



Body size, body composition, and fat distribution: a comparison of young New Zealand men of European, Pacific Island, and Asian Indian ethnicities

Elaine Rush, Lindsay Plank, Vishnu Chandu, Manaia Lulu, David Simmons, Boyd Swinburn, Chittaranjan Yajnik

Abstract

Aims To investigate body size and body fat relationships and fat distribution in young healthy men drawn from New Zealand European, Pacific Island, and Asian Indian populations.

Method A total of 114 healthy men (64 European, 31 Pacific Island, 19 Asian Indian) aged 17–30 years underwent measurements of height, weight, and body composition by total body dual-energy X-ray absorptiometry (DXA). Body mass index (BMI) was then calculated. Percent body fat (%BF), fat-free mass, bone mineral content, bone mineral density, abdominal fat, thigh fat, and appendicular skeletal muscle mass (ASMM) were obtained from the DXA scans.

Results For the same BMI, %BF for Pacific Island men was 4% points lower and for Asian Indian men was 7–8% points higher compared to Europeans. Compared to European men for the same %BF, BMI was 2–3 units higher for Pacific Island, and 3–6 units lower for Asian Indian. The ratio of abdominal fat to thigh fat, adjusted for height, weight, and %BF, was significantly higher for Asian Indian men than European ($p=0.022$) and Pacific Island ($p=0.002$) men. ASMM, adjusted for height and weight, was highest in Pacific Island and lowest in Asian Indian men.

Conclusions The relationship between %BF and BMI is different for European, Pacific Island, and Asian Indian men which may, at least in part, be due to differences in muscularity. Asian Indians have more abdominal fat deposition than their European and Pacific Island counterparts. Use of universal BMI cut-off points are not appropriate for comparison of obesity prevalence between these ethnic groups.

It is widely recognised that obesity (defined as an excess of body fat) and obesity-related diseases are an increasing global problem now reaching epidemic proportions.¹ Because of its general use and ease of measurement, body mass index (BMI) is commonly used as a surrogate measure for obesity. The World Health Organization (WHO) cut-off point for classification of obesity as a body mass index (BMI) above 30 kg/m^2 is intended as an internationally useful threshold for reflecting risk for Type 2 diabetes and cardiovascular diseases.

Based on this cut-off, Asian immigrants from the Indian subcontinent have low rates of obesity yet, relative to Europeans, they have a higher prevalence of coronary heart disease and Type 2 diabetes.^{2–5}

Increased BMI levels explain only about half of the increased prevalence of diabetes⁶ and hypertension⁷ among Pacific Island peoples compared with New Zealand Europeans. In New Zealand (specifically, in inner urban South Auckland), the

prevalence of Type 2 diabetes in Asian Indian peoples is more than four-fold and in Pacific Island peoples more than two-fold higher than in Europeans.⁸ These observations are of particular concern because of the increasing size of the resident Asian Indian and Pacific Island populations in this country. The 2001 census indicated that there are now more people of Asian than Pacific Island ethnicity resident in NZ. The Asian Indian subgroup comprises approximately 26% of the New Zealand Asian population.⁹

Ethnic differences in body build, fat patterning, and muscularisation may all contribute to differences in the relationship between BMI and body fat between ethnic groups. Asian Indians have a more central distribution of body fat than Europeans,² which is associated with increased risk of diabetes Type 2 and ischaemic heart disease.^{10,11} Polynesians have higher bone mass and muscle mass than Europeans.¹²⁻¹⁴

The WHO has recognised the deficiencies of a universal cut-off for overweight and obesity^{15,16} and in a recently published report¹⁷ suggested that further body composition studies of Asian and Pacific Island populations are needed to determine equivalent fatness levels and the relation of BMI to body size.

Dual-energy X-ray absorptiometry (DXA) is widely accepted as a valuable technique for the assessment of body composition and, in particular, fat distribution, muscle mass and bone mass. While not without drawbacks as a reference method,¹⁸ it has clear advantages over the traditional anthropometric approaches such as skinfold thicknesses, girths, and BMI. A significant drawback is that individuals with very high BMI are not easily accommodated.

On the other hand, the technology provides a more direct assessment of total body fat than anthropometric methods and offers regional composition analysis. We are not aware of any comparative analysis of the body composition of European, Asian Indian, and Pacific Island subjects using this technique.

