Asians are different from Caucasians and from each other in their body mass index/body fat per cent relationship

P. Deurenberg[1], M. Deurenberg-Yap[2] and S. Guricci[3]

[1]Wageningen University, the Netherlands, and University 'Tor Vergata', Rome, Italy, [2]Research and Information Management, Health Promotion Board, Singapore, [3]School of Public Health, University of Indonesia, Depok

Address reprint requests to: P Deurenberg, 135 Serangoon Avenue 3, no. 10-01, Chiltern Park, 556114 Singapore, Singapore.
E-mail: padeu@singnet.com.sg

Summary

The objective was to study the relationship between body mass index (BMI) and body fat per cent (BF%) in different population groups of Asians. The study design was a literature overview with special attention to recent Asian data. Specific information is provided on Indonesians (Malays and Chinese ancestry), Singaporean Chinese, Malays and Indians, and Hong Kong Chinese. The BMI was calculated from weight and height and the BF% was determined by deuterium oxide dilution, a chemical-for-compartment model, or dual-energy X-ray absorptiometry. All Asian populations studied had a higher BF% at a lower BMI compared to Caucasians. Generally, for the same BMI their BF% was 3–5% points higher compared to Caucasians. For the same BF% their BMI was 3–4 units lower compared to Caucasians. The high BF% at low BMI can be partly explained by differences in body build, i.e. differences in trunk-to-leg-length ratio and differences in slenderness. Differences in muscularity may also contribute to the different BF%/BMI relationship. Hence, the relationship between BF% and BMI is ethnic-specific. For comparisons of obesity prevalence between ethnic groups, universal BMI cut-off points are not appropriate.

Keywords: Body composition, body fat per cent, body mass index, Caucasians, Chinese Indians, ethnic, Malays, obesity, overweight

Introduction

The human body contains a considerable amount of fat, mainly meant to be a store of energy. The physiological normal amount of body fat depends on gender and age (1). In young- to middle-aged subjects the upper limit of a normal and healthy body fat per cent (BF%) is ≈25–30% in males and 35–40% in females (2,3). High levels of body fat are related to an increased risk of morbidity and mortality. The amount of body fat can be determined *in vivo* by a number of techniques (1,4–6), including densitometry, deuterium oxide dilution and dual-energy X-ray absorptiometry (DXA). The disadvantages of these methods are

that they normally require specialized equipment and techniques that can be prohibitive in terms of cost and time (5). For epidemiological studies, anthropometric measurements (e.g. skinfold thickness at various sites of the body, and body circumferences, i.e. waist circumference) or bioelectrical impedance measurements are suitable for assessing body composition. Unfortunately these techniques have been validated mainly in Caucasian populations and the reference techniques used in such validation studies assume rules and constants that may not be valid in other individuals or in other groups of subjects (6). Rules and constants may be different across ethnic groups, potentially leading to systematic bias when comparing body composition of groups of different ethnic origin (7).

142 Increased fat lean/ratios in Asians *P. Deurenberg* et al.

obesity reviews

Relationship between body mass index and body fat percent

Obesity is defined by the World Health Organization (WHO) as a condition of excessive fat accumulation in the body to the extent that health and well-being are adversely affected (8). An increased BF% is normally coupled to an increase in body weight. It has long been recognized that weight-for-height indices can be used as indicators of BF%. The Quetelet's index (9) or body mass index (BMI; weight × height^{-2}, kg m^{-2}) has the advantage over other indexes, such as the Ponderal Index [$^3\sqrt{}$(weight) × height^{-1}; ref. 10], in that the index is not or only minimally correlated with height, which is a prerequisite for an index that aims to adequately indicate body fatness.

It has been shown in many population studies that morbidity and mortality are increased at high levels of relative body weight or BMI. The WHO defininition of obesity in adults is a BMI of >30 kg m^{-2} (8). The relationship between BMI and risk of comorbidities is given in Table 1.

Womersley & Durnin published a report in which they described the relationship between BMI and BF% in males and females in different age categories (11). This report was followed by others (12–15), all showing that BF% can be adequately predicted from BMI as long as age and gender are taken into account.

