Original Article

Singaporean Chinese adolescents have more subcutaneous adipose tissue than Dutch Caucasians of the same age and body mass index

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Data on weight, height and skinfold thickness (biceps, triceps, subscapular and suprailiac) of 101 Singaporean Chinese adolescents (49 girls and 52 boys), aged 16-18 years, were compared with data of Dutch Caucasians (52 girls, 37 boys) of the same age. Age did not differ between the sexes in each ethnic group or between the ethnic groups within each sex group. The Chinese females were shorter, lighter and had a lower BMI, but the sum (mean ± SD) of four skinfolds was much higher (69.1 ± 15.4 mm) than in Caucasian girls (52.4 ± 17.8 mm). Also, the Chinese boys were shorter and lighter, but their body mass index was not lower compared to Caucasian boys. Their skinfold thickness was, as in girls, much higher compared to Caucasians (48.8 ± 17.0 mm versus 31.1 ± 10.2 mm). After correcting for (non significant) differences in age and skinfold thickness the Chinese adolescent girls had a 3.3 ± 0.4 kg/m^2 (mean ± SE) lower body mass index than their Caucasian counterparts. Singapore Chinese boys had a 2.7 ± 0.4 kg/m^2 lower body mass index (mean ± SE) than their Caucasian counterparts. Similarly, predicted body fat percent was 5.8 ± 0.6 percent points higher (mean ± SE) in Singapore Chinese girls compared to their Caucasian counterparts of the same age and body mass index. Singapore Chinese boys had 6.0 ± 0.6 percent more body fat percent (mean ± SE) than Caucasians of the same age and body mass index. The data confirm the high body fat percent/low body mass index relationship in Singaporean Chinese as is reported earlier in the literature for adults and children.

Key Words: body composition, subcutaneous body fat, skinfolds, Caucasian, Asian, body mass index, obesity, adolescents, Singaporeans, Dutch

Introduction

Obesity can be defined as a condition in which excess body fat has accumulated to the extent that health and well-being are adversely affected.[1] Body fat can be assessed in vivo using a variety of methods, ranging from scanning techniques to simple anthropometric methods such as skinfold thickness measurements, weight and height.[2,3] For population studies the body mass index (BMI, kg/m^2) can be used as a surrogate measure for body fatness[4,5] in both children and adults. Adults are considered obese if their BMI exceeds 30 kg/m^2, as this is the (arbitrary) point from which level onwards mortality and morbidity is exponentially increasing.[1] In children the BMI cut-off value for overweight and obesity is strongly age dependent as weight and height increase at different pace during growth.[6,7]

Recent studies in Asian population groups have shown that body fat percent is higher than in Caucasians of the same age and sex despite a lower body mass index in Asians.[8-11] This higher body fat percent compared to Caucasians of the same sex, age and BMI was also found in Singaporeans of adult age[11] as well as in children aged 7 to 12 years.[12] Reasons for this higher body fat percentage despite a lower BMI could be differences in body build,[11,13] but also a lower physical activity level and/or

different eating patterns are discussed.[14,15]

It seems logical that the high body fat percent/low BMI relationship as found in Singaporean children and adults can be extrapolated to adolescents, also because earlier studies have shown that from age 16 onwards the relationship between BF% and BMI is comparable in adolescents and adults.[5] However, currently no information is available about the relationship between body fat percent and BMI in Singaporean adolescents.

Aim of this study was to compare two data sets of young adolescents from Singapore (Chinese) and from Netherlands (Caucasian) in their relationship between BMI and body fat as assessed from skinfolds.

Subjects and methods

In a pilot study on body composition, in relation to food consumption patterns, anthropometric data of 49 girls and 52 boys, age 16 to 18 years, were collected. The participants were all students at Temasek Polytechnic, Singapore and were all of Chinese ancestry. A comparative data set of Dutch Caucasian adolescents of the same age was selected from a larger data set in such a way that mean age did not differ within each gender group between the races. All participants were self-selected volunteers. The studies were conducted in accordance with guidelines of the Helsinki Declaration for the Conductance of Experiments with Humans. Body weight was measured using a digital scale accurate to 0.1 kg, with a minimum of clothing and without shoes. Height was measured without shoes to the nearest 0.1 cm with a wall-mounted stadiometer. Body mass index (BMI) was calculated as weight divided by height squared (kg/m^2). From BMI, body fat percent (BF%) was estimated using age, sex and ethnic specific prediction equations. For Singapore Chinese: $BF\% = 1.034*BMI - 10.9*sex + 0.10*age + 6.51$[11]; for Caucasians: $BF\% = 1.200*BMI - 10.8*sex + 0.23*age - 5.4$[5] [where BMI = body mass index (kg/m^2); sex: females = 0, males = 1; and age in years]. These equations were originally developed in adult subjects.[5,11] Skinfolds were measured in triplicate at the left side of the body to the nearest 0.2 mm, using a Holtain skinfold caliper (Holtain Ltd, Bryberian, UK) and following the Durnin & Womersley protocol.[16]

