Dietary and 24-h fat oxidation in Asians and whites who differ in body composition.

Dietary and 24-h fat oxidation in Asians and whites who differ in body composition[1–3]

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ABSTRACT

Background: With the same BMI, age, and sex, Asians were reported to have a higher body fat percentage than whites.

Objective: This study aimed to determine the difference in body composition and its effect on dietary and 24-h fat oxidation between Asians and whites when they were fed a diet that contained 30% of energy as fat.

Design: Seventeen Asians (8 men) were matched with 17 whites (8 men) for BMI, age, and sex. Physical activity was measured for 7 d with an accelerometer. During the last 3 d of the activity measurement, subjects were given a diet to maintain energy balances. Energy expenditure and substrate use were measured for 24 h in a respiration chamber. Dietary fat oxidation was determined from the percentage recovery of deuterium in the urine after a breakfast meal that contained deuterated palmitic acid. Body composition was calculated with a 3-compartment model from body mass, body volume (hydrodensitometry), and total body water (deuterium dilution).

Results: Asians had 5% higher body fat than whites (28.1 ± 7.3% compared with 23.0 ± 6.9%, respectively; $P = 0.03$). The fat-free mass index tended to be lower in Asians than in whites (16.3 ± 1.6 compared with 17.0 ± 1.7 kg/m^2, respectively; $P = 0.07$). Dietary fat oxidation as a percentage of fat consumed was 11.7 ± 3.6% compared with 10.8 ± 4.5% ($P = 0.50$) for Asians and whites, respectively. In Asians and whites, the 24-h fat oxidation as a percentage of total energy expenditure was 17.7 ± 6.9% compared with 19.2 ± 5.1% ($P = 0.63$), respectively; carbohydrate oxidation was 68.0 ± 6.8% compared with 66.1 ± 5.1% ($P = 0.51$), respectively; and protein oxidation was 14.3 ± 2.2 compared with 14.7 ± 1.6% ($P = 0.61$), respectively.

Conclusion: Dietary and 24-h fat oxidation were not different between Asians and whites despite differences in body composition. This study was registered in the public trial registry at www.ccmo.nl as NL31217.068.10. *Am J Clin Nutr* 2012;95:1335–41.

INTRODUCTION

Several studies reported that Asians compared with whites with the same BMI, age, and sex were shown to have a higher body fat percentage (1–5) and a lower fat-free mass (FFM)[4] (6–8). These characteristics may partly explain the increasing prevalence of type 2 diabetes and metabolic syndrome in Asia (9, 10). In different Asian populations, in both adults (4, 11, 12) and children (13, 14), there were also differences in the BMI–body fat relation depending on the ethnic background (eg, Chinese, Malay, or South Asian Indian). This unfavorable body composition may be a consequence of a lower rate of energy metabolism and a higher respiratory quotient (RQ), which indicate a lower proportion of fat to carbohydrate oxidation. This effect has been reported in other ethnic groups such as in African Americans (15) or Pima Indians (16). Alternatively, a low rate of energy metabolism may be partly due to the unfavorable body composition.

The relation between body composition and energy metabolism has been studied extensively in health and disease. Studies have established FFM as the major determinant of resting energy expenditure (REE) (17), which is the largest component of daily total energy expenditure (TEE). Asians were reported to have a lower REE than that of whites because of the lower FFM; the difference in REE disappeared when adjusted for body composition (18).

Energy expenditure equals energy intake when in energy balance. Under conditions of a perfect energy and nutrient balance, the food quotient (FQ) equals the RQ (19). In the long term, an RQ higher than the FQ implicates a conversion of carbohydrate and protein to body fat, and an RQ lower than the FQ implicates a mobilization of energy from body fat (19). A higher RQ has been associated with weight gain in obesity-prone Pima Indians (16), although another study reported no evidence of a low metabolic rate and impaired fat oxidation in Pima Indians (20). However, one should acknowledge that the rise in endogenous fat storage that accompanies a prolonged increase in fat intake progressively leads to an enhanced fat oxidation in the

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[4] Abbreviations used: ACD, activity counts per day; BMR, basal metabolic rate; FFM, fat-free mass; FFMI, fat-free mass index; FQ, food quotient; PAL, physical activity level; REE, resting energy expenditure; RQ, respiratory quotient; SMR, sleeping metabolic rate; TEE, total energy expenditure.