In recent years, accumulating evidence has suggested that the relationship between BMI and BF% differs between ethnic groups (16). Wang *et al.* (17), using DXA, showed that 'Asians' living in the New York area have a lower BMI but a higher BF% compared to age-matched Caucasians. Two years later the same authors published another report showing that other ethnic groups also differ in their BMI/BF% relationship (18). Recently, Gallagher *et al.* reported higher BF% levels at lower BMI in Japanese when compared to Caucasians (from the United States and the UK) and American Blacks (19). Luke *et al.* (20) showed that population samples from Blacks in Nigeria, Jamaica and the United States differ in their BMI/BF% relationship.

Table 1 Classification of weight in adults according to body mass index (BMI) (8)

Classification	BMI (kg m^{-2})	Risk of comorbidities
Underweight	<18.5	Low
Normal range	18.5–24.9	Average
Overweight	>25.0	
Pre-obese	25.0–29.9	Increased
Obese class I	30.0–34.9	Moderate
Obese class II	35.0–39.9	Severe
Obese class III	>40	Very severe

Differences in physical activity level were discussed as a possible explanation. In a recent review, Wagner *et al.* (21) suggest that BMI cut-off values for obesity in American blacks should be defined at higher values to have national obesity figures compatible with American whites. Swinburn *et al.* (22,23) reported differences between Caucasians and Polynesians, and Norgan (24) explained the low BMI and relatively high body fat in Australian Aboriginals by their high relative leg length (compared to stature). Recent studies in Hong Kong show that Hong Kong Chinese have a higher BF% than Caucasians with comparable BMI (25,26). These findings are in agreement with the higher morbidity risks at low BMI in Hong Kong Chinese (27). There are also studies that report no differences in the BMI/BF% relationship across ethnic groups. For example, Gallagher *et al.* (15) found no differences between Caucasians and Afro-Americans living in New York, and Deurenberg *et al.* (28) found no difference between Dutch Caucasians and Beijing Chinese.

In 1998, data available from the literature were summarized in a meta-analysis and from this it can generally be stated that not all ethnic groups have the same BMI/BF% relationship (29). Possible explanations for these differences might be differences in activity level (20), in relative leg lengths (16,24) and/or in frame size (29).

Conflicting findings in the literature may be a result, in part, of methodological errors when different body composition methodologies were used. To avoid this, studies are necessary in which different ethnic groups are measured in the same laboratory using the same methodology, as carried out, for example, in the studies of Wang *et al.* (17,18) and Gallagher *et al.* (15), or using highly standardized methodology in different laboratories. However, even then, results may be biased owing to violations of assumptions that could differ for each study group (7). For this reason, the first study of Swinburn *et al.* (22) may be criticized, as not only a doubly indirect method (bioelectrical impedance) was used to assess BF%, but also different instruments and different standardization procedures were used when comparing Caucasians with Polynesians. In a second study, Swinburn *et al.* (23) used DXA as method of reference and confirmed the results of the first study; however, DXA cannot be regarded as a method of reference (30). In the comparison between Dutch Caucasians and Beijing Chinese (28), underwater weighing was used at both study sites, but the assumed constant and equal density of the fat-free mass may not be applicable to both populations. Recently it was shown that Singapore Chinese have a higher density of the fat-free mass than Dutch Caucasians (31), resulting in an underestimation of BF% when using densitometry and Siri's (32) equation. This could explain the conflicting results between the studies of Wang *et al.* (17) and Deurenberg *et al.* (28) among Chinese and Caucasians.

As obesity is defined as a condition where there is excess body fat (8), and not excess weight (in fact, excess BMI), a different BMI/BF% relationship among ethnic groups could result in different cut-off points for obesity. In the meta-analysis (29) mentioned above it was discussed that based on body composition data the BMI cut-off point for obesity in American Blacks should be higher than $30 \, \mathrm{kg \, m^{-2}}$, while that for Indonesians and Thais should be considerably lower.

For a well-defendable BMI cut-off point for obesity, however, not only body composition data are important, but also the relationship between body composition (BMI, in fact BF%) and risk factors for morbidity and mortality. Needless to say, lowering the cut-off point for obesity has consequences for prevalence figures in a population and hence for public health policies.