We sought in the current study of a group of young healthy males who underwent DXA to identify ethnic differences in:

- (1) The relationships between body fatness and body size,
- (2) Fat distribution,
- (3) Muscularity, and
- (4) Bone mineral density and mass.

Methods

Data from healthy male volunteers aged 17–30 years, who participated in cross-sectional studies of body composition conducted in the Department of Surgery, University of Auckland, were examined. All studies were approved by the local ethics committees and all participants provided written informed consent. Recruitment for these studies, principally from the urban Auckland area, was by personal contact, advertisement, or through existing networks of the recruiters.

Exclusion criteria were: total joint replacement, lifting weights more than once per week, major medical conditions (such as diabetes or cancer), and medication which could possibly affect body composition (such as oral steroids). Only one member of a family was measured. In addition, one subject was subsequently excluded from analysis because of a large difference (>3 kg) between recorded scale weight and DXA weight (sum of fat mass, fat-free soft tissue and bone mineral content). Of 114 volunteers, 64 self-identified as European, 31 as Pacific Island, and 19 as Asian Indian.

Height and weight were measured with participants wearing light clothing or standard hospital gown and no shoes. An estimated clothing weight was subtracted. Body composition (fat, fat-free soft tissue, and bone mineral content) and whole-body bone mineral density measurements were made using a single DXA machine (model DPX+ with software version 3.6y, Lunar Radiation Corp., Madison, WI). Fat-free mass (FFM) was calculated as the sum of the values for fat-free soft tissue and bone mineral content. Percent body fat was calculated as $100 \times \text{fat mass} / (\text{fat mass} + \text{FFM})$.

For assessing regional fat distribution, the whole-body DXA scans were analysed. Abdominal and thigh regions of interest were defined by the criteria of Ley et al.¹⁹ Abdominal fat was obtained from analysis of a region of interest positioned with the lower horizontal border on top of the iliac crest and the upper border approximately parallel with the junction of the T12 and L1 vertebrae. The sides of this region were adjusted to include the maximum amount of abdominal tissue. A region of interest of identical height placed over the thighs (with the upper horizontal border positioned immediately below the ischial tuberosities) was used to obtain fat content of the thighs. The lateral margins were adjusted to follow the shape of the thighs.

Appendicular skeletal muscle mass (ASMM) was derived from the DXA scans as total limb mass minus the sum of limb fat mass and wet bone mass, estimated as bone mineral content divided by 0.55.²⁰ In this model, mass of the skin and associated dermal tissues is assumed to be negligible relative to the skeletal muscle component.

Results are presented as means \pm SD. Between-group differences in subject characteristics were tested using one-way ANOVA followed by pairwise comparisons if a significant F test was obtained. Analysis of covariance was used to adjust body composition results for comparison across ethnic groups. Before carrying out analysis of covariance, similarity of regression slopes among the ethnic groups was verified by examining the significance of the interaction between the covariate(s) and the group variable. Data were analysed using SAS software, version 6.12 (SAS Institute Inc., Cary, NC). Results with p values <0.05 were considered significant.

Results

The subject characteristics are summarised in Table 1. Pacific Island men in this study were heavier with higher BMI than Europeans and Asian Indians. Asian Indians were shorter than Pacific Islanders and significantly fatter than Europeans and Pacific Islanders.

As a proportion of total body fat, abdominal fat was significantly higher for Asian Indians than Europeans ($p < 0.0001$) or Pacific Islanders ($p < 0.0001$), while thigh fat was significantly lower than Europeans ($p = 0.037$) or Pacific Islanders ($p = 0.015$) (Table 1). After adjustment for weight, height, and %BF, the ratio of abdominal to thigh fat was significantly higher for Asian Indians than Europeans ($p = 0.022$) and Pacific Islanders ($p = 0.002$).

ASMM for Pacific Islanders was significantly higher than Europeans ($p < 0.0001$); and for Europeans, ASMM was significantly higher than Asian Indians ($p = 0.0021$) (Table 1). This pattern remained after adjustment of ASMM for height and weight, with Pacific Islanders having significantly higher ASMM than Europeans ($p < 0.0001$), and Europeans having significantly higher ASMM than Asian Indians ($p = 0.0012$).

After adjustment for height and weight, bone mineral density was significantly higher in Pacific Islanders than European ($p = 0.0009$) and Asian Indian ($p = 0.0014$). Adjusted bone mineral density for European was similar to that for Asian Indian ($p = 0.46$). When adjusted for height and weight bone mineral content was significantly higher in Pacific Islanders than European ($p = 0.0021$) and higher in European than Asian Indian ($p = 0.0008$).