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dynamic phase of weight gain up to a reequilibrium in fat balance (21). In South Asian Indians, Hall et al (22) reported that, during submaximal exercise, they oxidized less fat than did Europeans, whereas at rest, there was no difference in fat oxidation. To our knowledge, there has been no study that compared the 24-h energy metabolism of Asians and whites measured in a respiration chamber. In addition, because humans spend the majority of 24 h in a fed (postprandial) state, fatty acids from dietary sources also play a major metabolic role (23). The objective of the current study was to determine the effect of differences in body composition between Asians and whites on 24-h fat oxidation and dietary fat oxidation.

SUBJECTS AND METHODS

Subjects

Subjects included 17 healthy adult Asians (8 men) and 17 whites (8 men). Subjects were matched for BMI (in kg/m^2), age, and sex. Subject characteristics are presented in **Table 1**. Asian subjects had 4 grandparents from Asia, whereas white subjects were non-Hispanic Europeans. Subjects were selected on the basis of the following inclusion criteria: healthy, not using medication (except oral contraceptives), aged between 20 and 40 y, had a BMI between 20 and 27, had a stable body weight for the past 3 mo, were not on a diet, and were not athletes. All subjects received verbal and written information before giving their consent to participate in the study. The study was approved by Medical Ethics Committee of Maastricht University Medical Centre (10–3-013).

Experimental design

This study had a cross-sectional study. Daily physical activity was measured for 7 consecutive days; during the last 3 d of activity measurement, subjects were given a diet to maintain energy balance. On the evening of day 3 of the balance diet, subjects came to the university to have dinner and started their 36-h stay in the respiration chamber (the test day). In the morning after the 36-h stay in the respiration chamber, body composition was measured.

Daily physical activity level

The daily physical activity level (PAL) was measured with a triaxial accelerometer (Tracmor; Philips Research) for movement registration. The accelerometer was attached to the lower back by means of an elastic belt. The accelerometer registered accelerations minute by minute in the mediolateral (x axis), longitudinal (y axis), and anterioposterior (z axis) of the trunk as described elsewhere (24). Subjects were instructed to wear the accelerometer for 7 consecutive days during waking hours except during water activities. Subjects were advised to maintain their habitual PAL and not to perform any strenuous physical activity the day before the test day. Accelerometer output was defined as activity counts per day (ACD) as the sum of all 3 axes over 7 d divided by 7. Daily PAL was calculated on the basis of the ACD by using the following formula:

$$\mathrm{PAL} = 1.267 + (1.437 \times 10^{-6} \times \mathrm{counts/d}) \qquad (1)$$

(R^2 = 0.59) (24). Daily TEE was calculated by using the formula of Plasqui et al (24) as follows:

$$\mathrm{TEE\ accelerometer} = -7.98 + 2.58 \times \mathrm{SMR} + 8.57 \times 10^{-3} \times \mathrm{kcounts} \qquad (2)$$

(R^2 = 0.95) by including ACD (from the accelerometer) and sleeping metabolic rate (SMR; from the respiration chamber measurement).

Energy intake

The energy-balance diet to be consumed at home for 3 d before the test day was calculated on the basis of average daily energy requirements with a moderate PAL of 1.75. The daily energy requirement was estimated as 1.75 times basal metabolic rate (BMR) (25). BMR was calculated on the basis of the Harris-Bennedict formula (26). A written instruction was given to prepare the diet at home. Subjects were provided with the diet in an amount in excess of the average daily energy requirement of 1.75 times the BMR. Subjects were allowed to eat more or less from the diet prescribed according to what they needed (ad libitum). Any additional amount from those prescribed foods was recorded. All unfinished foods were collected and returned to the university to calculate actual energy intakes.

