International Journal of Obesity (2001) 25, 164–169

0307–0565/01 $15.00
www.nature.com/ijo

PAPER

Obesity in Auckland school children: a comparison of the body mass index and percentage body fat as the diagnostic criterion

VJ Tyrrell[1], GE Richards[1], P Hofman[1], GF Gillies[1], E Robinson[2] and WS Cutfield[1]*

[1]*Department of Pediatrics, Faculty of Medicine and Health Science, The University of Auckland, Auckland, New Zealand; and*
[2]*Health Research Council Biostatistical Unit, The University of Auckland, Auckland, New Zealand*

OBJECTIVES: First, to determine obesity rates in Auckland school children according to their ethnic group using two different criteria: the body mass index (BMI) and percentage body fat (PBF) derived from bioelectrical impedance analysis (BIA). Second to examine the relationship between BMI and body composition across ethnic groups to determine if BMI references from European children accurately reflect obesity in other ethnic groups.
DESIGN: A total of 2273 Auckland school children, aged 5–10.9 y had their height, weight and bioelectrical impedance measured. Using these measurements, each child's BMI, fat free mass, fat mass and PBF were derived.
RESULTS: In all 14.3% of children were obese using the recommended definition of obesity (BMI) greater than the 95th percentile). There was no clinically significant difference in the relationship between BMI and body composition in different ethnic groups. Obesity rates varied with ethnicity ($P < 0.0001$) and were higher in Pacific Island (24.1%) and Maori (15.8%) than in European children (8.6%). Obesity rates also varied with age ($P < 0.03$), with the highest rates in older children. PBF levels were higher in females than males ($P < 0.0001$). Using a definition of obesity based on percentage body fat (PBF > 30%), obesity rates were higher in all ethnic groups.
CONCLUSIONS: Obesity rates are high in Auckland school children and there are clear differences in obesity rates in different ethnic groups. If BMI criteria are used to define obesity in our population, we recommend the same standards be used for children of all ethnicities.
International Journal of Obesity (2001) **25,** 164–169

Keywords: body composition; prevalence; bioelectrical impedance

Introduction

The prevalence of childhood obesity has increased dramatically.[1–4] In the USA the National Health and Nutrition Examination Surveys (NHANES) has found that the rate of childhood obesity (defined as body mass index (BMI) above the 95th percentile for age and sex) increased from 5.2% in 1963–1965 to 14% in 1988–1994.[5,6] There is limited information available about the prevalence of obesity in New Zealand children. In 1977 a study of 0–13 y olds found that 23% had weights above the 90th percentile, with Pacific Island children over-represented.[7] Pacific Island children had a median BMI that fell between the 75th and 95th centiles of European reference charts.[8] A comparison of cohorts of children in New Zealand and USA found that NZ children had higher BMIs than their American counterparts.[9] There are no published studies that have examined the prevalence of obesity in Maori children. Among NZ adults the prevalence of obesity is increasing.[10] In NZ children there has been only one small study of 10–15 y olds, which showed decreasing rates of obesity.[11,12]

Childhood obesity statistics clearly vary with the definition of obesity. Ideally, body fat, not body size, would be measured and obesity would be defined as the amount and/or distribution of body fat, which is associated with increased morbidity and mortality. The most commonly used estimate of body fatness is the BMI. In children age- and sex-specific reference ranges for BMI are available,[13] but

*Correspondence: WS Cutfield, Senior Lecturer in Pediatrics, Department of Pediatrics, Faculty of Medicine and Health Science, The University of Auckland, Private Bag 92019, Auckland, New Zealand.
E-mail: waynec@ahsl.co.nz
Received 30 November 1999; revised 4 August 2000; accepted 20 September 2000

the appropriate BMI level for defining obesity is not clear. Childhood obesity experts recommend that children with a BMI greater than the 95th percentile or BMI $\geq$ 30 be defined as obese, and BMI between the 85th and 95th percentile at risk of obesity.[14,15] In past studies the BMI has shown variable correlation with reference measures of body composition (dual-energy X-ray absorptiometry (DEXA), underwater weighing or isotope dilution) explaining, between 60 and 87% of the variance in fat mass (FM) and between 38 and 87% of the variance in percentage body fat (PBF).[16–22] BMI is limited because it may not account for variation in body composition between different individuals and different ethnicities.