Not all 'Asians' are equal

In the meta-analysis (29) mentioned above, a distinct difference was found in the BMI/BF% relationship among Chinese, on one hand, and Indonesians (Malays ancestry) and Thais, on the other. Even between Chinese groups living in New York, Beijing and Hong Kong there seemed to be differences, as was also observed between European and American Caucasians.

In 1997 and in 1998 two body composition studies were conducted in Indonesia. These studies aimed to investigate the relationship between BMI and BF% in population groups of different ethnic origin (Malays and Chinese). As the studies were field studies, BF% was determined by deuterium oxide dilution (1). It was assumed that hydration of the fat-free mass was constant and equal at 72.6% (33–35) for all population groups studied. A Dutch group was used as a 'reference' Caucasian group. All subjects were measured using the same standardized procedures. In the first study it was found that Indonesians of Malays ancestry [living on Java (Depok and Jakarta) and Sumatra (Palembang)] have, for the same age, gender and BMI, ≈5% more body fat than Dutch Caucasians (Fig. 1). For the same BF%, their BMI is ≈3 $\mathrm{kg \, m^{-2}}$ lower compared to Dutch Caucasians (36). In the second study, Indonesians of Chinese ancestry (living in Makale, Sulawesi) were assessed. In this group the difference in the BMI/BF% relationship compared to the Dutch was less pronounced but was also significantly different compared to the Malays Indonesians assessed in the first study. The differences between the Malays and Chinese Indonesians could be largely explained by differences in body build, namely frame size and relative leg length (37).

The Indonesian studies could be criticized for assuming the same, constant hydration fraction of the fat-free mass, which is not necessarily true. However, it is unlikely that at a population level differences in hydration of the fat-free
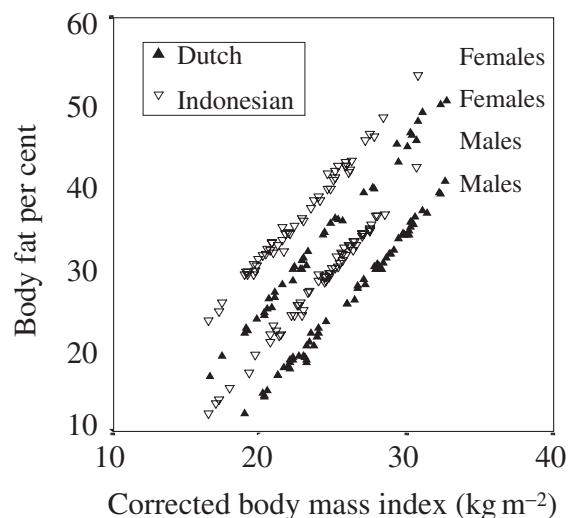

Figure 1 Differences in the relationship between body fat per cent (BF%) and body mass index (BMI) between Indonesian and Dutch males and females. BMI was corrected for age differences. Data were obtained from ref. 36.

mass exceed 1–2% (34,35), and it was discussed that even a mean hydration level of the fat-free mass as low as 70% would still have resulted in significant differences compared to Caucasians (36).

In early 1998, a pilot study was conducted in Singapore, in which body composition was measured in a small sample of young Chinese males and females using a variety of techniques (densitometry, deuterium oxide dilution, DXA, anthropometry). These data were used in comparative statistical analyses in which age-, gender- and BMI-matched Beijing Chinese and Dutch Caucasians were included. The BMI/BF% relationship was different between the three groups, the Singaporeans having the highest BF% and the Dutch the lowest BF% (38). The differences in the BMI/BF% relationship could be explained by differences in frame size and relative leg length (see Fig. 2), where frame size was calculated as a slenderness index (height ÷ sum of knee and wrist width). Figure 3 explains the effect of relative leg length and slenderness on the BMI/BF% relationship.

