International Journal of Obesity (1999) 23, 1178–1183
 0307–0565/99 $15.00
http://www.stockton-press.co.uk/ijo

Body size and composition in Polynesians

BA Swinburn[1]*, SJ Ley[1], HE Carmichael[1] and LD Plank[2]

[1]*Department of Community Health, University of Auckland, Auckland, New Zealand; and* [2]*Department of Surgery, University of Auckland, Auckland, New Zealand*

OBJECTIVES: To compare the relationship between body size and body composition in New Zealanders of Polynesian and European descent and to develop specific regression equations for fat mass for Polynesians.
SUBJECTS: 189 Maori (93 males, 96 females), 185 Samoans (88 males, 97 females) and 241 Europeans (89 males, 152 females) aged 20–70 y.
MEASUREMENTS: Height, weight, four skinfold thicknesses, bioelectrical impedance analysis (BIA) and dual energy X-ray absorptiometry (DXA).
RESULTS: At higher body mass index levels, Polynesians (Maori and Samoans combined) had a significantly higher ratio of lean mass : fat mass compared with Europeans. Four multiple regression equations incorporating resistance and reactance, height and weight, sum of four skinfolds or sum of two skinfolds were developed in two-thirds of the Polynesian participants using DXA fat mass as the dependent variable. In the remaining one-third of participants, the mean difference between fat mass predicted by these equations (r^2 range 0.89–0.93) and DXA fat mass ranged from −0.06 to +0.25 kg (s.d. −3.67 to +3.71 kg).
CONCLUSION: At higher BMI levels, Polynesians were significantly leaner than Europeans, implying the need for separate BMI definitions of overweight and obesity for Polynesians. The regression equations using BIA, height and weight or skinfold thicknesses were good predictors of body composition in Polynesians.

Keywords: body composition; body mass index; Samoans; Maori; Polynesians; bioelectrical impedance; anthropometry; dual energy X-ray absorptiometry

Introduction

Polynesian people have a high prevalence of obesity-related health problems,[1] such as coronary heart disease,[2] non-insulin dependent diabetes mellitus[3] and hypertension.[4,5] The mean body mass index (BMI) in these populations is very high compared with those of European descent.[6–8]

The interpretation of BMI values in non-Europeans, however, is difficult because the definitions of overweight and obesity are largely based on European data.[9] Studies using bioelectrical impedance (BIA)[10] and isotope dilution methods[11] found that, at any given BMI level, Polynesians appear to have higher levels of fat-free mass and less body fat than Europeans. The BMI definitions frequently used by health practitioners may therefore overestimate the body fat levels in Polynesian people.

Methods for the estimation of body composition which are inexpensive, relatively non-invasive and practical for field research include weight, height, BMI, skinfold thickness and BIA.[12] These methods, however, are limited by their need for population-specific equations to minimise error due to inter-population differences. The equations need be developed with reference to established standards for measuring body composition. Densitometry or dilution methods for estimating fat mass have been the traditional reference standards, but more recently dual-energy X-ray absorptiometry (DXA) has been used for whole body composition assessments.[13] The widespread availability of machines and their ease of use makes this an attractive method for measuring body composition, although it has some drawbacks as a reference standard compared with other methods.[14]

The present study compares body size and body composition in New Zealanders of Polynesian (Maori and Samoan) and European descent. The two largest Polynesian groups in New Zealand are Maori (who are indigenous but have a considerable admixture with Europeans) and Samoans (who are more recent migrants and have less admixture). Specific regression equations for estimating body fatness in these groups are needed for clinical and epidemiological purposes.