BIA provides a useful tool for the measurement of body composition in large population-based studies. We recently validated the foot-to-foot BIA for use in our population and also demonstrated that foot-to-foot BIA is more accurate than anthropometry alone at predicting body composition.

The aim of this study was to determine the prevalence of obesity in children of different ethnic groups in our community and to determine whether ethnicity affects obesity rates. In doing so we have used two different measures of 'fatness': firstly the BMI and secondly the PBF determined by BIA. We will also examined the relationship between BMI and body composition in children of different ethnicities.

Subjects and methods

Subjects

Students from seven Auckland primary schools were enrolled in the study. The schools were selected from different areas within the Auckland region and were chosen for their high proportion of Maori and Pacific Island children. Children aged 5–10 y were included if the parents and child consented. The study design was approved by the regional ethics committee. Of the 2565 children eligible, 2273 (88.6%) were measured and included in the analysis. In all 292 children were not included: 130 (5.1%) declined, 71 (2.8%) were unavailable during the measurement period, 70 (2.7%) did not receive the information letter (returned to sender), 16 (0.6%) could not be measured because of technical difficulties, and 5 (0.2%) had invalid impedance values. The Tanita TBF body fat analyzer requires the child's feet to make electrical contact with four pad electrodes and those who could not be measured had very small or congenitally deformed feet.

Methods

Measurements of height, weight and bioelectrical impedance were made on each subject at their school. The ethnicity of each subject was recorded from the school role and the ethnicities were combined into six groups: European, NZ Maori, Pacific Island, Indian, Asian and Other. The Department of Education socio-economic class decile coding of the school was recorded as a proxy measurement of the socio-economic status of the children. A decile code of 1 is the lowest socio-economic rating and 10 is the highest. Weight (to the nearest 100 g) was recorded and foot-to-foot impedance was measured using the Tanita TBF-105 Body Fat Analyzer (Tokyo, Japan). Children were weighed in school clothing and bare feet. A correction of 1 kg was made for the average weight of school clothing (representative samples of clothing were weighed prior to the study). Height to the nearest centimetre was measured using a stadiometer. All heights were measured by a single investigator (GG). BMI was calculated by dividing the weight (kg) by the height (m) squared. The BMI standard derivation score (BMI-SDS) was calculated using tables published by Rosner *et al.*[23] Fat free mass (FFM) was calculated using the following prediction equation:

$$\text{FFM} = 0.31 \times \text{ZI} + 0.17 \times \text{height} + 0.11 \times \text{weight} + 0.942 \times \text{sex} - 14.96$$

(where ZI = height^2 impedance and sex = 1 for females and 2 for males). The prediction equation was derived on the same equipment in a representative subgroup of 82 European, Maori and Pacific Island children using DEXA as the reference for FFM. The r^2 between the DEXA-FFM and the BIA-derived FFM was 0.97 and, using the Bland–Altman method to test equivalence, the BIA-FFM underestimated the DEXA-FFM by a mean of 0.75 kg (95% confidence intervals 0.52, 0.99). FM and PBF were then calculated from the FFM and weight.

Statistical analysis

Simple descriptive statistics were used to determine obesity rates. We determined the percentage of children with a BMI greater than the 95th percentile for age and sex, using NHANES reference data.[13] We then calculated obesity rates using various PBF values. A logistic regression was used to examine the effects of age, sex, school decile code and ethnicity on obesity rates. The binomial test was used to investigate for each ethnic group whether the proportion of children above the 95th percentile was different from the expected rate of 5%. Linear regressions were used to test the relationship between BMI and body composition (FFM, FM and PBF) in the three main ethnic groups (European, Maori and Pacific Island) and to test the relationship between BMI-SDS and PBF.

Results

The ethnicity, age, BMI-SDS and PBF of the study population are shown in Table 1. There were 1130 females (49.7%) and 1143 males (50.3%) in the population. The decile codes ranged from 1 to 7 (median 3). In the Auckland region 38% of primary schools are decile 1–3, whereas 71% of our subjects are from schools with decile code 1–3, ie the sample population is skewed towards lower socio-economic groups.

