Human Variation and Body Mass Index: A Review of the Universality of BMI Cut-offs, Gender and Urban-rural Differences, and Secular Changes

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Abstract Use of BMI as a surrogate for body fat percentage is debatable and universal BMI cut-off points do not seem appropriate; lower cut-off points than currently recommended by WHO should be used in some populations, especially in Asia. The adult WHO BMI database indicates that, on average, women are more obese than men, while men are more likely to be pre-obese than women. Urban rates of overweight and obesity are generally higher than rural rates in both sexes. The trend in pre-obesity and obesity over time is generally upward, with very marked increases in the USA and UK in both sexes over the last 10 years. J Physiol Anthropol 26(2): 109–112, 2007 http://www.jstage.jst.go.jp/browse/jpa2 [DOI: 10.2114/jpa2.26.109]

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Introduction

Excessive body fat or obesity is associated with increased mortality and morbidity. However fat mass in the human body is difficult to measure under field conditions, and obesity has been defined by WHO (1995) based on Body Mass Index (BMI, weight/height², kg/m²). Because BMI does not measure fat mass or fat percentage and because there are no clearly established cut-off points for fat mass or fat percentage that can be translated into cut-offs for BMI, the WHO Expert Committee in 1995 decided to express different levels of high BMI in terms of degrees of overweight rather than degrees of obesity, which would imply knowledge of body composition. Later, in 1998, WHO defined obesity as a condition with excess body fat such that health and well-being are adversely affected.

For adults, the Expert Committee of WHO (WHO, 1998) proposed a BMI classification with cut-offs of 25, 30, and 40 for Grades I, II, and III, respectively, based principally on the association between BMI and mortality. They made, though, important points in interpreting these cut-offs which need reiterating:

1. The recommended cut-offs are appropriate for identifying the extent of overweight in individuals and populations, but do not imply targets for intervention.
2. The broad ranges of BMI do not imply that an individual can fluctuate within this range without consequence; for example, for an individual 1.75 m tall, the BMI range of 18.5–24.9 covers a weight range of 20 kg.
3. Weight gain in adult life may be associated with increased morbidity and mortality independently of the original degree of overweight.
4. The cut-offs for degrees of overweight should not be interpreted in isolation but always in combination with other determinants of morbidity and mortality, e.g., disease, smoking, blood pressure, glucose intolerance, type of fat distribution, etc.

The method used to establish BMI cut-offs has been largely arbitrary and has been based on the visual inspection of the relationship between BMI and mortality whereby the cut-off of 30 relates to a point of flexion of the curve. However a number of studies on BMI and mortality have methodological drawbacks (such as failure to control for cigarette smoking and to eliminate early mortality) and most have been conducted on people living in Western Europe or the USA (Duerenberg, 2001).

Even with these caveats there are some general points which can be made:

1. Weight gain is associated with increased morbidity and mortality.
2. Overweight is associated with increased morbidity and mortality.
3. Weight cycling (repeated treatment of overweight) may be associated with increased morbidity and mortality.
4. Weight loss in the overweight is difficult to sustain, and is still of uncertain benefit to health in the long term, and may lead to weight cycling.

The relationship between BMI and mortality is U-shaped, or J-shaped. The minimum follow-up period is about 5 years and at least 7000 individuals need to be studied for there to be sufficient power to detect a positive association between BMI and mortality. The high deaths at low BMI are dominated by digestive and pulmonary disease, but high BMI is related
predominantly to cardiovascular disease, diabetes mellitus, and gallbladder disease.

It has been argued that the high mortality at low BMI is due to smoking and disease confounders and that the relationship between BMI and mortality may be linear. A study of 8828 Seventh-Day Adventist men for whom such confounders were minimal did demonstrate a linear association, with the lowest mortality among the leanest men (BMI <20) (WHO, 2004).

A number of studies have found evidence that overweight is associated with increased prevalence of cardiovascular risk factors such as hypertension, unfavourable blood lipid concentrations, and diabetes mellitus. Overweight does not appear to be a major risk factor for stroke (although abdominal fatness is associated with increased risk) (WHO, 2004).

**BMI as a Measure of Body Fatness**

BMI appears to be quite a good indicator of the deposition of excess energy as fat in adult white men and women living in Europe and North America. It is less appropriate for other populations who differ in body build and body proportions. Even so, using BMI to classify individuals according to fatness may result in misclassification because of the varying contributions of bone mass, muscle mass, and fluid to body weight.

The percentage of body fat (%BF) increases with aging and is higher in women than men—for example, a BMI of 30 in Dutch men implies a body fat content of about 30% at 20 years of age and about 40% at 60 years of age. In women at these ages, the percentages are 40% and 50%, respectively.

**Universal BMI Cut-offs?**

The classification initially put forward by WHO was:

- Normal range: BMI 18.50–24.99
- Grade I overweight: BMI 25.00–29.99
- Grade II overweight: BMI 30.00–39.99
- Grade III overweight: BMI ≥40.00

However, a number of studies over the past decade or so have shown that the relationship between BMI and %BF is not only age- and sex-dependent, but also differs among ethnic groups. For example, ‘Asians’ living in New York, USA, had a lower BMI but higher %BF than age- and sex-matched Caucasians (Wang et al., 1994). The BMI-%BF relationship differed in Indonesians, Japanese, Polynesians, Singaporean Chinese, Malays, and Indians, and African groups compared with Caucasians. There are also studies which do not find differences among ethnic groups, for example, Beijing Chinese and Dutch Caucasians. These data are not necessarily conflicting, but the methods and/or formulae used for the assessment of %BF rely on assumptions that are not valid for the population under study. In addition, studies have shown that in some Asian populations morbidity and mortality of obesity-related diseases are high at low levels of BMI.