TABLE 1
Subject characteristics[1]

	Men		Women		All		*P*		
Characteristic	Asian	White	Asian	White	Asian	White	Ethnicity	Sex	Ethnicity × sex
n	8	8	9	9	17	17	—	—	—
Age (y)	27 ± 3.7	26 ± 4.2	28 ± 3.6	24 ± 1.9	28 ± 4	25 ± 3	0.06	0.47	0.44
Weight (kg)	66.9 ± 7.5	72.4 ± 5.1	54.8 ± 7.4	60.1 ± 7.6	60.5 ± 9.5	65.9 ± 9.0	0.32	0.001	0.97
Height (m)	1.7 ± 0.1	1.8 ± 0.1	1.6 ± 0.1	1.7 ± 0.1	1.62 ± 0.1	1.73 ± 0.1	0.001	0.001	0.39
BMI (kg/m^2)	23.5 ± 2.5	23.1 ± 1.7	22.4 ± 2.6	21.2 ± 2.5	22.9 ± 2.5	22.1 ± 2.3	0.36	0.08	0.65
Fat mass (%)	25 ± 6.1	19.7 ± 6.6	30.9 ± 7.4	25.9 ± 6.0	28.1 ± 7.3	23.0 ± 6.9	0.03	0.01	0.94
Fat mass (kg)	16.9 ± 4.9	14.4 ± 5.4	17.3 ± 6.0	15.8 ± 5.1	17.1 ± 5.4	15.2 ± 5.1	0.29	0.63	0.78
Fat-free mass (kg)	50.0 ± 4.9	58.0 ± 4.1	37.4 ± 2.7	44.3 ± 4.0	43.3 ± 7.4	50.7 ± 8.1	0.001	0.001	0.65
FMI (kg/m^2)	6.0 ± 1.9	4.6 ± 1.8	7.0 ± 2.4	5.6 ± 1.8	6.5 ± 2.2	5.1 ± 1.8	0.05	0.14	0.95
FFMI (kg/m^2)	17.5 ± 1.2	18.4 ± 0.9	15.3 ± 1.1	15.6 ± 0.8	16.3 ± 1.6	17.0 ± 1.7	0.07	0.001	0.34

[1] All values are mean ± SDs and were analyzed by using 2-factor ANOVA (ethnicity and sex). *P* values are presented for main effects of ethnicity, sex, and the interaction between ethnicity and sex. FFMI, fat-free mass index; FMI, fat mass index.

The energy requirement in the respiration chamber was estimated as 1.35 times the BMR. Percentages of energy from the diet were divided as follows: 20% from breakfast, 40% from lunch, 35% from dinner, and 5% from evening snacks. Breakfast was served at 0830, lunch was served at 1200, dinner was served at 1800, and evening snacks were served at 2000. The macronutrients distribution of the diet before and during the chamber stay was 55% carbohydrate, 15% protein, and 30% fat.

The diet was a combination of typical Western and Asian diets. Breakfast was a typical Western diet with bread and spreads, which is becoming more common in Asia as well. Lunch was a sandwich with a chicken burger or fish filet. Dinner was a typical Asian diet of rice and other dishes and a Mediterranean diet of pasta, which is also commonly eaten in Asia as noodles. Foods were selected by reviewing ingredient contents to avoid an effect of certain ingredients on fat oxidation (such as spices). During the chamber stay, subjects were also provided with decaffeinated coffee and fruit tea because caffeine has also been reported to increase fat oxidation.

The diet was given 3 d before and during the stay in the respiration chamber. In total, the diet was given for 4 d. To simulate the variety of foods as on a day-to-day basis, the diet was arranged as follows: day 1 = day 3, and day 2 = day 4. This arrangement also allowed subjects to become accustomed to the diet in the respiration chamber because they already had the diet before the chamber stay.

Energy expenditure

Subjects stayed in the respiration chamber from 2000 in the evening of the third day of their balance diet (day 3) until 0800 in the morning of day 5 (36 h). The respiration chamber was a 14-m^3 room furnished with a full-sized foldaway bed, a bureau with a built-in sink, a folding chair, a television, a DVD player, an alarm clock, a telephone, an automated intercom, and a computer-network connection. The chamber gave the impression of a normal room with windows positioned in the door for contact with researchers, in the wall (outside view), and between the chambers for visual contact between subjects. A more detailed description of the chamber has been provided elsewhere (27).

During the 36-h stay in the respiration chamber, oxygen consumption and carbon dioxide production were measured continuously. Subjects were allowed to move freely, sit, lie down, study, use the telephone, listen to the radio, watch television, and use the computer from 0700 to 2300 but were not allowed to do strenuous physical activity (exercise) or sleep. The TEE over 24 h and 24-h RQ were calculated from 0800 on the first morning until 0800 on the second morning in the respiration chamber. A radar system based on the Doppler principle was used to measure the spontaneous physical activity of subjects in the chamber. The TEE was calculated by using the following equation of Carpenter as published by Brouwer (28):

$$\text{TEE (kJ/d)} = 16 \times \text{O}_2\text{ (L/d)} + 5 \times \text{CO}_2\text{ (L/d)} - 0.95 \times P \quad (3)$$

where P is oxidized protein in grams per day.