Firstly we examined obesity rates using BMI criteria. In our study group 14.3% of children had a BMI greater

Table 1 Physical characteristics of the study population according to ethnicity

	All children	European	Maori	Pacific Island	Asian	Indian	Other
Number of children	2273	903	424	627	180	93	46
Age (y)	7.6±1.5	7.6±1.5	7.8±1.5	7.7±1.5	7.4±1.5	7.7±1.5	7.6±1.4
	(5.0–10.9)	(5.0–10.7)	(5.1–10.9)	(5.1–10.6)	(5.0–10.4)	(5.2–10.5)	(5.2–10.2)
BMI-SDS	0.3±1.3	0.0±1.1	0.5±1.2	0.9±1.5	−0.3±1.0	−0.1±1.4	0.0±1.2
	(−2.2, 11.1)	(−2.2, 5.7)	(−1.7, 5.8)	(−1.7, 11.1)	(−2.0, 3.8)	(−1.9, 4.7)	(−1.5, 2.6)
PBF (%)	28.6±7.4	27.1±7.0	29.6±7.2	31.0±7.5	25.1±6.4	29.1±8.1	28.8±8.1
	(7.2–57.2)	(7.2–52.6)	(13.5–51.6)	(9.9–57.2)	(11.3–44.9)	(11.6–48.4)	(15.3–47.1)

Mean±standard deviation with range in parentheses.

than the reference 95th centile for age and sex. A logistic regression of obese or not as an outcome and age, sex, ethnicity and school decile as explanatory variables found that the age and ethnicity of the child had a significant effect on obesity rates ($P=0.03$ and $P<0.0001$ respectively). Obesity rates increased with age with 11.6% of 5 y olds and 14.7% of 10 y olds being obese. The Pacific Island and Maori children were more likely to be obese than the Europeans (odds ratio 3.0 (95% CI 2.24, 4.01) and 1.9 (95% CI 1.35, 2.58), respectively). Asian children were less likely to be obese than European (odds ratio 0.7 (95% CI 0.35, 1.18). The Asian children were the only group that did not have a greater than expected proportion of children above the reference 95th centile for BMI.

Next we examined obesity rates using BIA-determined PBF criteria. The proportion of children above various PBF levels are shown in Table 2. Use of Ellis' definition of obesity of >30% body fat[42] therefore increases the proportion of children classified as obese in all ethnic groups. Females had higher PBF than males ($P<0.0001$) with a mean of 31.6% (±6.7) in the females and 25.7% (±7.0) in the males. The 95th centile for PBF in our study group was 44.2 for females and 39.8 for males and the 85th centile was 38.5 for females and 32.6 for males. Figure 1 shows the linear relationship between BMI-SDS and PBF. A BMI-SDS of 1.65 (corresponding to the reference 95th centile for BMI) was equivalent to a PBF of 37.7% in females and 32.2% in males. The relationship between BMI and body composition (FFM, FM, PBF) was examined in the three main ethnic groups. This relationship was significantly affected by ethnicity for FFM ($P=0.04$), FM ($P=0.03$) and PBF ($P=0.0004$). Figures 2–4 show these

Table 2 Rates of obesity according to definition used and according to ethnicity and sex

	BMI > 95th centile	PBF ≥ 30%	PBF ≥ 35%	PBF ≥ 40%
All children	*14.3*	*38.3*	*18.0*	*8.9*
European	8.6	30.3	12.6	5.1
Maori	15.8	45.5	20.5	10.4
Pacific Island	24.1	49.3	25.8	14.5
Asian	5.6	19.4	6.7	3.9
Indian	11.8	45.2	25.8	11.8
Other	15.2	39.1	21.7	8.7
Male	15.3	21.4	10.1	5.0
Female	13.2	55.4	25.9	12.9

relationships. The differences, although statistically significant, are small, and result primarily from the greater number of children with higher BMI in the Pacific Island group. The