In the autumn of 1998, another body composition study was conducted in which nearly 300 Chinese, Malays and Indian male and female Singaporeans participated. Body fat was measured using a four-compartment model (39): body weight = (fat mass+mineral+water+protein). Body water was determined by deuterium oxide dilution, minerals by DXA and protein by densitometry. Body fat obtained by a four-compartment model is minimally influenced by assumptions (40) and the calculated error in this model is as low as 1%. The results of this study show that in Singapore, for the same age, gender and BMI, Indians have a

higher BF% than Malays, who in turn have a slightly higher BF% than Chinese (41). All three groups have a considerably higher BF% for the same BMI than Caucasians of the same age and gender. It was calculated that a 'Caucasian compatible' BMI cut-off point for obesity would vary from ≈26 kg m^{-2} in Indians to ≈27.5 kg m^{-2} in Singapore Chinese (see Fig. 4). Detailed results of this study have been published previously (41). Also, in this study differences in frame size and in leg length explained differences between the three Singaporean groups. These BMI cut-off values are higher than the values suggested by Ko *et al.* (25) and He *et al.* (26) for Hong Kong Chinese (at 23 and 25 kg m^{-2} for overweight and obesity, respectively). Differ-

ences in reference methodology for BF% (Ko *et al.* bioelectrical impedance; He *et al.* DXA) may offer an explanation for this, but true differences in the BMI/BF% relationship between Singapore Chinese and Hong Kong Chinese cannot be excluded.

From all studies it is obvious that the BMI is a reasonably good indicator for BF%, but the relationship between BMI and BF% is age-, gender- and ethnicity-dependent. Ethnic differences could be explained by differences in frame size and relative leg length, but physical activity level, as indicated by Luke *et al.* (20), could also be a contributory factor.

From the data that are available in the literature, no general conclusion about the BMI/BF% relationship in
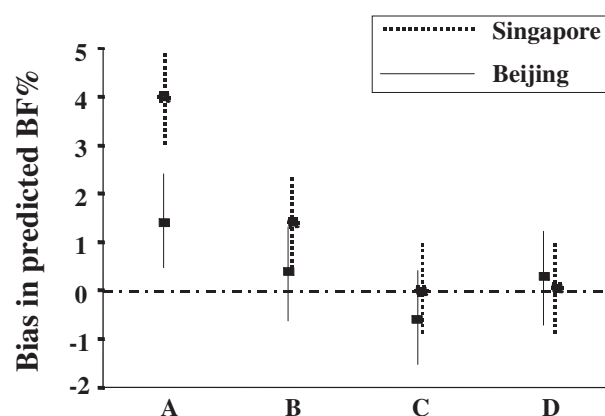

Figure 2 Bias of predicted body fat per cent (BF%) from body mass index (BMI) in Beijing and Singaporean Chinese before and after correction for parameters of body build. Bias: measured BF% minus predicted BF% from the BMI [14]. A, no correction; B, corrected for relative leg lengths; C, corrected for frame size; D, corrected for relative leg lengths and frame size. Data were obtained from ref. 38.
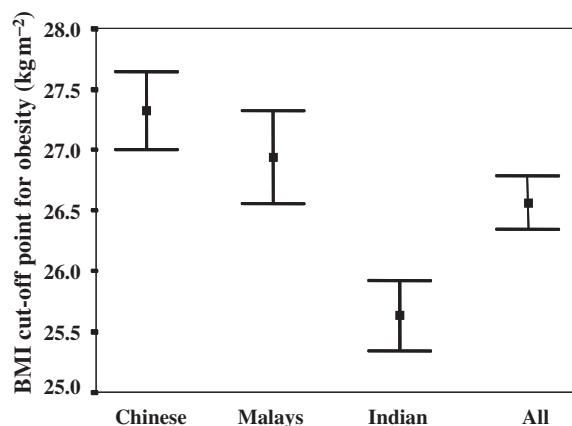