The SMR was calculated by assessing the lowest mean activity of subjects during 3 consecutive hours between 0000 and 0700 during the second night of their stay in the respiration chamber. The SMR was also corrected for body composition (FFM) on the basis of the previous study (18).

Substrate oxidation

Substrate oxidation was calculated from 24-h urinary nitrogen, oxygen consumption, and carbon dioxide production. Urine samples (24 h) were collected from the second voiding on day 4 until the first voiding on day 5. To prevent nitrogen loss through evaporation, 24-h urine was collected in containers with 10 mL HCl, whereas the total volume was measured afterward. Nitrogen concentrations were measured with a nitrogen analyzer (CHN-O-Rapid; Heraeus). Protein oxidation (g/d) was calculated by multiplying 24-h urinary nitrogen (g/d) by 6.25. Carbohydrate (g/d) and fat oxidation (g/d) were calculated by using the following equations of Carpenter as published by Brouwer (28):

$$\text{Carbohydrate oxidation} = -2.97 \times \text{O}_2\text{ (L/d)} + 4.17 \times \text{CO}_2\text{ (L/d)} - 0.39 \times P \quad (4)$$

$$\text{Fat oxidation} = 1.72 \times \text{O}_2\text{ (L/d)} - 1.72 \times \text{CO}_2\text{ (L/d)} - 0.32 \times P \quad (5)$$

Dietary fat oxidation

Deuterated palmitic acid (d31-palmitic acid, 98 atom%; Cambridge Isotope) at a dose of 20 mg/kg body weight was added to 200 mL hot chocolate milk, which was previously heated up to 65°C and consumed simultaneously with breakfast while subjects were fed in energy balance in the respiration chamber (29). Deuterium (^{2}H) was measured in a baseline urine sample collected before dosing, and samples were collected 12 and 14 h after dosing. Urine samples were analyzed for deuterium content with an isotope-ratio mass spectrometer (Optima; VG) after preparation by using the platinum-equilibration methodology (30). Urine samples of 300 μL were placed in the bottom of 3-mL glass containers with 4 mg catalyst (5% platinum-on alumina, 325 mesh; Aldrich Chemical Company Ltd) in an insert, filled with hydrogen from a cylinder to 60 kPa above atmospheric pressure, and left for 3 d at room temperature before analysis. The recovery of deuterium from palmitic acid oxidation was calculated as excess ^{2}H multiplied by the dilution space divided by the dose of ^{2}H administered as described by Vortubra et al (31).

Body composition

Body composition was determined according to a 3-compartment model on the basis of body weight, body volume, and total body water. Body weight and body volume were determined in the morning in a fasting state after the overnight stay in the respiration chamber. Body volume was determined by using hydrodensitometry with simultaneous measurement of residual lung capacity by using the helium-dilution technique. Total body water was determined by using deuterium dilution according to the Maastricht protocol (32). Body composition was calculated

from body density and total body water by using the equation of Siri (33).

Statistical analysis

Data are presented as means and SDs and were analyzed with 2-factor ANOVA (ethnicity and sex). The main effect of ethnicity, sex, and the interaction between ethnicity and sex were assessed. To assess the contribution of several independent variables to the variability of the dependent variables, multiple regression analysis was applied. The SPSS program (version 16; SPSS) was used for statistical analysis, and statistical significance was set as $P < 0.05$.

RESULTS

Subject characteristics

Asian subjects were South Asian Indian ($n = 4$; 3 men) and Pakistani ($n = 3$; 2 men), Southeast Asian Indonesian ($n = 5$; 2 men) and Thai ($n = 1$ woman), and East Asian Chinese ($n = 4$; 1 man). Thirteen of these subjects were measured within 1 y of their stay in the Netherlands, 3 subjects were measured within 2–3 y of their stay in the Netherlands, and one subject had been in Europe for 5 y. White subjects were Western European Dutch ($n = 7$; 4 men) and Germans ($n = 3$ women) and Eastern Europeans ($n = 7$; 4 men). Eastern Europeans were measured within 1 y ($n = 4$) and 3 y ($n = 3$) of their stay in the Netherlands. Subject characteristics are presented in Table 1.