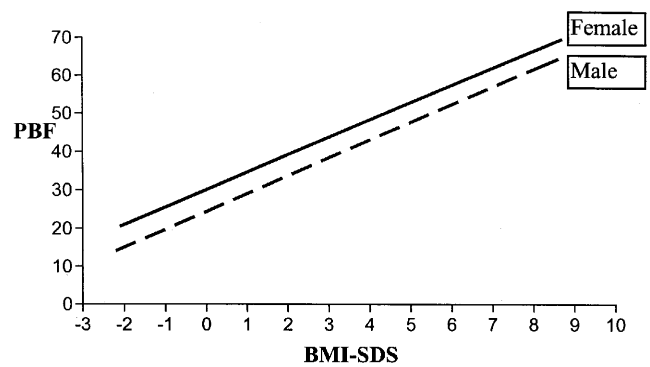

Figure 1 The relationship between BMI-SDS (standard deviation scores) and PBF. The linear regressions are: PBF = 4.58 × BMI-SDS + 30.16 for females (solid line) ($r^2=0.77$, s.e. = 0.08 for slope and 0.10 for intercept) and PBF = 4.69 × BMI-SDS + 24.42 for males (dashed line) ($r^2=0.79$, s.e. = 0.07 for slope and 0.10 for intercept).

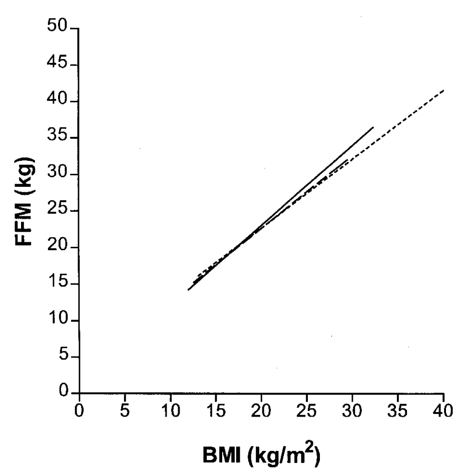

Figure 2 The relationship between FFM (fat-free mass) and BMI. The linear regressions are: FFM = 1.10 × BMI + 1.06 for European (solid line) ($r^2=0.39$, s.e. = 0.05 for slope and 0.76 for intercept) FFM = 1.00 × BMI + 2.66 for Maori (dashed line) ($r^2=0.40$, s.e. = 0.06 for slope and 1.06 for intercept) and FFM = 0.95 × BMI + 3.74 for Pacific Islanders (dotted line) ($r^2=0.47$, s.e. = 0.04 for slope and 0.76 for intercept).

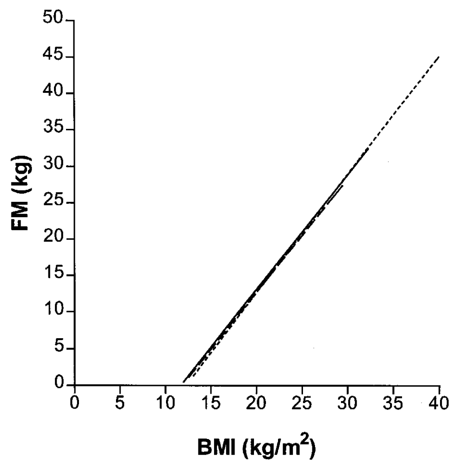

Figure 3 The relationship between FM (fat mass) and BMI. Linear regression equations are: FM = 1.58 × BMI-18.4 for Europeans (solid line) ($r^2 = 0.89$, s.e. = 0.02 for slope and 0.31 for intercept) FM = 1.56 × BMI-18.5 for Maori (dashed line) ($r^2 = 0.90$, s.e. = 0.03 for slope and 0.46 for intercept) and FM = 1.63 × BMI-20.0 for Pacific Islanders (dotted line) ($r^2 = 0.92$, s.e. = 0.02 for slope and 0.37 for intercept).

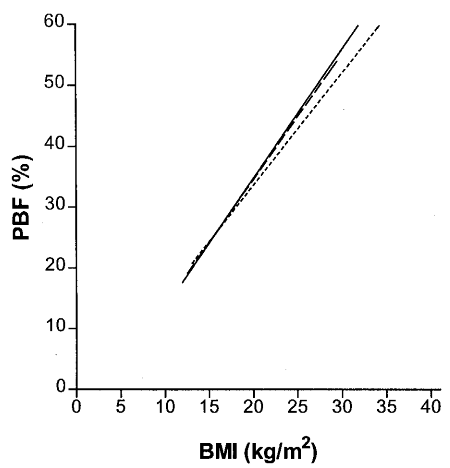

Figure 4 The relationship between PBF (percentage body fat) and BMI. Linear regression equations are: PBF = 2.14 × BMI-8.07 for European (solid line) ($r^2 = 0.60$, s.e. = 0.06 for slope and 0.97 for intercept) PBF = 2.08 × BMI-7.01 for Maori (dashed line) ($r^2 = 0.68$, s.e. = 0.07 for slope and 1.24 for intercept) and PBF = 1.89 × BMI-3.59 for Pacific Islanders (dotted line) ($r^2 = 0.73$, s.e. = 0.05 for slope and 0.86 for intercept).