Participants and methods

Participants
Polynesian volunteers (381) were recruited from urban Auckland or the rural sectors of the upper North Island of New Zealand. This was done through existing networks of the recruiters with limited advertising. Of these, 189 were self-identified as being at

*Correspondence: Dr Boyd Swinburn, Department of Community Health, University of Auckland, Private Bag 92019, Auckland, New Zealand.
E-mail: b.swinburn@auckland.ac.nz
Received 25 January 1999; revised 22 April 1999; accepted 25 May 1999

least 75% Samoan and 192 were self-identified as Maori. As there has been a substantial level of intermarriage over the last 200 years between Maori and other ethnic groups, predominantly European, it was not possible to quantify this admixture in the Maori group. The European sample ($n = 251$) was recruited as part of a larger, ongoing study and all were self-identified as of European origin. All participants were between 20 and 70 years of age with similar numbers from each decade across the different groups. The exclusion criteria were: pregnancy, total joint replacements, lifting weights more than once a week, major medical conditions (such as diabetes or cancer) and medication which could possibly affect body composition (such as oral steroids). In addition, particularly large people who could not fit within the scanning area of the DXA were, by necessity, excluded. A further 10 European, four Samoan and two Maori participants were subsequently excluded from the analyses because of large differences (> 3 kg) between recorded scale weight and DXA weight (sum of fat mass, fat-free soft tissue and bone mineral content). One Maori female was excluded because she was a significant outlier in the relationship between body fat and BMI in the Maori group. Approval for the study was given by the Northern Regional Health Authority Ethics Committee.

Measurements
Body composition measurements of fat mass, fat-free soft tissue, and bone mineral content were made using the same DXA machine (model DPX + with software version 3.6y, Lunar Radiation Corp., Madison, WI). Resistance (*R*) and reactance (*Xc*) in ohms were measured on a BIA-1 01 analyser (RJL-Systems, Clinton Twp, MI) with a 50 kHz, 800 μA current, following the directions of the manufacturer. Height and weight were taken with participants wearing light clothing and no shoes. An estimated clothing weight was subtracted at the time of recording. Triceps, biceps, subscapular and suprailiac skinfold readings were taken with Harpenden callipers in triplicate and a mean of these three measurements calculated. The sum of all four skinfold sites and the sum of two (triceps and subscapular) skinfold sites were used to develop the skinfold equations. Two European (1 male, 1 female), 11 Maori (one male, 10 female) and 31 Samoan (eight male, 23 female) participants had skinfolds which were too large to fit within the calliper or had skin which was unable to be firmly grasped into a skinfold. They were excluded from the development of the skinfold equations.

Statistical analyses
Statistical analyses were performed using PC-SAS (version 6.10; SAS Institute Inc., Cary, NC). The differences between the characteristics of the three ethnic groups were tested by comparing mean levels. The relationship between DXA fat mass (dependent variable) and BMI (independent variable) was compared between the three ethnic groups using a general linear models procedure. As there was no significant difference in the relationship between Maori and Samoan groups the remainder of the analyses combined these two groups into one Polynesian group.

Four multiple linear regression models were used in the Polynesian group to assess the best predictors of fat mass measured by DXA using BIA, weight and height, the sum of four skinfolds, or the sum of two skinfolds. Variables tested included body weight (kg), age, height (cm), sex (where 1 = males and 0 = females), conductor volume (Ht^2/R in cm^2/ohms), reactance (*Xc* in ohms), BMI (kg/m^2), sum of four skinfolds (mm) and sum of two skinfolds (mm). Additional variables tested included $height^2$, log_{10} sum of four skinfolds and two skinfolds, and the interaction variables weight × sum of four skinfolds and weight × sex. The variables which gave the highest multiple correlation coefficient squared (r^2) value for the model were then used to develop Polynesian equations to predict fat mass from DXA in a computer-generated random selection of two-thirds of participants. The remaining one-third of participants were used to cross-validate the equations by measuring the differences between the fat mass values obtained from the prediction equations and the fat mass measured by DXA. The accuracy of the equations to predict body composition was estimated statistically, by the Bland–Altman method of measuring the mean difference ± s.d. between the predicted and reference measures.[15] Differences in subject characteristics in the two-thirds and one-third selection groups were tested using *t*-tests.

Results

Participant characteristics
The general and body composition characteristics of the 241 European, 189 Maori and 185 Samoan participants are shown in (Table 1). On average, the Maori and Samoan groups were significantly older, heavier, shorter and had greater BMI measurements than their European counterparts. Body composition measurements by DXA showed a significantly higher percentage body fat and fat mass (kg) in Maori and Samoans than in Europeans. Maori women and both Samoan men and women had significantly higher fat-free soft tissue than their European counterparts, and Samoans had significantly more fat-free soft tissue than Maori. Resistance and reactance measured by BIA were significantly lower for Maori and Samoans, and Samoan values were significantly lower than Maori. Skinfold measurements were significantly greater in both Samoan and Maori than Europeans, except for triceps measurements in Maori. Some skinfold measurements were significantly greater for Samoans than Maori.