Asian subjects had a 5% higher body fat percentage than that of whites ($P = 0.03$). Because whites were significantly taller than Asians, the absolute FFM of whites was significantly higher than that of Asians ($P = 0.001$). To adjust the difference in fat-free mass for height, we used the fat-free mass index [FFMI; FFM divided by the square of height (in kg/m^2)]. With this index, Asians tended to have a lower FFM per square meter of height compared with that of whites ($P = 0.07$) (Table 1).

Body composition

As expected, there was a sex difference in body composition in both ethnicities (Table 1). The body fat percentage was higher in women than in men ($P = 0.01$), whereas the FFMI was higher in men than in women ($P = 0.001$). As shown in Table 1, the ANOVA analysis revealed that there was an ethnic difference ($P = 0.03$) and a sex difference ($P = 0.01$), but there was no interaction between ethnicity and sex in relation to percentage body fat.

In general, Asians had a slightly lower FFMI than that of whites, but the difference was not significant. Compared with their white counterparts, Asian women had a 0.3-kg lower FFM per square meter, whereas Asian men had a 1-kg lower FFM per square meter (Table 1).

Energy balance before test day

There was no difference in ACD and, hence, no difference in the daily PAL between ethnicities (**Table 2**). The TEE was significantly higher in whites. The energy balance before the test day was not significantly different between ethnicities ($P = 0.22$) (Table 2).

Energy metabolism and substrate oxidation in respiration chamber

The TEE was higher in whites than in Asians ($P = 0.02$) and was mostly contributed by a higher SMR ($P = 0.001$). The difference in the SMR was no longer seen when adjusted for FFM (**Table 3**). Asians were more active in the respiration chamber than were whites [ie, the lower SMR was compensated with a higher PAL (1.36 compared with 1.30, respectively; $P = 0.03$)]. The radar output was not different between Asians and whites (1883 compared with 1620 counts/d, respectively; $P = 0.14$).

Both ethnicities were in a slightly positive energy balance in the respiration chamber, but there was no difference between ethnicities, sex, and ethnicity by sex ($P = 0.98$, $P = 0.96$, and $P = 0.95$, respectively). There was no difference in the 24-h RQ between Asians and whites (both groups had an RQ of 0.9).

There was no difference in the 24-h substrate oxidation between ethnicities (**Figure 1**). Carbohydrate, protein, and fat oxidation as a percentage of TEE were not different between Asians and whites. For Asians and whites, the 24-h fat oxidation

TABLE 2
Daily PAL, energy expenditure, energy intake, and energy balance before the test day[1]

	Men		Women		All		*P*		
	Asian	White	Asian	White	Asian	White	Ethnicity	Sex	Ethnicity × sex
n	7	7	9	9	16	16	—	—	—
Physical activity accelerometer (kcounts/d)	320 ± 125	301 ± 87	287 ± 131	373 ± 121	302 ± 125	340 ± 109	0.41	0.64	0.20
Daily PAL	1.73 ± 0.18	1.70 ± 0.13	1.68 ± 0.19	1.80 ± 0.17	1.70 ± 0.18	1.75 ± 0.16	0.40	0.65	0.20
TEE accelerometer (MJ/d)	10.2 ± 2.0	12.1 ± 1.4	7.3 ± 1.8	9.7 ± 2.0	8.6 ± 2.3	10.8 ± 2.1	0.002	0.001	0.68
Energy intake (MJ/d)	11.3 ± 0.7	13.4 ± 2.4	9.0 ± 0.8	9.3 ± 0.7	10.0 ± 1.4	11.1 ± 2.6	0.01	0.001	0.052
Diet composition during 3 d before the chamber stay (%)									
Carbohydrate	55.4 ± 1.2	56.0 ± 1.1	55.7 ± 1.0	54.5 ± 1.8	55.6 ± 1.1	55.1 ± 1.7	0.48	0.21	0.07
Protein	15.3 ± 0.5	15.2 ± 0.8	15.5 ± 0.7	15.5 ± 0.7	15.4 ± 0.6	15.3 ± 0.7	0.74	0.25	0.95
Fat	29.3 ± 1.3	28.9 ± 0.8	28.8 ± 0.7	30.1 ± 1.9	29.0 ± 1.0	29.6 ± 1.6	0.34	0.49	0.06
Energy balance (MJ/d)	1.0 ± 2.1	1.3 ± 2.8	1.7 ± 2.0	−0.4 ± 1.8	1.4 ± 2.0	0.3 ± 2.4	0.22	0.48	0.14

[1] All values are mean ± SDs and were analyzed by using 2-factor ANOVA (ethnicity and sex). *P* values are presented for main effects of ethnicity, sex, and the interaction between ethnicity and sex. PAL, physical activity level; TEE, total energy expenditure.