greatest ethnic difference was between PBF and BMI, where the PBF did not increase as rapidly with BMI in the Pacific Island group as in the other two groups (Figure 4). Our population also included two other smaller groups of Asian and Indian children. The linear regression lines for the relationship between BMI and PBF for these groups are as follows: Asian PBF = 2.29 × BMI-10.64 ($r^2 = 0.53$, se = 0.16 for slope and 2.54 for intercept) and Indian PBF = 2.23 × BMI-7.56 ($r^2 = 0.75$, s.e. = 0.13 for slope and 2.24 for intercept). These linear regressions also demonstrate that in all the ethnicities BMI is a stronger predictor of FM ($r^2 = 0.89 - 0.92$) than of PBF ($r^2 = 0.53 - 0.73$) and FFM ($r^2 = 0.39 - 0.47$), as we have found previously.

Discussion

Childhood obesity rates are high in Auckland children. Using the recommended definition of childhood obesity, rates in Auckland are similar to those found in the most recent NHANES survey in the USA (14.3% and 13.7%, respectively). Obesity rates varied with ethnicity and the highest rates were seen in Pacific Island children (24.1%). Obesity rates also varied with age with rates increased with increasing age. There was no difference in obesity rates between males and females. School decile code was examined as an indicator of socioeconomic status of the children studied and did not affect obesity rates.

In choosing schools with high Maori and Pacific Island roles the sample is skewed to over-represent these groups and consequently over-represented the lower socioeconomic groups. The rates may therefore not accurately reflect the national situation. Nonetheless, this is the largest study of obesity rates in New Zealand children and the only study that has determined specific rates for Maori and Pacific Island children.

Defining childhood obesity is difficult. In defining childhood obesity one aims to identify those children for whom their amount and/or distribution of body fat puts them at increased risk of morbidity and mortality. The recommendation of an expert committee on obesity is that children with a BMI > 95th centile, greater than the 85th centile with complications or BMI > 30 be considered obese.[14,15] Morbidity studies have shown a variety of different obesity estimates to be associated with negative health consequences.[24–28] BMI greater than the 75th centile for age and sex (using NHANES I reference ranges) in adolescence is associated with increased mortality in men and increased morbidity from coronary heart disease and atherosclerosis in men and women.[24] If BMI criteria are used to define obesity then rates will also be affected by which reference population is chosen to define the 95th centile and in which year it was studied.[1–4,13,23,29]

Another limitation of the BMI as the measure of obesity is that it may not account for differences in body composition between ethnicities. Pacific Island adults are leaner (ie have higher FFM and lower PBF) than Europeans at any given BMI.[30,31] A BMI of 30 in European women related to a PBF of 42.5% and in Pacific Island women to a PBF of 38.9%. The converse situation has been demonstrated in Indian men, who have a greater PBF at any given BMI than African American or Caucasian men.[32] We hypothesized that similar differences may exist in children and that the use of reference ranges developed from white children may overestimate obesity in Pacific Island children. However, we found no clinically relevant difference in the relationship between

BMI and body composition in European, Maori and Pacific Island children in the normal range of BMI (< 30). The small, but statistically significant, effect of ethnicity on this relationship is attributable to the number of Pacific Island children with BMI > 30. This skewing should not justify the use of different BMI percentiles for the different ethnicities. The small group of Indian children showed a difference similar to that seen in adults with a higher PBF at any given BMI than the European children. However one should use caution in interpreting our results from the Indian group as there were only 93 children in the group and we used a BIA prediction equation which was not specifically developed for either Indian or Asian children.