Figure 4 Recalculated cut-off point for obesity in different ethnic groups in Singapore. The cut-off point was calculated based on body fat per cent (BF%) in Caucasians of the same age and gender with a body mass index (BMI) of 30 kg m^{-2}. Data were obtained from ref. 41.
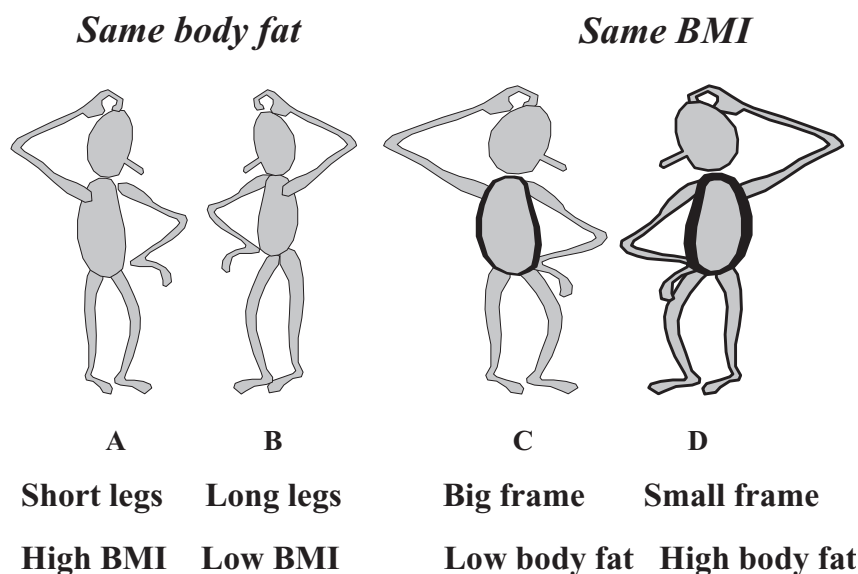

Same body fat   ## Same BMI

A	**B**	**C**	**D**
Short legs	**Long legs**	**Big frame**	**Small frame**
High BMI	**Low BMI**	**Low body fat**	**High body fat**

Figure 3 The effect of relative leg length and frame size on the body mass iindex (BMI)/body fat per cent (BF%) relationship. Subject A has the same BF% as subject B, but because he has shorter legs his BMI will be higher (more mass per cm length in the trunk). Subject C has the same BMI as subject D, but because his frame is bigger (stockier) he will have more skeletal mass, more muscle mass and more connective tissue. Therefore, for the same BMI he will have less BF%.

'Asians' can be drawn. Even within apparently equal groups, such as 'Indonesians' or 'Chinese', relatively large differences exist.

It is advisable that well constructed and standardized body composition studies in distinct population groups should be conducted, using a recognized reference method (e.g. deuterium oxide dilution) to measure BF%. Ideally those studies should include subjects over a wide range of BMI and age.

If body build is responsible for a high BF%/low BMI relationship in some populations, cut-off points for under-nutrition (currently at $18.5 \, kg \, m^{-2}$; see ref. 8) may also need revision. For example, in the recent (1998) National Health Survey in Singapore, as many as 11% of the females and 7% of the males had a BMI below $18.5 \, kg \, m^{-2}$. The pro-portion of Singaporeans with a BMI lower than $20 \, kg \, m^{-2}$ were 25 and 15% for females and males, respectively (42). There is no reason at all to assume that undernutrition is epidemic among Singaporeans.

As for the cut-off point for obesity, the relationship with risk factors is important, and undernutrition, health and work capacity should be considered before redefining cut-off points.

Conclusion

The relationship between BMI and BF% may be different among ethnic groups. If obesity is defined as excess body fat and not as excess body weight, such a different rela-tionship has consequences for the definition of obesity cut-off points based on the BMI. However, before redefining the cut-off points it should first be determined whether the high BF% at a lower BMI corresponds also with an increased risk of morbidity and mortality.