In 2004, a WHO expert consultation addressed the debate about interpretation of recommended BMI cut-off points for determining overweight and obesity in Asian populations and considered whether population-specific cut-off points for BMI were necessary. The consultation concluded that the proportion of Asian people with a high risk of type 2 diabetes and cardiovascular disease is substantial at BMIs lower than the existing cut-off point for overweight. However, the available data did not indicate a clear BMI cut-off point for all Asians for overweight and obesity. The cut-off point for observed risk varied between a BMI of 22 and 25 in different Asian populations; for high risk it varied between a BMI of 26 and 31. No attempt was made, therefore, to redefine cut-off points for each population separately and the consultation identified further potential public health action points of 23.0, 27.5, 32.5, and 37.5 along the continuum of BMI.

**The WHO BMI Adult Database**

The WHO Global Database on BMI (www.who/bmi), was initially developed to provide a systematic collation of nationally representative and sub-national prevalences of overweight, pre-obese, and obese together with BMI means and standard deviations. However, information covering the entire spectrum of under- and overweight among adult populations is underway. So far the database includes about 400 surveys (about 50% of which are national surveys), carried out between 1942 and the present, from about 100 countries and territories and covers about 88% of the world’s population. The smallest national sample is currently from Fiji (n=1157) and the largest from China (n=239,972), with a median sample size of 5,311.

The highest obesity prevalences are found in Oceania (Nauru, 79.4%, Tonga, 56.0%, Cook Islands, 43.0%, French Polynesia, 40.9%) and North America (USA, 30.9%). The lowest prevalences (<5%) are in parts of Asia (India, 0.45%, Laos, 1.1%, Korea, 2.4%, Japan, 3.1%, and Pakistan, 3.4%) and Africa (Gambia, 2.3%, and Ghana, 3.1%). Pre-obesity rates are, on average, nearly 15% higher than obesity rates (range −8.4% to +26.0%) and only the Oceanic countries have higher obesity than pre-obesity rates. On average, a 1% change in pre-obesity prevalence is associated with a 0.65% change in obesity.

**Gender differences in overweight and obesity**

No significant difference in overweight prevalence between the sexes was found using the WHO database. Females, were, on average, significantly more obese (female-male difference of +4.6%) and these higher rates are found in 81% of the countries studied. The greatest excess of female over male obesity is in countries in the African region: South Africa (20.8% excess), followed by Egypt (20.4%) and Seychelles (19.7%). Countries with higher male than female obesity prevalences are mainly found in Europe (Croatia, Denmark,
Estonia, Ireland, Italy, Spain, and Switzerland). Males on average have higher rates of pre-obesity than females (5.4%) and the higher rates are found in 68% of countries.

**Urban-rural differences in overweight and obesity**

National data on urban-rural pre-obesity and obesity rates in the same survey were available for eight countries (Czech Republic, Egypt, India, Iran, Morocco, Pakistan, Peru, and South Africa) from 5 of the 6 regions (all except North America). After taking into account between-country and gender variation, urban obesity (and pre-obesity) rates were, on average, just significantly higher than rural ones with mean differences of 2.2% and 5.3% in males and females respectively.

**Secular trends in the prevalence of overweight and obesity**

In 22 out of the 29 countries with two surveys, the prevalence of female obesity rose between surveys with an average increase of 1.4%. For males there was a rise in 21 out of the 28 countries. The time between surveys was on average just under 6 years (range 1–14 years) and the yearly increase in obesity was highly significant, averaging +0.48%/year. For pre-obesity the results were in the same direction: for females in 15 of the 25 countries there was a rise (mean

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**Fig. 1** Secular trends in obesity.
increase = +0.86%), while in males, pre-obesity prevalence rates rose in 17 of the 24 countries (mean increase = +0.67%). The average increase per year was 0.40%. For overweight in females there was a higher prevalence in the latest survey for 17 of the 27 countries, while in males there was an increase in the most recent study for 17 of the 26 countries. On average the rise was 2.0% and 2.67% in males and females, respectively.

Eleven countries have conducted 4 or more national surveys over the past 30 years. Figure 1 presents the secular trends in obesity for 7 of these countries. There are very marked increases in obesity in the USA and UK but only very limited increases in Japan, especially in females.

Discussion

This paper has shown that there are caveats in using BMI as a surrogate for percentage body fat and the validity of universal cut-off points is highly questionable, especially in Asian populations. For example, Ko et al. (2001) examined the BMI and body fat in 5,153 Hong Kong Chinese and found that the BMI corresponding to the conventional upper limit of normal body fat was 22.5–23.1 kg/m², and the BMI corresponding to the 90th percentile of body fat was 25.4–26.1 kg/m². They suggested a BMI of 23 kg/m² and 26 kg/m² as the cut-off values to define overweight and obesity in Hong Kong Chinese. However, lowering the cut-off point for obesity in Singapore from a BMI of 30 to a BMI of 27 would increase the prevalence of obesity from about 6% to 16% (Deurenberg-Yap et al., 2000) and that has an important impact on public health policies of a country, as well as massive economic implications.

The newly constructed WHO adult database provides for the first time evidence that across countries there is some consistency with men, on average, being more likely to be pre-obese, women more likely to be obese, but no gender difference in the percentage who are overweight. For those countries with national urban and rural data, urban rates of pre-obesity and obesity were generally higher in both sexes urban populations.

The trend in pre-obesity and obesity over time is generally upward, with very marked increases in the USA and UK over the last 10 years. Global estimates of the number of people who are overweight or obese are over 1 billion, which exceeds for the first time in human history the numbers (800 million) who do not have enough to eat.

References


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