Table 1. Characteristics of 64 New Zealand European, 31 Pacific Island, and 19 Asian Indian men aged 17–30 years

Variable	European Mean (SD)	Pacific Island Mean (SD)	Asian Indian Mean (SD)	p value*
Age (y)	23.8 (3.7)	22.7 (2.6)	24.2 (3.4)	0.24
Height (cm)	177.5 (6.2)	179.1 (7.3)	174.0 (6.1) ^P	0.030
Weight (kg)	79.1 (10.7) ^P	94.7 (17.5)	79.6 (14.9) ^P	<0.0001
BMI (kg/m ²)	25.2 (3.4) ^P	29.6 (5.3)	26.3 (4.8) ^P	<0.0001
Fat-free mass (kg)	63.2 (5.9) ^P	72.0 (8.9)	55.9 (7.2) ^{PE}	<0.0001
Total body fat (kg)	15.9 (8.7)	22.7 (12.6)	23.7 (10.2) ^{PE}	0.001
Total body fat (%)	19.4 (8.2) ^P	22.7 (9.5)	28.8 (8.0) ^E	0.002
Abdominal fat (kg)	1.23 (0.86) ^P	1.73 (1.09)	2.11 (0.99) ^E	0.001
Abdominal fat (% of total fat)	7.3 (1.2)	7.3 (1.3)	8.8 (1.2) ^{PE}	<0.0001
Thigh fat (kg)	1.47 (0.70) ^P	2.14 (1.11)	2.07 (0.86) ^E	0.0005
Thigh fat (% of total fat)	9.5 (1.1)	9.7 (1.1)	8.9 (1.3) ^{PE}	0.045
Abdominal-to-thigh fat ratio	0.79 (0.20)	0.77 (0.19)	1.02 (0.24) ^{PE}	<0.0001
ASMM (kg)	26.9 (2.8) ^P	31.7 (2.4)	24.1 (3.4) ^{PE}	<0.0001
ASMM (%)	34.3 (4.0)	34.0 (4.3)	30.7 (4.0) ^{PE}	0.004
Bone mineral content (kg)	3.33 (0.42) ^P	3.81 (0.45)	2.92 (0.44) ^{PE}	<0.0001
Bone mineral density (g/cm ²)	1.24 (0.08) ^P	1.34 (0.09)	1.22 (0.10) ^P	<0.0001

ASMM=appendicular skeletal muscle mass; *analysis of variance; ^Ep<0.05 vs European, ^Pp<0.05 vs Pacific Island

Curvilinear relationships between %BF and BMI for each ethnic group were linearised by logarithmically transforming BMI (Figure 1). No significant difference was found between the slopes of the regressions of %BF on the logarithm of BMI for the three ethnic groups, but covariance analysis showed their elevations to be significantly different (p<0.0001).

The common slope regression equation for predicting %BF from BMI for the three ethnic groups was:

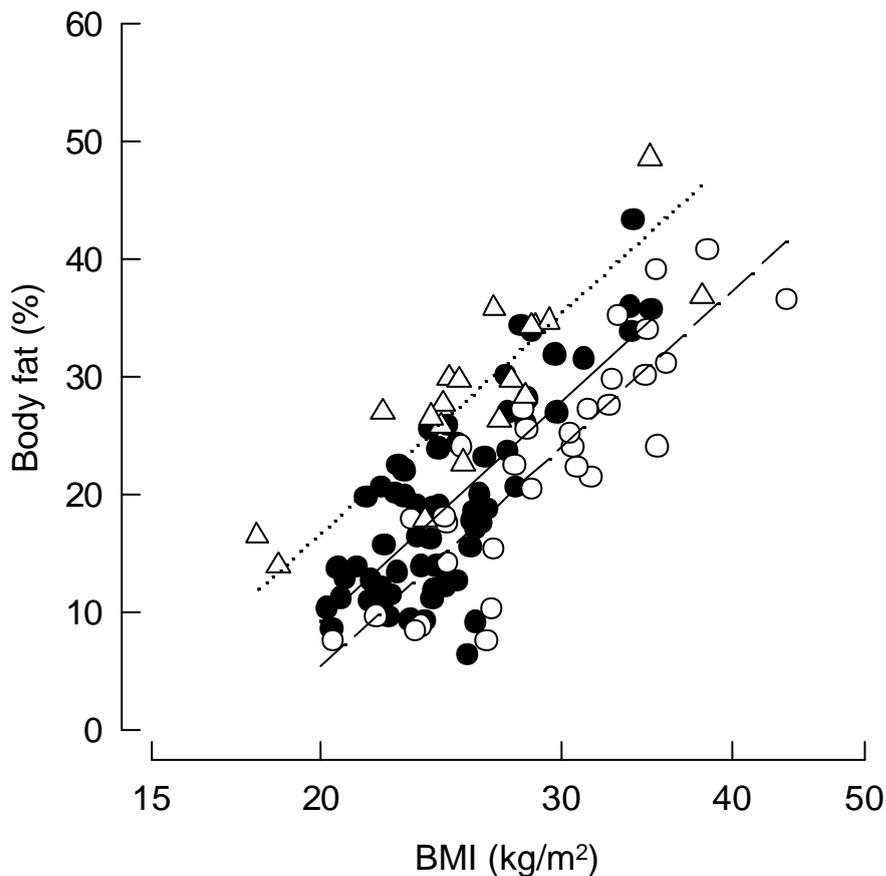
- %BF = 105.79 log₁₀(BMI) – 128.42 – 3.77 group1 + 7.60 group2
- (SEE (standard error of estimate) = 4.89%, R² = 0.72)