TABLE 3
Energy expenditure and energy balance in the respiration chamber[1]

	Men		Women		All		*P*		
	Asian	White	Asian	White	Asian	White	Ethnicity	Sex	Ethnicity × sex
n	7	7	9	9	16	16	—	—	—
TEE (MJ/d)	8.2 ± 0.8	9.0 ± 0.7	6.7 ± 0.4	7.2 ± 0.8	7.4 ± 1.0	8.0 ± 1.2	0.02	0.001	0.64
SMR (MJ/d)	6.0 ± 0.6	6.8 ± 0.5	4.9 ± 0.3	5.6 ± 0.6	5.4 ± 0.7	6.1 ± 0.8	0.001	0.001	0.80
SMR adjusted for FFM (MJ/d)	5.8 ± 0.3	5.5 ± 0.5	5.6 ± 0.5	5.9 ± 0.2	5.7 ± 0.3	5.7 ± 0.3	0.62	0.93	0.83
PAL[2]	1.37 ± 0.1	1.33 ± 0.04	1.36 ± 0.06	1.29 ± 0.08	1.36 ± 0.08	1.30 ± 0.05	0.03	0.28	0.62
Radar output (counts/d)	2154 ± 854	1677 ± 418	1702 ± 359	1575 ± 530	1883 ± 621	1620 ± 471	0.14	0.17	0.39
Energy intake (MJ/d)	9.0 ± 0.6	9.8 ± 0.7	7.5 ± 0.6	8.0 ± 0.5	8.2 ± 1.0	8.8 ± 1.1	0.006	0.001	0.57
Energy balance (MJ/d)	0.8 ± 0.7	0.8 ± 0.8	0.8 ± 0.6	0.8 ± 0.4	0.8 ± 0.6	0.8 ± 0.6	0.98	0.96	0.95
24-h RQ	0.92 ± 0.01	0.92 ± 0.01	0.92 ± 0.02	0.90 ± 0.01	0.92 ± 0.02	0.91 ± 0.02	0.41	0.32	0.14
Postabsorptive RQ (2300–0800)	0.89 ± 0.03	0.88 ± 0.02	0.89 ± 0.03	0.88 ± 0.02	0.89 ± 0.03	0.88 ± 0.02	0.31	0.79	0.95
Dietary fat oxidation (% of fat intake)	13.0 ± 3.9	11.7 ± 3.6	10.6 ± 3.0	10.0 ± 5.2	11.7 ± 3.6	10.8 ± 4.5	0.50	0.15	0.78

[1] All values are mean ± SDs and were analyzed by using 2-factor ANOVA (ethnicity and sex). *P* values are presented for main effects of ethnicity, sex, and the interaction between ethnicity and sex. FFM, fat-free mass; PAL, physical activity level; RQ, respiratory quotient; SMR, sleeping metabolic rate; TEE, total energy expenditure.
[2] Physical activity in the respiration chamber was calculated on the basis of the TEE divided by the SMR.

as a percentage of TEE was 17.7 ± 6.9% compared with 19.2 ± 5.1% ($P = 0.63$), respectively; carbohydrate oxidation was 68.0 ± 6.9% compared with 66.1 ± 5.1% ($P = 0.51$), respectively; and protein oxidation was 14.3 ± 2.2% compared with 14.7 ± 1.6% ($P = 0.61$), respectively. In addition, dietary fat oxidation as a percentage of fat eaten was not different between Asians and whites ($P = 0.50$) (Table 3).

Determinants of 24-h fat oxidation and dietary fat oxidation

A multiple regression analysis was performed to determine predictors of 24-h fat oxidation. In a model with 24-h fat oxidation as the dependent variable, ethnicity, percentage of fat mass, energy balance in the respiration chamber, and daily physical activity (accelerometer ACD) were included as independent variables. These variables were chosen on the basis of previous studies. The energy balance in the respiration chamber ($P = 0.04$) and daily physical activity counts ($P = 0.04$) together explained 32% of the variation in 24-h fat oxidation.