Table 1 Characteristics of European, Maori and Samoan participants (mean ± s.d.)

	Males			*Females*		
	European (n = 89)	*Maori (n = 93)*	*Samoan (n = 88)*	*European (n = 152)*	*Maori (n = 96)*	*Samoan (n = 97)*
Age (y)	36.5 ± 13.1	42.4 ± 14.3[a]	44.0 ± 15.1[a]	37.0 ± 12.3	42.9 ± 13.6[a]	43.6 ± 14.5[a]
Weight (kg)	80.3 ± 11.9	92.1 ± 15.4[a]	94.7 ± 13.9[a]	68.0 ± 12.8	80.4 ± 17.0[a]	85.7 ± 17.2[a]
Height (m)	1.77 ± 6.4	1.74 ± 6.9[a]	1.73 ± 6.3[a]	1.65 ± 6.1	1.61 ± 5.3[a]	1.61 ± 6.0[a]
Body mass index (kg/m^2)	25.6 ± 3.5	30.5 ± 5.0[a]	31.8 ± 4.6[a]	25.1 ± 4.8	31.0 ± 6.6[a]	33.3 ± 6.3[a]
Body composition (DXA):						
body fat (%)	20.7 ± 8.0	27.8 ± 8.1[a]	26.0 ± 7.2[a]	33.7 ± 8.9	40.2 ± 7.3[a]	40.8 ± 6.8[a]
fat mass (kg)	17.4 ± 8.9	26.6 ± 10.7[a]	25.4 ± 9.2[a]	23.8 ± 10.1	33.3 ± 11.8[a]	35.7 ± 11.4[a]
fat-free soft tissue (kg)	60.3 ± 5.8	62.6 ± 7.3	66.4 ± 7.3[ab]	41.4 ± 4.5	44.5 ± 6.2[a]	47.2 ± 7.1[ab]
bone mineral content (kg)	3.3 ± 0.4	3.4 ± 0.4	3.5 ± 0.4	2.6 ± 0.4	2.6 ± 0.3	2.7 ± 0.4
bone mineral density (g/cm^2)	1.24 ± 0.09	1.28 ± 0.09[a]	1.31 ± 0.09[ab]	1.16 ± 0.09	1.20 ± 0.08[a]	1.22 ± 0.11[a]
Bioelectrical impedance:						
resistance (Ω)	457.2 ± 44.8	409.1 ± 50.5[a]	389.6 ± 40.4[ab]	571.1 ± 62.3	502.3 ± 75.5[a]	476.7 ± 65.4[ab]
reactance (Ω)	55.8 ± 8.8	49.8 ± 10.3[a]	44.5 ± 7.3[ab]	62.5 ± 9.6[a]	53.1 ± 11.7[a]	49.1 ± 9.0[ab]
Skinfolds:[c]						
triceps (mm)	13.0 ± 7.0	15.3 ± 8.3	17.3 ± 9.8[a]	24.8 ± 9.8	25.6 ± 10.8	32.0 ± 11.8[ab]
biceps (mm)	5.4 ± 3.7	9.9 ± 6.1[a]	8.8 ± 4.1[a]	9.7 ± 6.5[a]	14.9 ± 8.1[a]	21.6 ± 10.5[ab]
subscapular (mm)	15.0 ± 7.6	24.5 ± 10.1[a]	25.4 ± 9.6[a]	20.3 ± 10.6	30.5 ± 11.5[a]	31.8 ± 10.5[a]
suprailiac (mm)	18.1 ± 9.3	24.2 ± 12.9[a]	30.7 ± 12.1[ab]	18.9 ± 9.6	28.0 ± 13.5[a]	34.9 ± 11.1[ab]
sum of four skinfolds (mm)	50.9 ± 25.0	73.4 ± 31.1[a]	79.2 ± 29.1[a]	73.6 ± 33.7	96.1 ± 37.8[a]	113.7 ± 38.4[ab]
sum of two skinfolds (mm)	18.3 ± 10.1	25.2 ± 13.2[a]	26.1 ± 13.0[a]	34.5 ± 15.6	40.5 ± 18.2[a]	53.6 ± 21.7[ab]

[a]Significantly different from Europeans at $P < 0.01$ level.
[b]Significantly different from Maori at $P < 0.01$ level.
[c]Some subjects deleted for technical reasons (see Methods).