where group1 is coded as 0 for European, 1 for Pacific Islanders, 0 for Asian Indians—and group2 is coded as 0, 0, 1 for these respective ethnic groups. Hence, for fixed BMI, compared with Europeans, Pacific Islanders had lower %BF by 3.8% (95% confidence interval: 1.4%–6.1%) and Asian Indians had higher %BF by 7.6% (5.0%–10.2%). At a BMI of 30 for Europeans the predicted %BF (28%) equates to a BMI of 33 for the Pacific Islanders and 25 for the Asian Indians (Table 2).

Table 2. Comparison of European body mass index (BMI) and corresponding percent body fat with estimated BMI equivalents for Pacific and Asian Indians derived from equations relating BMI to percent body fat

European		Pacific Island	Asian Indian
BMI (kg/m ²)	Body fat (%)	Approximate BMI equivalent (kg/m ²)	Approximate BMI equivalent (kg/m ²)
20	9	22	17
25	20	27	21
30	28	33	25
35	35	38	30
40	41	43	34

Figure 1. Relation between percentage body fat (%BF) and BMI for 64 European (closed circles), 31 Pacific Island (open circles), and 19 Asian Indian (triangles) men. The common slope linear regressions are given by %BF = 105.8 log₁₀(BMI) – intercept, where intercept=128.4 for the European (solid line), 132.2 for the Pacific Island (dashed line), and 120.8 for the Asian Indian men (dotted line)



Discussion

In a group of young European, Pacific Island and Asian Indian young men, we have shown that the relationship between percent body fat and BMI is ethnicity specific.

The most commonly used measure of obesity is BMI, and we found that, for a fixed BMI, Pacific Island men had significantly less body fat while Asian Indian men had significantly more body fat than their European counterparts. At a fixed %BF, BMI in Pacific Island men was 2–3 units higher and in Asian Indian men was 3–6 units lower than in European men. The BMI differences are smallest at low %BF and diverge with increasing %BF. This effect is seen in Table 2 and also is evident in Figure 1 when allowance is made for the logarithmic transformation of BMI. The results for Pacific Island men confirm our previous observations.²¹

Ethnic differences in the BMI-body fat relationships may be explained, at least in part, by differences in body build, particularly muscularity. We have shown that, compared with European men of similar weight and height, Asian Indian men have significantly less skeletal muscle in the limbs while Pacific Island men have significantly more. (Appendicular skeletal muscle is approximately 75% of total body skeletal muscle mass.)²²

We have also shown, by examination of the distribution of fat in our subjects, that Asian Indian men have a more central fat deposition pattern than European or Pacific Island men. The propensity for abdominal adiposity found in Asian Indians had been inferred from measurements of waist-to-hip girth ratios in a number of studies.^{2,23} Central obesity is closely associated with risk for cardiovascular disease and Type 2 diabetes.³

The greater bone mineral mass and bone density that we observed in Pacific Island men (relative to Europeans) may also contribute to differences in the body fat-BMI relationship for these ethnic groups. While bone mineral mass was lower in Asian Indians than Europeans, their bone mineral density was similar after adjustment for body size. Others have shown that both bone mineral density and bone mineral content in Asian men (predominantly Chinese) were similar to European men after controlling for weight, height, and age.²⁴ Age was not a significant covariate for our restricted-age range data.