There are now ethnicity-specific BMI reference ranges available and there are clear differences in the 95th centile levels for different ethnicities.[23] If one uses these ethnicity-specific references as the criteria for identifying obese children then one needs to consider the relationship of BMI to body composition in the different ethnicities. If, as in our population, the BMI indicates similar body composition across ethnicities, then it would not be appropriate to use ethnicity-specific BMI centiles in the definition of obesity. There may be other ethnicity related factors which modify the risk of obesity-related disorders. However, in a group such as the Pacific Islanders, who have a high rate of obesity-related disease, accepting higher BMI values for Pacific Island children would simply be accepting a different level of health for those children. We therefore recommend for NZ children that the same BMI value be used to identify obesity in all ethnicities. Further work is needed to determine at what age or level of pubertal development ethnically determined differences in body composition become clinically important for Pacific Island children. The interesting observation of increased PBF at any given BMI for Indian children also needs further investigation.

An alternative way of defining obesity would be to determine the level of body fat that is associated with disease. We have illustrated many different PBF levels for defining obesity. We would recommend the use of sex-specific criteria, as our study confirmed that females have higher PBF than males in childhood. The 95th centiles for our population are higher than those previously reported.[19] We found that the reference 95th centile for BMI corresponded to a PBF value of 37.7% for females and 32.2% for males. In this study we used BIA to determine PBF and have previously shown that BIA is more accurate than anthropometry at predicting PBF.

There are some examples in the literature where body composition, and not simply body size, has been shown to be important in disease risk. Higher levels of body fatness (determined by DEXA) are associated with unfavourable left ventricular geometry.[34] The level of PBF (determined by skin fold thickness (SFT)) is negatively associated with forced vital capacity (FVC) and forced expiratory volume in one second (FEV_1).[35] Conversely, body weight is positively associated with FVC and FEV_1.[35] High cholesterol levels in normal body weight, 8–10 y old children are associated with high body fat levels (determined by SFT).[36] Insulin levels are correlated with FM and PBF ($r = 0.55$ and 0.5 respectively) and blood pressure is also associated with FM.[34,37] In obese children the distribution of adipose tissue may also be important. Central adiposity (determined by abdominal SFT or waist-to-height ratio) is strongly associated with cardiovascular risk factors, as in adults.[38] In obese 7–11 y olds visceral adipose tissue was the better predictor of adverse lipid profile than PBF or FM (determined by DEXA).[37]

There is only limited information about normal body composition in children and how it varies with age and sex. PBF is higher in females than in males at all ages.[19,39–41] PBF increases with age in females but is relatively constant in males during childhood. From the literature there is no clear PBF level at which to define obesity and some authors have used arbitrary PBF values. Ellis *et al*[42] defined normal as < 25% fat, overweight as 25–30% fat and obese as > 30%. Goulding *et al.*[17] found that virtually all children with a BMI > 90th centile had PBF > 30%. Another difficulty in using PBF criteria for defining obesity is that the PBF determined using different methodologies are not interchangeable.[42]

In summary, this study shows high rates of childhood obesity in Auckland school-children, irrespective of the definition used. Obesity rates varied with ethnicity and age. Particularly high rates are seen in Pacific Island children. We have discussed several alternative PBF criteria which could be used to identify obesity. PBF in childhood needs to be prospectively studied to determine if it provides a better predictor of obesity-related morbidity than currently used anthropometric indices. Finally, we found no clinically significant differences in the relationship between BMI and body composition in different ethnicities. Therefore, if using BMI criteria to identify obesity, we recommend that the same BMI standards be used for children of all ethnicities.

Acknowledgement

The authors thank the Wilson Sweet Trust for their financial support in providing a research fellowship.

References

1 Freedman DS, Srinivasan SR, Valdez RA, Williamson DF, Berenson GS. Secular increases in relative weight and adiposity among children over two decades: the Bogalusa Heart Study. *Pediatrics* 1997; **99**: 420–426.
2 Hardcastle DM, Shrimpton S, Renigeris AS, Baptist ED, Baur LA. Increasing prevalence of childhood obesity. [Letter] *Med J Australia* 1997; **167**: 342.
3 Campaigne BN, Morrison JA, Schumann BC, Falkner F, Lakatos E, Sprecher D, Schreiber GB. Indexes of obesity and comparisons with previous national survey data in 9- and 10-year-old black and white girls: the National Heart, Lung, and Blood Institute Growth and Health Study. *J Pediatr* 1994; **124**(5 Pt 1): 675–680.
4 Barth N, Ziegler A, Himmelmann GW, Coners H, Wabitsch M, Hennighausen K, Mayer H, Remschmidt H, Scahfer H, Hebebrand J. Significant weight gains in a clinical sample of obese children and adolescents between 1985 and 1995. *Int J Obes Relat Metab Disord* 1997; **21**: 122–126.