There were no significant differences in bone mineral content (kg) between all three ethnic groups, but Maori and Samoans had higher bone mineral density (g/cm^2) than Europeans. After correcting for the other major determinants of bone mineral density (age, height and percentage body fat),[16] Maori still had higher bone mineral density values than Europeans (males $P = 0.014$, females $P = 0.011$). Samoans in turn had higher bone mineral density values than Maori ($P = 0.012$ for both sexes) and Europeans ($P = 0.006$ for both sexes).

Relationship between body size and composition

The relationships between fat mass measured by DXA and BMI in Samoans, Maori and Europeans are shown in Figure 1 (males) and Figure 2 (females). Separate comparisons of the regression lines for both males and females indicated significant heterogenicity in the slopes ($P <$ 0.0001 for BMI × group interaction), reflecting the bigger ethnic differences at the higher BMI levels. Among males, the slope for the Europeans was steeper than for Samoans ($P = 0.009$), but borderline for Maori ($P = 0.08$). For females, the slope for the Europeans was steeper than for both Maori ($P < 0.0001$) and Samoans ($P = 0.0005$). For males and females there were no significant differences in the slopes or intercepts between Maori and Samoans. Because of this similarity, the Maori and Samoan groups were combined into a single Polynesian group for the remainder of the analyses.

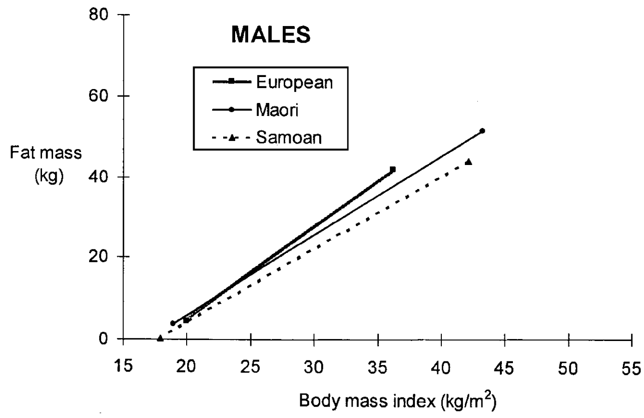

Figure 1 Males—relationship between fat mass (kg) measured by DXA and body mass index (BMI). Europeans, fat mass = 2.32 BMI − 41.89 ($r^2 = 0.82$); Maori, fat mass = 1.96 BMI − 33.23 BMI ($r^2 = 0.85$); Samoans, fat mass = 1.81 BMI − 32.21 ($r^2 = 0.81$).

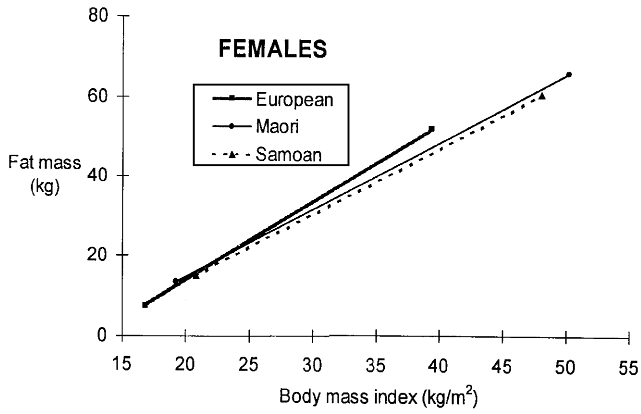

Figure 2 Females—relationship between fat mass (kg) measured by DXA and body mass index (BMI). Europeans, fat mass = 2.00 BMI − 26.37 ($r^2 = 0.89$); Maori, fat mass = 1.71 BMI − 19.67 ($r^2 = 0.92$); Samoans, fat mass = 1.69 BMI − 20.41 ($r^2 = 0.88$).