Body fat was estimated from skinfolds using the prediction equations from Durnin & Womersley, based on the sum of four skinfolds,[16] from Slaughter et al.,[17] based on triceps and subscapular skinfolds, and from Deurenberg et al.,[18] also based on the sum of four skinfolds. Data were analysed using SPSS for Windows.[19] Comparisons between variables within each gender/ethnic group were done with paired T-test. Comparisons of variables between the gender/ethnic groups were done by analysis of variance (ANOVA) or analysis of co-variance (ANCOVA), with correction for possible confounding variables. Correlation coefficients are Pearson's product moment correlations coefficients. Values are expressed as mean ± SD unless otherwise stated. Significance is set at $P < 0.05$.

Results

Table 1 gives the characteristics of the female and male subjects in each ethnic group. Within each ethnic group males and females did not differ in age, but males were taller and heavier and their sum of skinfolds was remarkably lower than in females. In the Caucasian adolescents BMI was not different between males and females, but the Chinese females had a lower BMI than the Chinese males. In females, age was not different across the ethnic groups, but the Caucasian females were taller, heavier, had a higher BMI, but a lower sum of skinfolds. In males, age and BMI did not differ, but the Caucasians were taller, heavier and had a lower sum of skinfolds compared to the Chinese. Notable from the data in Table 1 is that the Chinese have lower BMI but a higher sum of skinfolds. Table 2 gives for each ethnic and gender group predicted body fat percent using various

Table 1. Characteristics of the subjects.

	Chinese				Caucasians			
	Females (N=49)		Males (N=52)		Females (N=52)		Males (N=37)	
	mean	SD	mean	SD	mean	SD	mean	SD
Age (years)	17.5	0.6	17.5	0.6	17.6	0.6	17.5	0.7
Height (m)	1.60*#	0.05	1.71#	0.06	1.69*	0.05	1.81	0.06
Weight (kg)	49.6*#	6.5	60.2#	8.8	61.0*	7.5	69.7	10.1
Body mass index (kg/m^2)	19.5*#	2.7	20.5	2.7	21.2	2.4	21.1	2.1
Sum of four skinfolds[a]	69.1*#	15.4	48.8#	17.0	52.4*	17.8	31.1	10.2

* $P<0.05$ between the sexes within the same ethnic group; # $P<0.05$ between the ethnic groups within the same sex group;
[a]sum of biceps, triceps, subscapular and suprailiac skinfold (mm)

Table 2. Total body fat estimates using various prediction equations.

	Chinese				Caucasians			
Body fat percent equation	Females (N=49)		Males (N=52)		Females (N=52)		Males (N=37)	
	mean	SD	mean	SD	mean	SD	mean	SD
Durnin & Womersley[16]	30.2	3.1	18.3	3.7	26.1	4.3	13.0	3.6
Slaughter et al.,[17]	27.5	3.1	20.2	5.6	23.8	4.2	11.9	4.0
Deurenberg et al.,[18]	27.9	3.8	15.9	2.5	22.7	5.4	12.2	2.5
From Body Mass Index[a]	28.4	2.8	18.5	2.8	24.1	2.9	13.2	2.6