5 Troiano RP, Flegal KM, Kuczmarski RJ, Campbell SM, Johnson CL. Overweight prevalence and trends for children and adolescents. The National Health and Nutrition Examination Surveys, 1963 to 1991. *Arch Pediat Adolescent Med* 1995; **149**: 1085–1091.
6 Anonymous. Update: prevalence of overweight among children, adolescents, and adults—United States, 1988–1994. *Morbid Mortal Wkly Rep* 1997; **46**: 198–202.
7 Anderson NE, Gorman DF, Lines DR. The nutritional status of Auckland children. *N Z Med J* 1977; **85**: 49–52.
8 Salesa JS, Bell AC, Swinburn BA. Body size of New Zealand Pacific Islands children and teenagers. *N Z Med J* 1997; **110**: 227–229.
9 Kelly JL, Stanton WR, Silva PA, Jordan TE. Comparison of United States and New Zealand children's body mass scores. [See comments.] *J R Soc Health* 1991; **111**: 51–53.
10 Simmons G, Jackson R, Swinburn B, Yee RL. The increasing prevalence of obesity in New Zealand: is it related to recent trends in smoking and physical activity? *N Z Med J* 1996; **109**: 90–92.
11 Thomson ME, Cruickshank FM. Survey into the eating habits of New Zealand pre-adolescents in relation to overweight and obesity. *N Z Med J* 1979; **89**: 7–9.
12 Randolph PM, Beck DJ, Thomson ME, Spears GFS. Anthropometry and leisure activities of some Dunedin children aged 11 to 13, 1976 and 1984. *N Z Med J* 1987; **100**: 634–635.
13 Hammer LD, Kraemer HC, Wilson DM, Ritter PL, Dornbusch SM. Standardized percentile curves of body-mass index for children and adolescents. *Am J Dis Child* 1991; **145**: 259–263.
14 Himes JH, Dietz WH. Guidelines for overweight in adolescent preventive services: recommendations from an expert committee. The Expert Committee on Clinical Guidelines for Overweight in Adolescent Preventive Services. *Am J Clin Nutr* 1994; **59**: 307–316.
15 Barlow SE, Dietz WH. Obesity evaluation and treatment: expert committee recommendations. *Pediatrics* 1998; **102**: e29.
16 Goran MI, Driscoll P, Johnson R, Nagy TR, Hunter G. Cross-calibration of body-composition techniques against dual-energy X-ray absorptiometry in young children. *Am J Clin Nutr* 1996; **63**: 299–305.
17 Goulding A, Gold E, Cannan R, Taylor RW, Williams S, Lewis-Barned NJ. DEXA supports the use of BMI as a measure of fatness in young girls. *Int J Obes Relat Metab Disord* 1996; **20**: 1014–1021.
18 Pietrobelli A, Faith MS, Allison DB, Gallagher D, Chiumello G, Heymsfield SB. Body mass index as a measure of adiposity among children and adolescents: a validation study. *J Pediatr* 1998; **132**: 204–210.
19 Boot AM, Bouquet J, De Riddler MAJ, Krenning EP, De Munick Keizer-Schrama SMPF. Determinants of body composition measured by dual-energy X-ray absortiometry in Dutch children and adolescents. *Am J Clin Nutr* 1997; **66**: 232–238.
20 Gutin B, Litaker M, Islam S, Manos T, Smith C, Treiber F. Body-composition measurement in 9–11-y-old children by dual-energy X-ray absorptiometry, skinfold-thickness measurements, and bioimpedance analysis. *Am J Clin Nutr* 1996; **63**: 287–292.
21 Bandini LG, Vu DM, Must A, Dietz WH. Body fatness and bioelectrical impedance in non-obese pre-menarcheal girls: comparison to anthropometry and evaluation of predictive equations. *Eur J Clin Nutr* 1997; **51**: 673–677.
22 Roche AF, Siervogel RM, Chumlea WC, Webb P. Grading of body fatness from limited anthropometric data. *Am J Clin Nutr* 1981; **34**: 2831–2838.
23 Rosner B, Prineas R, Loggie J, Daniels SR. Percentiles for body mass index in US children 5 to 17 years of age. [See comments.] *J Pediatr* 1998; **132**: 211–222.