In a model with dietary fat oxidation as the dependent variable, ethnicity, percentage of fat mass, energy balance in the respiration chamber, and radar output, which represented spontaneous physical activity in the chamber, were included as independent variables. Only the energy balance ($P = 0.077$) and radar output ($P = 0.089$) tended to predict the dietary fat oxidation.

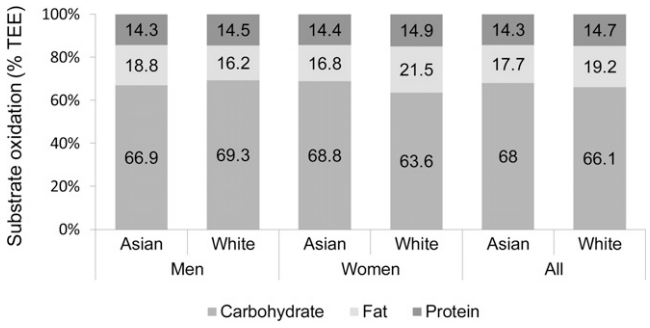

FIGURE 1. Substrate oxidation as a percentage of total energy expenditure in Asians (7 men; 9 women) and whites (7 men; 9 women) [2-factor ANOVA (ethnicity × sex)]. There was no difference between ethnicities or sexes and no interaction between ethnicity and sex in substrate oxidation (carbohydrate: *P*-ethnicity = 0.51, *P*-sex = 0.37, and *P*-ethnicity × sex = 0.08; fat: *P*-ethnicity = 0.63, *P*-sex = 0.43, and *P*-ethnicity × sex= 0.09; protein: *P*-ethnicity = 0.61, *P*-sex = 0.74, and *P*-ethnicity × sex = 0.89). TEE, total energy expenditure.

DISCUSSION

This study confirmed the findings from previous studies that there were differences in body composition between Asians and whites matched for sex, BMI, and age (1–8). Asians had a 5% higher body fat percentage, a lower FFM, and a tendency toward a lower FFMI. Despite differences in body composition, dietary and 24-h fat oxidation were not different between ethnicities.

Asian subjects in this study were South Asian Indian and Pakistani, Indonesian Malay, and East Asian Chinese, which represented 3 major ethnic groups in Asia. A previous study showed similar results with Asian subjects who were predominantly Indonesians (18). Deurenberg-Yap et al (11) reported that South Asian Indians had the most pronounced difference in body fat percentages compared with those of whites, followed by Malay and Chinese subjects. The FFMI tended to be lower in Asians than in whites. This result is in agreement with that of a large population study by Hull et al (34) that showed that Asians had the lowest FFMI compared with that of other ethnicities such as whites, African Americans, and Hispanics.

The 24-h fat oxidation did not differ between Asians and whites. In a respiration chamber study, Weyer et al (18) reported that there was no evidence for a lower metabolic rate or impaired 24-h fat oxidation in obesity-prone Pima Indians who also had a higher body fat percentage compared with that of whites. This result could be explained by the phenomenon that the high

proportion of total fat oxidation in obese subjects was due to the increased supply of fat substrates from an enlarged fat mass (21, 35). We included normal- and overweight subjects with BMI $\leq$27 to avoid the complexity of metabolic changes because of obesity. However, the effect of an enlarged fat mass on fat oxidation could have occurred in Asians who, in absolute amounts, had 1.5 kg more fat mass per square meter of height than did whites (Table 1). In a prospective study, Schutz et al (36) predicted that, for each 10-kg increase in fat mass, there is an expected increase in fat oxidation that averages ~20 g/d, or a 12% increase in fat oxidation when expressed as a percentage of REE

In the current study, dietary fat oxidation (exogenous fat oxidation) was not different between Asians and whites. Most exogenous fat is stored in adipose tissue during the postprandial period, whereas a limited fraction (~10%) is directly oxidized (37). The range of dietary fat oxidation (ie, 3–20%), was within previously reported ranges (31). Dietary fat oxidation was shown to be negatively correlated with the percentage body fat (ie, it was lowest in obese and highest in lean subjects) (38, 39). In comparison with with these studies (38, 39), our subjects were within a narrow range of BMI, and there was not a huge difference in body composition (ie, between lean and obese subjects). Other authors who used ^{13}C as a tracer and showed an increase in dietary fat oxidation with increasing body fat suggested that this result may reflect a mechanism to protect other tissues from fat exposure (40) or to prevent an additional increase in fat mass (37).