Prediction equations for Polynesians

The best body composition measurements found to predict DXA fat mass in a randomly selected two-thirds sample of Polynesians are shown by the equations in (Table 2). There were no significant differences found in age, sex, fat mass or body weight between the group used to develop the equations (two-thirds) and the group used for cross-validation (one-third). The Bland–Altman method[15] was used to compare the two methods of estimating fat mass (regression equations and DXA) in the cross-validation group (Figure 3). The range of agreement between the regression equations and DXA fat mass was -0.061 to 0.2 kg (s.d. range -3.67 to $+3.71$).

BMI equivalents for Polynesians

Because of the similarities between the Maori and Samoan groups (Figures 1 and 2), combined Polynesian equations were developed for the relationship between body fat by DXA and BMI. For males, body fat in kg $= -30.56 + 1.817 \times \text{BMI}$ ($n = 181$, $r^2 = 0.79$) and for females, body fat in kg $= -20.26 + 1.707 \times \text{BMI}$ ($n = 193$, $r^2 = 0.90$). Using these and the European equations (from Figures 1 and 2), equivalent BMI values were estimated using body fat in kg as the common factor (Table 3).

Discussion

These results confirm that there are distinct differences in body composition between Europeans and Polynesians and population-specific equations have been developed for field-based body composition assessments. Although the Polynesian groups had a higher mean fat mass and percentage body fat than the European group, their corresponding body fat levels at higher equivalent BMI values were significantly lower than for Europeans. Conversely, at high equivalent levels of fat mass, the Polynesian BMI values were up to 5 kg/m^2 higher than Europeans of equivalent fatness.

This confirms earlier work using BIA and isotope dilution techniques to assess body composition where predicted body fat levels in Polynesians were lower than Europeans,[10,11] although the greater differences at higher levels of BMI were more marked in the present study. For clinical and epidemiological purposes, we propose that the definition for overweight for Polynesians should be a BMI of 26–32 kg/m^2 and that obesity is defined as a BMI > 32 kg/m^2.[17]

The equations for Polynesians developed in this study using the field-based measurements (BIA, weight, height, skinfold thickness) explained about 90% of the variance in DXA fat mass. This compares

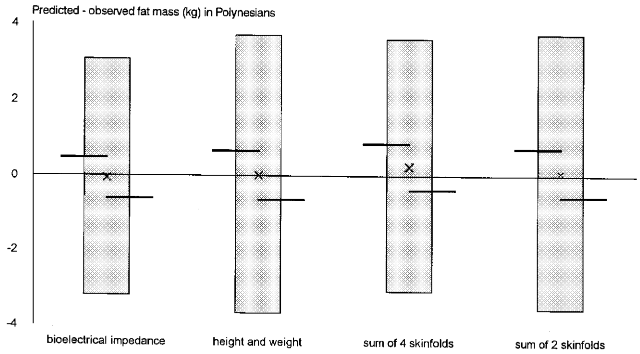

Figure 3 Cross-validation of prediction equations derived from DXA fat mass from two-thirds of the group and applied to the other one-third. Means (crosses), 95% confidence intervals (lines) and standard deviations (bars) for the differences are shown.

Table 2 Prediction equations to estimate fat mass (kg) by DXA for Polynesians derived from two-thirds of participants

Equations		$r^{2\,a}$
Bioelectrical impedance	11.58 + 0.79 (weight) − 0.15 (height) + 0.04 (age) − 6.0 (sex) − 0.39 (height^2/resistance)	0.93
Height and weight	35.98 + 0.64 (weight) − 10.51 (sex) − 0.35 (height) + 0.05 (age)	0.91
Sum of four skinfolds	25.13 + 0.05 (sum of four skinfolds) + 0.55 (weight) − 8.39 (sex) − 0.27 (height) + 0.05 (age)	0.89
Sum of two skinfolds	31.66 + 0.06 (sum of two skinfolds) + 0.59 (weight) − 9.05 (sex) − 0.32 (height) + 0.05 (age)	0.91

Sex = 1 for males and 0 for females, weight in kg, height in m, age in years, resistance and reactance in ohms, sum of skinfolds in mm.
[a]Cross-validation r^2 in remaining one-third of participants.