A limitation of the present study is the comparatively small Asian Indian group and our results need to be confirmed with a larger sample from this ethnic group. In addition, our study does not address the other Asian subgroups which make up the majority of Asians in New Zealand.

The WHO BMI classifications of overweight (≥ 25 kg/m²) and obesity (≥ 30 kg/m²), although intended for international use, are based on the relationship between BMI and cardiovascular morbidity in Western populations.¹ Based on percent body fat levels a BMI of 26 kg/m² has been suggested as an obesity cut-off point in Asian Indians equivalent to that for Europeans,²⁵ and revised cut-off values to define overweight (23 kg/m²) and obesity (25 kg/m²) in Asian Indians have been proposed by the WHO.¹⁵

Current New Zealand Ministry of Health cut-offs for 'overweight' and 'obesity' are 26 and 32 kg/m², respectively in both Maori and Pacific Island adults. Studies are required to define the BMI range that may be considered 'healthy' in Asian Indian

and Pacific Island people on the basis of risk for obesity-related diseases. A consistent finding among migrant Asian Indian populations is hyperinsulinaemia and insulin resistance,²⁶ characteristics which may be important in the development of type 2 diabetes and cardiovascular disease.

Simmons et al²⁷ have reported that young Asian Indians are relatively hyperinsulinaemic compared to their European counterparts with the same BMI. Vikram et al²⁸ have shown that Asian Indians with 'normal' BMI (<25 kg/m²) have high cardiovascular disease risk. Pacific Islanders in New Zealand, by contrast, are not hyperinsulinaemic relative to Europeans of the same BMI²⁹ and whilst they have a high prevalence of type 2 diabetes, they are believed to have a lower rate of cardiovascular disease.³⁰

Our results demonstrate the marked differences in body build, body composition, and fat distribution that characterise male New Zealanders of European, Asian Indian and Pacific Island ancestry. We speculate that these may be related to differences in risk for cardiovascular disease and different pathways to Type 2 diabetes among these ethnic groups. The results emphasise the inadequacy of universal BMI cut-off points for determination of percentage body fat and obesity and the need to consider ethnic-specific weight targets.

Author information: Elaine Rush, Associate Professor, Faculty of Health, Auckland University of Technology, Auckland; Lindsay Plank, Senior Research Fellow, Department of Surgery, University of Auckland, Auckland; Vishnu Chandu, Student, Faculty of Science and Engineering, Auckland University of Technology, Auckland; Manaia Laulu, Student, Department of Applied Science, Auckland University of Technology, Auckland; David Simmons, Professor, Waikato Clinical School, University of Auckland, Hamilton; Boyd Swinburn, Professor, Physical Activity and Nutrition Research Unit, School of Health Sciences, Deakin University, Melbourne, Australia; ChittaranjanYajnik, Director, Diabetes Unit, KEM Hospital Research Centre, Pune, India

Acknowledgements: This research was supported, in part, by the Auckland University of Technology, the Public Health Commission, and the Health Research Council of New Zealand (grant number 99/660).

Correspondence: Associate Professor Elaine Rush, Faculty of Health, Auckland University of Technology, Private Bag 92006, Auckland. Fax: (09) 917 9973; email: elaine.rush@aut.ac.nz

References:

1. World Health Organization. Obesity: preventing and managing the global epidemic. Report of a WHO Consultation on Obesity. Technical Report Series No. 894. Geneva: World Health Organization; 2000.
2. McKeigue PM, Shah B, Marmot MG. Relation of central obesity and insulin resistance with high diabetes prevalence and cardiovascular risk in South Asians. *Lancet*. 1991;337:382–6.
3. Dhawan J, Bray CL, Warburton R, Ghambhir DS, Morris J. Insulin resistance, high prevalence of diabetes, and cardiovascular risk in immigrant Asians. Genetic or environmental effect? *Br Heart J*. 1994;72:413–21.
4. Balarajan R. Ethnic differences in mortality from ischaemic heart disease and cerebrovascular disease in England and Wales. *Br Med J*. 1991;302:560–4.