Hall et al (22) reported that, during submaximal exercise, Asian Indians oxidized less fat than did Europeans, whereas at rest, there was no difference in fat oxidation, which pointed out the role of skeletal muscle in fat oxidation. In the current study, fat oxidation was measured in a respiration chamber with limited physical activity. In agreement with previous studies, Asians had a lower absolute FFM than that of whites (6, 7), which is the major determinant of REE. However, FFM is not an energetically homogeneous compartment but varies systematically in heat-producing components as a function of body mass and FFM (ie, high metabolic tissues and organs and low metabolic tissues) (41). In adults, 70–80% of the REE is derived from organs that constitute only ~5% of body weight (42). In contrast, skeletal muscle constitutes 40–50% of total body weight and accounts for only 20–30% of REE (43). Therefore, in the resting or sedentary condition, whole-body fat oxidation was less determined by skeletal muscle (22), of which whites had significantly more than did Asians. This result may also explain the similar contribution of fat oxidation to 24-h TEE in Asians and whites when physical activity was limited in the respiration chamber.

We observed a variability in the spontaneous PAL (PAL equals TEE divided by SMR) of subjects in the respiration chamber that ranged from 1.21 to 1.51. Ravussin et al (44) also reported the variability in PAL even within the confines of a respiration chamber. The spontaneous physical activity per se was reported not to correlate with the 24-h RQ. Instead, the 24-h RQ was associated with and sensitive to the 24-h energy balance (16). It seems that whites benefited from the more favorable body composition (higher FFM and, thus, SMR) in reaching a significantly higher TEE, whereas Asians compensated a lower SMR with a slightly higher PAL (Table 3), which resulted in no difference in energy balances. In a multiple regression analysis, the energy balance in the respiration chamber was the significant predictor of 24-h fat oxidation. Although the energy balance was not different between groups, subjects were in a slightly positive energy balance. In a perfect energy and nutrient balance, RQ equals FQ (19). In a positive energy balance, both ethnicities had an RQ of 0.91–0.92, which indicated a greater reliance on carbohydrate oxidation. The glycogen stores of the body are so small that regulatory mechanisms are capable of efficiently adjusting carbohydrate oxidation to carbohydrate intake, whereas fat oxidation is regulated primarily by events that pertain to the carbohydrate economy of the body rather than by fat intake (45). Thus, in a condition of a positive energy balance when glycogen stores are ensured, the proportion of carbohydrate from the diet that are oxidized is larger than it is in a condition of a perfect or negative energy balance. Although the variation in both 24-h fat oxidation and dietary fat oxidation was predicted by the variation in energy balance, the energy balance was the same between ethnicities.

Daily activity counts as a measure of the daily PAL also predicted 24-h fat oxidation, whereas 24-h fat oxidation was not related with ethnicity and body composition. On average, the PAL was 1.7 in Asians and 1.75 in whites and ranged from 1.5 to 2.1, which, thus, was within the range of "sustainable lifestyles" (46). Eckel et al (47) reported that subjects with a high daily PAL were able to maintain a positive carbohydrate balance during a period of inactivity in the respiration chamber, which meant that they relied to a greater extent on fat oxidation than did subjects who were more sedentary in daily life. Also, even within the range of normal daily life activities, the mitochondrial oxidative capacity was positively associated with the PAL (48). Thus, an active lifestyle leads to an increased capacity of these vital organelles involved in the oxidative degradation of macronutrients to maintain the cellular ATP amount (48).

In conclusion, we observed no differences in dietary and 24-h fat oxidation despite differences in body composition in young moderately active Asians and whites. The energy balance in the respiration chamber significantly predicted the 24-h fat oxidation and tended to predict the dietary fat oxidation. The daily PAL (ACD) significantly predicted the 24-h fat oxidation, whereas spontaneous physical activity as radar output tended to predict the dietary fat oxidation.

It could be interesting to address the metabolic responses of Asians and whites when they are challenged to a high-fat diet, which may better mimic the current changes in lifestyles in Asia.

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