Table 3 Comparison of European body mass index (BMI) and corresponding body fat (kg) levels, with predicted BMI equivalents for Polynesians derived from the regression equations for predicting fat mass from BMI

Males			*Females*		
Europeans		*Polynesians*	*Europeans*		*Polynesians*
BMI (kg/m²)	*Fat (kg)*	*Approximate BMI equivalent (kg/m²)*	*BMI (kg/m²)*	*Fat (kg)*	*Approximate BMI equivalent (kg/m²)*
20	4.5	19.3	20	13.6	19.8
25	16.1	25.7	25	23.6	25.7
30	27.7	32.1	30	33.6	31.6
35	39.3	38.4	35	43.6	37.4
40	50.9	44.8	40	53.6	43.4
45	62.5	51.2	45	63.6	49.1

favourably with other studies which have developed BIA equations for prediction of fat mass.[18,19]

The degree to which these data are representative of Polynesians in general is an important consideration. An even age distribution of Maori and Samoan participants was achieved by selection of equal numbers in each decade from 20 to 70 years. Underestimation of variance in body size and composition in the wider population is expected to have occurred due to the potential effect of clustering in the sample selection and the limitations of measuring very large individuals by the DXA method. Age-adjusted comparisons of Samoans in this study with a community-based study[20] showed that the current female participants were lighter but males were similar. Compared with the Life in New Zealand study,[21] a representative sample of the New Zealand population, the Europeans were similar with small differences occurring in the older age groups in both sexes. However, it is not the absolute levels of body fatness which need to be representative to allow wider use of these data, it is the relationship between body size and body composition. Polynesian populations which are still very physically active, such as in remote Pacific Islands, would be expected to have an even higher ratio of lean : fat tissue.

There is debate about the suitability of using DXA as a reference method for body composition assessment.[14,22] DXA, however, is an attractive option because of its availability, low invasiveness and its ability to estimate bone, fat and lean masses. Preliminary data in our laboratory, comparing the body composition derived from this DXA machine and from a four-compartment 'gold standard' model (water by tritium dilution, protein by *in vivo* neutron activation, and mineral content by using DXA for bone ash and estimating non-bone minerals as 5.7% of protein) in 203 volunteers, indicate that the difference of 0.26 kg found between the two measurements was not significant (LD Plank, unpublished data, 1996). Another potential measurement error of DXA comes from the relatively narrow scanning width of DXA which in very large individuals can lead to the underestimation of total body mass. We tried to control for this error by excluding data from volunteers whose weight on the scale was > 3 kg different from weight assessed by DXA.

The greater whole-body bone mineral density values in the Polynesian groups supports previous work which found similar differences in a variety of regional bone mineral density measurements.[23,24]

We conclude that Polynesians with a BMI over about 25 kg/m^2 have more fat-free mass and less fat mass than Europeans at equivalent BMI levels. The field-based estimates of body fatness in Polynesians, even those just using weight, height, age and sex, are surprisingly accurate and should suffice for most clinical and epidemiological purposes. The suggested new definitions of overweight and obesity for Polynesians require validation from long-term studies of the relationship between BMI and morbidity and mortality in these populations.

Acknowledgements
The authors wish to acknowledge the support of the Ministry of Health for the funding of the study and the support of Dr Hunaara Ka, Department of Maori and Pacific Health, University of Auckland. Dr L D Plank was supported by the Health Research Council of New Zealand, and Dr B A Swinburn by the National Heart Foundation of New Zealand. The authors also wish to thank the recruiters and volunteers who participated in this study.