24 Must A, Jacques PF, Dallal GE, Bajema CL, Dietz WH. Long-term morbidity and mortality of overweight adolescents. *New Engl J Med* 1992; **327**: 1350–1355.
25 Javier Nieto F, Moyses S, Comstock GW. Childhood weight and growth rate as predictors of adult mortality. *Am J Epidemiol* 1992; **136**: 201–213.
26 Hoffmans MDAF, Kromhout D, De Lezenne Coulander C. The impact of body mass index of 78,612 18-year old Dutch men on 32-year mortality from all causes. *J Clin Epidemiol* 1988; **41**: 749–756.
27 Hoffmans MDAF, Kromhout D, De Lezenne Coulander C. Body mass index at the age of 18 and its effects on 32-year mortality from coronary heart disease and cancer. *J Clin Epidemiol* 1989; **42**: 513–520.
28 Sonne-Holm S, Sorensen TIA, Christensen U. Risk of early death in extremely overweight young men. *Br Med J* 1983; **287**: 795–797.
29 Cole TJ, Freeman JV, Preece MA. Body mass index reference curves for the UK, 1990. *Arch Dis Child* 1995; **73**: 25–29.
30 Swinburn BA, Craig PL, Daniel R, Dent DP, Strauss BJ. Body composition differences between Polynesians and Caucasians assessed by bioelectrical impedance. *Int J Obes Relat Metab Disord* 1996; **20**: 889–894.
31 Rush EC, Plank LD, Laulu MS, Robinson SM. Prediction of percentage body fat from anthropometric measurements: comparison of New Zealand European and Polynesian young women. *Am J Clin Nutr* 1997; **66**: 2–7.
32 Banerji MA, Faridi N, Atluri R, Chaiken RL, Lebovitz HE. Body composition, visceral fat, leptin, and insulin resistance in Asian Indian men. *J Clin Endocrinol Metab* 1999; **84**: 137–144.
33 Reilly JJ, Wilson J, Durnin JVG. Determination of body composition from skinfold thickness: a validation study. *Arch Dis Child* 1995; **73**: 305–310.
34 Gutin B, Treiber F, Owens S, Mensah GA. Relations of body composition to left ventricular geometry and function in children. *J Pediatr* 1998; **132**: 1023–1027.
35 Lazarus R, Colditz G, Berkey CS, Speizer FE. Effects of body fat on ventilatory function in children and adolescents: cross-sectional findings from a random population sample of school children. *Pediatr Pulmon* 1997; **24**: 187–194.
36 Tershakovec AM, Jawad AF, Stallings VA, Cortner JA, Zemel BS, Shannon BM. Age-related changes in cardiovascular disease risk factors of hypercholesterolemic children. [See comments.] *J Pediatr* 1998; **132**(3 Pt 1): 414–420.
37 Owens S, Gutin B, Ferguson M, Allison J, Karp W, Le NA. Visceral adipose tissue and cardiovascular risk factors in obese children. *J Pediatr* 1998; **133**: 41–45.
38 Berenson GS, Srinivasan SR, Wattigney WA, Harsha DW. Obesity and cardiovascular risk in children. *Ann NY Acad Sci* 1993; **699**: 93–103.
39 Guo SS, Chumlea WC, Roche AF, Siervogel RM. Age- and maturity-related changes in body composition during adolescence into adulthood: the FELS Longitudinal Study. *Int J Obes Relat Metab Disord* 1997; **21**: 1167–1175.
40 Ogle GD, Allen JR, Humphries IRJ, Wen Lu P, Briody JN, Morley K, Howman-Giles R, Cowell CT. Body-composition assessment by dual-energy x-ray absorptiometry in subjects aged 4–26 y. *Am J Clin Nutr* 1995; **61**: 746–753.
41 Taylor RW, Gold E, Manning P, Goulding A. Gender differences in body fat content are present well before puberty. *Int J Obes Relat Metab Disord* 1997; **21**: 1082–1084.
42 Ellis KJ. Measuring body fatness in children and young adults: comparison of bioelectric impedance analysis, total body electrical conductivity, and dual-energy X-ray absorptiometry. *Int J Obes Relat Metab Disord* 1996; **20**: 866–873.