[a]using ethnic specific prediction equations: for Chinese: 1.034*BMI -10.9*sex + 0.1*age + 6.5[11];
for Caucasians: 1.200*BMI -10.8*sex + 0.23*age - 5.4[5]

prediction equations based on skinfolds and predicted total body fat from BMI, using ethnic specific prediction equations. As can be seen in the Table, the values differ, sometimes substantially, and are in many cases statistically significant. As all values are predicted values no conclusions can be drawn about the validity of either value. As expected, the correlation coefficients between predicted body fat percent from skinfolds using either formula was high (in all ethnic/gender groups r >0.95, $P<0.001$). The correlation coefficients between sum of skinfolds and predicted body fat percent from BMI were 0.56, 0.79, 0.76 and 0.49 in Chinese females, Chinese males, Caucasian females and Caucasian males respectively (all values $P<0.001$). Body fat predicted from BMI differed significantly from skinfold body fat in Chinese females (for Durnin & Womersley and Slaughter et al., equation), in Chinese males (for Deurenberg et al., and Slaughter et al., equation), in Caucasians females (for Durnin & Womersley and Deurenberg et al., equation) and in Caucasian males (for Deurenberg et al., and Slaughter et al., equation). As no information is available about the validity of the used prediction equations in the Chinese, in further analysis only the sum of four skinfolds was used as a crude indicator of the amount of subcutaneous adipose tissue.

Analysis of co-variance, correcting for age and differences in skinfold thickness, shows that Singaporean adolescent females have a 3.3 ± 0.4 kg/m^2 lower ($P<0.001$) BMI than their Caucasian counterparts and Singaporean adolescent males have a 2.7 ± 0.4 kg/m^2 lower ($P<0.001$) BMI than their Caucasian counterparts of the same age and sum of skinfolds. Similarly, the Chinese female and male adolescents have a substantially higher skinfold thickness than Caucasian adolescents of the same age and BMI (in females and males 25.4 ± 2.7 and 20.4 ± 2.2 mm higher respectively) and consequently are likely to have a higher body fat percent. Depending on the prediction formula used these differences in body fat percent would be as large as 5.8 ± 0.6, 5.2 ± 0.6 and 7.2 ± 0.8 in females and 6.0 ± 0.6, 9.1 ± 0.7 and 4.1 ± 0.4 in males for the Durnin and Womersley equations,[16] Slaughter et al.,[17] equations and Deurenberg et al.,[18] equations respectively. Figure 1 visualises the mean ($\pm$ SE) differences in body fat percent (Durnin & Womersley,[16]) between Chinese and Caucasians adolescents, after correcting (ANCOVA) for differences in age and BMI.

Discussion

The Singapore adolescents volunteered in a pilot study on body composition and food consumption pattern and were self-selected volunteers. They were all students of Temasek Polytechnic, following various study curricula. They cannot be regarded as representative for the Singapore adolescent population. Unfortunately little information is available about Singaporeans of this age group, as they do not participate anymore in the programs of the School Health Services and (for the boys) they are still too young to be compared to data of national service men (military conscripts). The Dutch Caucasian counterparts were selected from a larger sample of subjects volunteering in various studies on body composition and

energy metabolism at the Wageningen University. During the selection procedure care was taken that (mean) age would not differ between the ethnic groups in each gender group. Despite the similar (mean and SD) age it cannot be excluded that the ethnic groups differ in biological age, i.e. maturation, a difference that could have an impact on the validity of used prediction formulas.[16-18]

As expected, the Chinese adolescents were smaller and lighter than their Caucasian counterparts, and in girls also the BMI was lower. Lower heights and weights in Singapore Chinese compared to Dutch Caucasians have been reported earlier.[13] Generally the BMI in Asians is lower than in Caucasians.[20,21] The higher skinfold thickness, in fact subcutaneous adipose tissue, in Singapore Chinese is in line with findings in Singapore adults and children aged 7-12 years, in which high body fat percent at low BMI values were reported earlier.[11,12] Body fat percent was predicted from skinfolds using various prediction equations.[16-18] The validity of these prediction equations in Chinese adolescents is not yet proven and this study shows that results of predicted body fat percent values has to be interpreted with care. The Durnin & Womersley equations were developed in a slightly older population (17 to 29 years old) and one could argue that because of a lower amount of internal fat in adolescents, the formulas might overestimate body fat percent in adolescents. A recent study showed, however, that the formulas tend to underestimate body fat percent in young Chinese Singaporeans.[22] The use of the formulas of Slaughter et al.,[17] and Deurenberg et al.,[18] both developed in adolescents, might be more correct as they were developed in adolescents (but of younger age) and they could be biased due to differences in biological age.