Acknowledgements

References

1 Forbes GB. *Human Body Composition*. Spinger Verlag: New York, 1987.
2 World Health Organization. *Physical Status: the Use and Inter-pretation of Anthropometry*. Technical Report Series 854. WHO: Geneva, 1995.
3 Lohman TG, Houtkoper L, Going SB. Body fat measurements goes high tech. Not all are created equal. *ACSM's Health Fitness J* 1997; **1**: 30–35.
4 Roche AF, Heymsfield SB, Lohman TG. *Human Body Compo-sition*. Human Kinetics: Champaign, IL, 1996.
5 Lukaski HC. Methods for the assessment of body composition: traditional and new. *Am J Clin Nutr* 1987; **46**: 437–456.
6 Deurenberg P. *The Assessment of Body Composition: Use and Misuse*. Annual Report pp. 35–72. Nestlé Foundation: Lausanne, 1992.
7 Deurenberg P, Deurenberg-Yap M. Differences in body compo-sition assumptions across ethnic groups: practical consequences. *Curr Opin Clin Nutr Metab Care* 2001; **4**: 377–383.
8 World Health Organization. *Obesity: Preventing and Managing the Global Epidemic*. WHO Obesity Technical Report Series no. 894. WHO: Geneva, 2000.
9 WHO/NUT/NCD/98.1. Geneva 1998. In: Quetelet LA (ed.). *Physique Social*, Vol. 2, pp 92. C. Muquardt: Brussels, 1869.
10 Livi R. L'indici ponderal o repporto tra la stature e il peso. *Atti Soc Romano Antrop* 1897; **5**: 125–153.
11 Womersley J, Durnin JVGA. A comparison of the skinfold method with extent of overweight and various weight–height relationships in the assessment of obesity. *Br J Nutr* 1977; **38**: 271–284.
12 Norgan NG, Ferro-Luzzi A. Weight–height indices as estima-tors of fatness in men. *Hum Nutr Clin Nutr* 1982; **36c**: 363–372.
13 Garrow JS, Webster J. Quetelet's index (W/H^2) as a measure of fatness. *Int J Obesity* 1985; **9**: 779–792.
14 Deurenberg P, Weststrate JA, Seidell JC. Body mass index as a measure of body fatness: age and sex specific prediction formulas. *Br J Nutr* 1991; **65**: 105–114.
15 Gallagher D, Visser M, Sepulveda D, Pierson RN, Harris T, Heymsfield SB. How useful is BMI for comparison of body fatness across age, sex and ethnic groups? *Am J Epidemiol* 1996; **143**: 228–239.
16 Norgan NG. Population differences in body composition in relation to BMI. *Eur J Clin Nutr* 1994; **48**: S10–S27.
17 Wang J, Thornton JC, Russell M, Burastero S, Heymsfield SB, Pierson RN. Asians have lower BMI (BMI) but higher percent body fat than do Whites: comparisons of anthropometric mea-surements. *Am J Clin Nutr* 1994; **60**: 23–28.
18 Wang J, Thornton JC, Burastero S, Shen J, Tanenbaum S, Heymsfield SB, Pierson RN. Comparison for BMI and body fat percent among Puerto Ricans, Blacks, Whites and Asians living in the New York City area. *Obesity Res* 1996; **4**: 377–384.
19 Gallagher D, Heymsfield SB, Heo M, Jeb SA, Murgatroyd PR, Sakamoto Y. Healthy percentage body fat ranges: an approach for developing guidelines based on body mass index. *Am J Clin Nutr* 2000; **71**: 694–701.
20 Luke A, Durazo-Arvizzu R, Rotimi C, Prewitt E, Forrester T, Wilks R, Ogunbiyi OL, Schoeller DA, McGee D, Cooper RS. Rela-tion between BMI and body fat in black population samples from Nigeria, Jamaica and the United States. *Am J Epidemiol* 1997; **145**: 620–628.
21 Wagner DR, Heyward VH. Measures of body composition in blacks and whites: a comparative review. *Am J Clin Nutr* 2000; **71**: 1392–1402.
22 Swinburn BA, Craig PL, Daniel R, Dent DPD, Strauss BJG. Body composition differences between Polynesians and Caucasians assessed by bioelectrical impedance. *Int J Obesity* 1996; **20**: 889–894.
23 Swinburn BA, Ley SJ, Carmichael HE, Plank LD. Body size and composition in Polynesians. *Int J Obesity* 1999; **23**: 1178–1183.
24 Norgan NG. Interpretation of low body mass indices: Australian Aborigines. *Am J Phys Anthropol* 1994; **94**: 229–237.
25 Ko GTC, Tang J, Chan JCN, Wu MMF, Wai HPS, Chen R. Lower BMI cut-off value to define obesity in Hong Kong Chinese:

146 Increased fat lean/ratios in Asians *P. Deurenberg* et al.

obesity reviews

an analysis based on body fat assessment by bioelectrical impedance. *Br J Nutr* 2001; **85**: 239–242.

