addition, the corresponding range for normal BFMI was arbitrarily adjusted to 2.9–5.0 kg/m². There are still limited data from Asian populations on the relationship between low BMI (especially low BFMI or FFMI) and morbidity or mortality (Garcia & Kennedy, 1994; Yuan et al. 1998; Khongsdier, 2002). In the current analysis, this point is not certain by looking.
at BMI alone. It is, however, likely that men with a BFMI of <2.9 or >5.0 kg/m² would have a higher risk of becoming sick than those with a normal BFMI (2.9–5.0 kg/m²).

Study limitations

Anthropometric measurements, including skinfold thickness, are the classical techniques used by anthropologists for comparative studies of human forms at a population level. Although they are useful in the field because they are simple and easy to perform, their lack of precision and specificity is a drawback in estimating the body composition at an individual level (Johnston, 1982). Thus, prediction equations of total body fatness from skinfold measurements are primarily population-specific, thereby lacking a general validity (Norgan & Ferro-Luzzi, 1985). Moreover, such equations assume that the proportion of internal and external fat stores is constant at any level of fatness. Thus, individual and/or population variation, besides age and sex variation, in the distribution of internal and external fat stores may affect the general validity of prediction equations based on skinfold thickness (Davies, 1994). This holds true with the Durnin and Womersley equation, which was derived from skinfold measurements of Caucasian subjects. Using a four-compartment model as a reference, it has been recently shown that the Durnin and Womersley equation also underestimates the percentage of body fat (Peterson et al. 2003). Nonetheless, it is crucial to realise that methods used for assessing the body composition of populations are subject to approximation and are not entirely free from limitations or different types of error. Although it is always necessary to develop more accurate methods, it is also crucial to realise that human biological variation and its associated morbidity/mortality might be best measured with a consistency of the use of methods or techniques of measurements and analyses. As for skinfold equations, the Durnin and Womersley equation is commonly used, and it appears to be ‘the best of a poor bunch’ (Norgan, 1995), especially among Indians (Jones et al. 1976).

The other limitation of the present study is concerned with the data on morbidity, which were based on self-reported illness during the 4 weeks before the survey. The SRM was simply a sweeping generalisation about ill health, regardless of specific diseases or impairments that the subjects had suffered. Moreover, the present study might have failed to ascertain information about chronic illness that did not cause the subject to report the days of being ill in the last 4 weeks before the survey. Longitudinal studies should thus be also carried out in order to have a better understanding of the relationship between BMI, or body composition, and morbidity in developing countries.

Conclusions

Despite certain limitations of this study, it is possible that BMI alone may provide misleading information about the relationship between morbidity and body fat or body energy stores. Subject to further studies, breaking up BMI into BFMI and FFMI is likely to provide more information about the nature and degree of such relationship. This does not, however, mean that BMI is not at all suitable for assessing the nutritional and health status of a population. BMI as an indicator variable continues to serve well for different purposes, including the assessment of standards of living in developing countries (Nube et al. 1998). BMI may be useful in screening those individuals who are likely to be malnourished. As a composite measure of the total body mass relative to height, BMI needs to be supplemented by other quantitative and qualitative measures of the health and nutritional status of an individual or a population.

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References