As Table 2 shows, in each of the four ethnic/gender groups there are differences between the predicted values. As no reference method was used in this study no conclusion can be drawn about the validity of each body fat assessment. Differences in the values of predicted body fat percent from skinfolds can be due to differences in subcutaneous fat distribution and to differences in the ratio of subcutaneous fat to total fat as compared to the population in which the formula was developed.[22,23] Although differences in measuring technique cannot be excluded as a source of error,[23] it has been shown that the formulas are quite robust, especially when a combination of skinfolds is used in the prediction.[24] It is, however, notable, that with the exception of the Deurenberg et al., formula[18] in the Chinese males all values are rather close and also similar to the value predicted from BMI using ethnic specific prediction equations.[5,11]

If the BMI is corrected for the (not significant) differences in age and for differences in sum of skinfolds (as indicator of body fatness), female Singaporean Chinese adolescents have a 3.3 ± 0.4 kg/m^2 lower BMI than their Caucasian counterparts. For Singaporean adolescent males the BMI is 2.7 kg/m^2 lower than in Caucasians of the same age and skinfold thickness. These values are in accordance with the lower BMI values (for the same age sex and body fatness) as found in Singapore Chinese adults (2.7kg/m^2)[11] and in children (1.3 kg/m^2).[12]
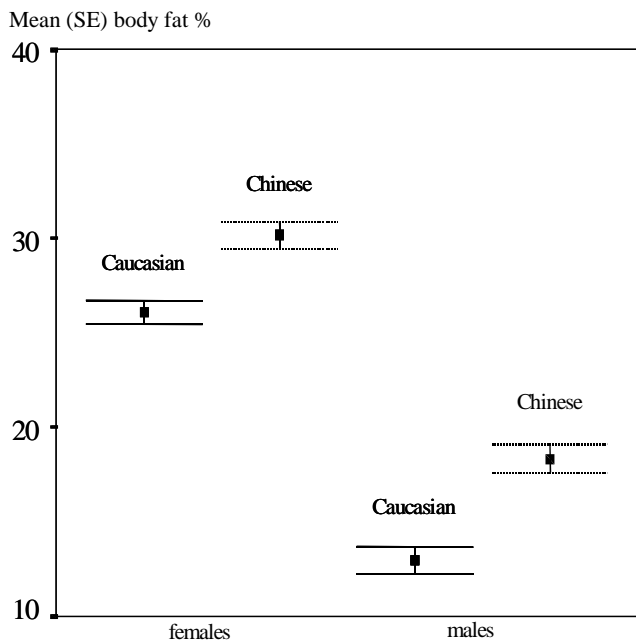
Mean (SE) body fat %

Figure 1. Mean (SE) body fat percent in Singaporean Chinese and Dutch Caucasian adolescents corrected for differences in age and body mass index. Body fat percent predicted from sum of four skinfolds (Durnin & Womersley[16]). Corrections for age and body mass index made by analysis of co-variance.

For the same BMI, age and sex body fat percent in Singaporean Chinese adolescents is about 6 percent higher compared to Caucasians, a value also comparable to the values found in adults and children.[11,12] The higher body fat percent at lower levels of BMI in adolescents was to be expected based on the findings in children and adults. This has practical consequences for the definition of overweight and obesity in adolescents and for the application of growth charts (for the younger adolescents) based on Caucasian data. There are various possible reasons for the higher body fat percent at a lower BMI value. It has been shown in adults that differences in body build (relative leg length and frame size) are at least partly responsible.[10,11,13,25] Also, as these differences in the body fat percent/BMI relationship are more pronounced in adults than at younger ages (unpublished data) and the younger generations in Singapore are less physically active than the older generations,[15] lack of adequate physical activity is likely to contribute as well. Luke et al.,[26] discussed physical activity as a possible reason for differences in the BMI/BF% relationship across various African groups. Differences in food consumption patterns may also be another contributor. For example, the younger generation is more likely to have a higher intake of 'westernised' food, with higher energy percent fat and sugar and lower intake of dietary fibre.

In conclusion, Singaporean Chinese adolescents have, similarly to adults and children, a higher body fat percent for the same age and BMI (weight and height) than Caucasians. This has consequences for the definition of obesity based on BMI and for the application of 'international' growth charts, based on Caucasian data. The study shows the need to validate prediction formulas for body composition against a proper reference method.

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