26 He M, Tan KCB, Li ETS, Kung AWC. Body fat determination by dual energy X-ray absorptiometry and its relation to body mass index and waist circumference in Hong Kong Chinese. *Int J Obesity* 2001; **25**: 748–752.

27 Ko GTC, Chan JC, Cockram CS, Woo J. Prediction of hypertension, diabetes, dyslipidaemia or albuminuria using simple anthropometric indexes in Hong Kong Chinese. *Int J Obes* 1999; **23**: 1136–1142.

28 Deurenberg P, Ge K, Hautvast JGAJ, Wang J. BMI as predictor for body fat: comparison between Chinese and Dutch adult subjects. *Asia Pacific J Clin Nutr* 1997; **6**: 102–105.

29 Deurenberg P, Yap M, Staveren van WA. Body mass index and percent body fat: a meta analysis among different ethnic groups. *Int J Obesity* 1998; **22**: 1164–1171.

30 Roubenoff R, Kehayia JJ, Dawson-Hughes B, Heymsfield SB. Use of dual energy X-ray absorptiometry in body composition studies: not yet a gold standard. *Am J Clin Nutr* 1993; **58**: 589–591.

31 Werkman A, Deurenberg-Yap M, Schmidt G, Deurenberg P. A comparison between the composition and density of the fat-free mass of young adult Singaporean Chinese and Dutch Caucasian. *Ann Nutr Metab* 2000; **44**: 235–242.

32 Siri WE. Body composition from fluid spaces and density: analysis of methods. In: Brozek J, Henschel A (eds). *Techniques for Measuring Body Composition*. National Academy of Sciences: Washington, DC, 1961 pp. 223–244.

33 Pace N, Rathbun EN. Studies on body composition: water and chemically combined nitrogen content in relation to fat content. *J Biol Chem* 1945; **158**: 685–691.

34 Wang ZM, Deurenberg P, Wang W, Pietrobelli A, Baumgartner RM, Heymsfield SB. Hydration of fat free mass: new physio-logical modelling approach. *Am J Physiol* 1999; **276** (Endocrinol Metab 39): E995–E1003.

35 Wang ZM, Deurenberg P, Wang W, Pietrobelli A, Baumgartner RM, Heymsfield SB. Hydration of fat-free body mass: review and critique of a classic body composition constant. *Am J Clin Nutr* 1999; **69**: 833–841.

36 Guricci S, Hartriyanti Y, Hautvast JGAJ, Deurenberg P. Relationship between body fat and body mass index: differences between Indonesians and Dutch Caucasians. *Eur J Clin Nutr* 1998; **52**: 779–783.

37 Guricci S, Hartriyanti Y, Hautvast JGAJ, Deurenberg P. Differences in the relationship between body fat and body mass index between two different Indonesian ethnic groups: the effect of body build. *Eur J Clin Nutr* 1999; **53**: 468–472.

38 Deurenberg P, Deurenberg-Yap M, Wang J, Lin FP, Schmidt G. The impact of body build on the relationship between body mass index and body fat percent. *Int J Obesity* 1999; **23**: 537–542.

39 Baumgartner RN, Heymsfield SB, Lichtman SM, Wang J, Pierson RN Jr. Body composition in elderly people: effect of criterion estimates on predictive equations. *Am J Clin Nutr* 1991; **53**: 1345–1353.

40 Pietrobelli A, Heymsfield SB, Wang ZW, Gallagher D. Multicomponent body composition models: recent advances and future directions. *Eur J Clin Nutr* 2001; **55**: 69–75.

41 Deurenberg-Yap M, Schmidt G, Staveren WA, Deurenberg P. The paradox of low body mass index and high body fat percent among Chinese, Malays and Indians in Singapore. *Int J Obesity* 2000; **24**: 1011–1017.

42 Ministry of Health. *Report of the National Health Survey 1998*. Epidemiology and Disease Control Department: Singapore, 1999.