References

1 Bathgate M, Alexander D, Mitikulena A, Borman B, Roberts A, Grigg M. *The health of Pacific Islands people in New Zealand*. Public Health Commission: Wellington, 1994.
2 Bell C, Swinburn B, Stewart, A, Jackson R, Tukuitonga C, Tipene-Leach D. Ethnic differences and recent trends in coronary heart disease incidence in New Zealand. *NZ Med J* 1996; **109**: 66–68.
3 Zimmet P, Faaiuso S, Ainuu J, Whitehouse S, Milne B, DeBoer W. The prevalence of diabetes in the rural and urban Polynesian population of Western Samoa. *Diabetes* 1981; **30**: 45–51.
4 Scragg R, Baker J, Metcalf P, Dryson E. Hypertension and its treatment in a New Zealand multicultural workforce. *NZ Med J* 1993; **106**: 147–150.
5 Bullen C, Tipene-Leach D, Van der Hoorn S, Jackson R, Norton R, MacMahon S. Ethnic differences in blood pressure: findings from the Fletcher Challenge-Auckland University Heart and Health Study. *NZ Med J* 1996; **109**: 395–397.
6 Collins V, Dowse G, Zimmet P. Prevalence of obesity in Pacific and Indian Ocean populations. In Baba S, Zimmet P (eds). *World data book of obesity*. Elsevier Science, Amsterdam, 1990, pp 29–32.
7 McGarvey S. Obesity in Samoans and a perspective on its etiology in Polynesians. *Am J Clin Nutr* 1991; **53**: 1586S–1594S.
8 Dryson E, Metcalf P, Baker J, Scragg R. The relationship between body mass index (BMI) and socioeconomic status (SES) in New Zealand: ethnic and occupational factors. *NZ Med J* 1992; **105**: 233–235.
9 Garrow J S, Webster J. Quetelet's index (W/H^2) as a measure of fatness. *Int J Obes* 1985; **9**: 147–153.
10 Swinburn B A, Craig P L, Daniel R, Dent D P D, Strauss B J G. Body composition differences between Polynesians and Caucasians assessed by bioelectrical impedance. *Int J Obes* 1996; **20**: 889–l894.
11 Rush E C, Plank L D, Laulu M S, Robinson S M. 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.
12 Lukaski H C. Methods for the assessment of human body composition: traditional and new. *Am J Clin Nutr* 1987; **46**: 537–656.
13 Jebb S A, Elia M. Techniques for the measurement of body composition: a practical guide. *Int J Obes* 1993; **17**: 611–621.
14 Roubenoff R, Kehayias J J, Dawson-Hughes B, Heymsfield S B. Use of dual-energy X-ray absorptiometry in body composition studies: not yet a ''gold standard''. *Am J Clin Nutr* 1993; **58**: 589–591.
15 Bland J M, Altman D G. Statistical methods for assessing agreement between two methods of clinical measurement. *Lancet* 1986; **i**: 307–310.

16 Reid I R, Ames R, Evans M C, Sharpe S, Gamble G, France J T, Lim T M, Cundy T F. Determinants of total body and regional bone mineral density in normal postmenopausal women — a key role for fat mass. *J Clin Endocrinol Metab* 1992; **75**: 45–51.
17 Swinburn B A. Using the body mass index: weigh then weigh up. *NZ Med J* 1998; **111**: 377–379.
18 Heitmann B L. Evaluation of body fat estimated from body mass index, skinfolds and impedance. A comparative study. *Eur J Clin Nutr* 1990; **44**: 831–837.
19 Rising R, Swinburn B A, Larson K, Ravussin E. Body composition in Pima Indians: validation of bioelectrical resistance. *Am J Clin Nutr* 1991; **53**: 594–598.
20 Bell A C, Amosa H, Swinburn B A. Nutrition knowledge and practices of Samoans living in New Zealand. *Pacific Health Dialogue* 1997; **4**: 26–32.
21 Russell D G, Wilson N C. *Life in New Zealand commission report*. Vol. 1: *Executive Overview*. University of Otago: Dunedin, 1991.
22 Johansson A G, Forslund A, Sjodin A, Mallmin H, Hambraeus L, Ljunghall S. Determination of body composition — a comparison of dual-energy X-ray absorptiometry and hydrodensitometry. *Am J Clin Nutr* 1993; **57**: 323–326.
23 Reid I R, Cullen S, Schooler B A, Livingston N E, Evans M C. Calcitropic hormone levels in Polynesians: evidence against their role in interracial differences in bone mass. *J Clin Endocrinol Metab* 1990; **70**: 1452–1456.
24 Cundy T, Cornish J, Evans M C, Gamble G, Stapleton J, Reid I R. Source of interracial variation in bone mineral density. *J Bone Mineral Res* 1995; **10**: 368–373.