5. Simmons D, Williams DR, Powell MJ. The Coventry Diabetes Study: prevalence of diabetes and impaired glucose tolerance in Europids and Asians. *Q J Med.*1991;81:1021–30.
6. Scragg R, Baker J, Metcalf P, Dryson E. Prevalence of diabetes mellitus and impaired glucose tolerance in a New Zealand multiracial workforce. *N Z Med J.* 1991;104:395–7.
7. Scragg R, Baker J, Metcalf P, Dryson E. Hypertension and its treatment in a New Zealand multiracial workforce. *N Z Med J.* 1993;106:147–50.
8. Simmons D, Harry T, Gatland B. Prevalence of known diabetes in different ethnic groups in inner urban South Auckland. *N Z Med J.* 1999;112:316–9.
9. Statistics NZ. 2001 Census: Asian People 2001. Wellington: Statistics New Zealand; 2001.
10. Vague J. The degree of masculine differentiation of obesities: a factor determining predisposition to diabetes, atherosclerosis, gout and uric calculous disease. *Am J Clin Nutr.* 1956;4:20-34.
11. Després J. Abdominal obesity as important component of insulin-resistance syndrome. *Nutrition* 1993;9:452–9.
12. Houghton P. The adaptive significance of Polynesian body form. *Ann Hum Biol.* 1990;17:19–32.
13. Reid IR, Cullen S, Schooler BA et al. Calcitropic hormone levels in polynesians: evidence against their role in interracial differences in bone mass. *J Clin Endocrinol.* 1990;70:1452–6.
14. 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.
15. WHO/IASO/IOTF. The Asia-Pacific perspective: redefining obesity and its treatment. Health Communications Australia: Melbourne; 2000.
16. James WPT, Chen C, Inoue S. Appropriate Asian body mass indices? *Obesity Rev.* 2002;3:139.
17. World Health Organization. Appropriate body-mass index for Asian populations and its implications for policy and intervention strategies. *Lancet.* 2004;363:157–63.
18. Roubenoff R, Kehayias J, Dawson-Hughes B, Heymsfield S. Use of dual-energy x-ray absorptiometry in body composition studies: not yet a "gold-standard". *Am J Clin Nutr.* 1993;58:589–91.
19. Ley C, Lees B, Stevenson J. Sex- and menopause associated changes in body-fat distribution. *Am J Clin Nutr.* 1992;55:950–4
20. Heymsfield S, Smith R, Aulet M, et al. Appendicular skeletal muscle mass: measurement by dual-photon absorptiometry. *Am J Clin Nutr.* 1990;52:214–8.
21. Swinburn BA, Ley SJ, Carmichael HE, Plank LD. Body size and composition in Polynesians. *Int J Obes.* 1999;23:1178–83.
22. Snyder WS, Cook MJ, Nasset ES, et al. Report of the Task Group on Reference Man. Pergamon: Oxford; 1975.
23. Potts J, Simmons D. Sex and ethnic group differences in fat distribution in young United Kingdom South Asians and Europids. *J Clin Epidemiol.* 1994;47:837–41.
24. Russell-Aulet M, Wang J, Thornton J, et al. Bone mineral density and mass by total-body dual-photon absorptiometry in normal white and Asian men. *J Bone Min Res.* 1991;6:1109–13.
25. Deurenberg-Yap M, Schmidt G, van Staveren WA, Deurenberg P. The paradox of low body mass index and high body fat percentage among Chinese, Malays and Indians in Singapore. *Int J Obes.* 2000;24:1011–7.

26. Banerji MA, Faridi N, Atluri R, et al. Body composition, visceral fat, leptin, and insulin resistance in Asian Indian men. *J Clin Endocrinol Metab.* 1999;84:137–44.
27. Simmons D, Powell MJ. Metabolic and clinical characteristics of South Asians and Europeans in Coventry. *Diabetic Med.* 1993;10:751–8.
28. Vikram NK, Pandey RM, Misra A, et al. Non-obese (body mass index <25 kg/m²) Asian Indians with normal waist circumference have high cardiovascular risk. *Nutrition.* 2003;19:503–9.
29. Simmons D, Thompson CF, Volklander D. Polynesians: prone to obesity and Type 2 diabetes mellitus but not hyperinsulinaemia. *Diabetic Med.* 2001;18:193–8.
30. Tukuitonga CF, Stewart A, Beaglehole R. Coronary heart disease among Pacific Island people in New Zealand. *N Z Med J.* 1990;103:448–9.