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Low Resting Energy Expenditure in Asians Can Be Attributed to Body Composition

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Objective: To compare resting energy expenditure (REE) between Asians and whites after adjusting for fat-free mass measured with a two- or more-compartment model.

Methods and Procedures: Participants were 10 white men (28 ± 3 years), 10 Asian men (30 ± 4 years), 10 white women (22 ± 4 years), and 11 Asian women (31 ± 7 years). REE was measured with a ventilated hood system under strictly controlled conditions. Body composition was measured with a two-compartment model based on body mass (BM) and body volume (hydrodensitometry), a three-compartment model adding total body water (TBW) (deuterium dilution), and a four-compartment model incorporating bone mass (dual-energy X-ray absorptiometry (DXA)) as well. Lean BM in the trunk and in the extremities was assessed with DXA. All measurements were performed at Maastricht University. Measurements on Asian subjects were performed within 3 months after their arrival in the Netherlands.

Results: Absolute REE was lower in Asians (5.87 ± 0.91 MJ/day) than in whites (7.00 ± 1.11 MJ/day). There was no significant difference in REE between the two races after adjustment for fat-free mass.

Discussion: There were no significant differences in REE between Asians and whites after adjustment for differences in body composition based on a two- or more-compartment model.

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INTRODUCTION

The FAO/WHO/UNU "committee on Protein and Energy requirements" recommends that energy requirements should be based on measurements of energy expenditure (1). In this estimation, resting energy expenditure (REE) is the basis of the factorial approach to estimate total energy expenditure. This approach emphasized the importance of REE, which represents the largest component of total energy expenditure.

Measuring REE is not always possible because indirect calorimetry is not widely available. Then, REE is usually calculated from prediction equations. The Harris–Benedict equation, the FAO equation, and the Schofield equation are formulas commonly used to estimate REE (2–4). Several studies have shown that these equations, which are derived from white subjects, overestimate the REE of Asian subjects (4–7). On the other hand, the Liu equation, which is derived from measurements in healthy Chinese adults predicts the REE of Asians more accurately (7,8). Therefore, many studies have concluded that Asians have a lower REE than whites. The possible influence of a racial factor on REE is studied several times. Henry *et al.*, Henry and Rees, and Ulijaszek and Strickland concluded that there are no differences in REE of Asians living in Britain when compared with Europeans (9–11). de Boer *et al.* and Lawrence *et al.* concluded that REE expressed per kg fat-free mass was higher in Asians than in whites, while absolute REE was lower in Asians (12,13). Because of a mathematical bias, it is incorrect to express metabolic rate data per kilogram fat-free mass as the relationship between metabolic rate and fat-free mass has a *y* and *x* intercept significantly different from zero. This means that the metabolic body size estimated from fat-free body mass (BM) will be proportionally underestimated in those with small fat-free BM and overestimated in those with large fat-free BM (14). Soares *et al.* already mentioned this artifact in earlier studies when they determined the contribution of body composition to differences in REE between Indians and Australians. They found that absolute REE was significantly lower in Indians when compared with Australians, while there were no significant differences between the two groups when REE was adjusted for fat-free mass (15). The measurements of body composition determined by Soares *et al.* were based on the sum of four skinfolds and equations of Durnin and Womersley (16). The prediction of body fat percent from skinfold thickness is a doubly indirect method, which is based on a statistical relationship between skinfolds and body fat as measured with underwater weighing. Additionally, most body composition studies have been done in Europe and USA, thus most equations and assumptions are based on data obtained in whites. The skinfold methodology assumes that there are no differences in subcutaneous fat patterning;

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however, there is a difference in fat distribution among various races. This difference could be a reason for the different validity of the skinfold methodology across ethnic groups (17). Densitometry, dilution techniques, and multicompartment models have a functional relation to a known component and are therefore less population specific. Furthermore dual-energy X-ray absorptiometry (DXA) gives the opportunity to separate the more visceral and more muscular parts of the fat-free mass. Visceral organs contribute more to REE than do muscles. Therefore, the objective of this study was to compare REE between Asians and their white counterparts after adjusting for fat-free mass measured with DXA and two-, three-, or four-compartment models.

METHODS AND PROCEDURES

Subjects

Participants were 10 white men (age 28 ± 3 years), 10 Asian men (age 30 ± 4 years), 10 white women (Age 22 ± 4 years), and 11 Asian women (31 ± 7 years). Eighteen subjects were from Indonesian origin. One subject was Chinese, one Malaysian, and one came from Sri Lanka. Measurements on Asian subjects were performed within 3 months after their arrival in the Netherlands. All measurements were performed at Maastricht University.

Subjects were in good health as assessed by medical history. They were weight stable during the last 6 months (±3 kg), did not consume special diets or participate in exercise programs, and none of them were taking medications which could affect the variables of the study. The women were either users of oral contraceptives or in preovulatory phase at the measurement day.

Subjects were informed of the procedures before they gave their consent to participate and the Medical Ethical Committee approved the protocol of this study.

REE

REE was measured after an overnight stay at the University. Subjects arrived at 7 PM after they ate their normal dinner at home. That dinner was their last consumption of the day. Subjects were asked to avoid exercise the day before testing. They went to bed at their normal bedtime, which was between 10 and 12 PM. Using a ventilated hood system (Omnical, Maastricht University, the Netherlands), REE was measured for 30 min, in the supine position under standard conditions of rest, fasting, immobility, thermoneutrality (22–24 °C), and mental relaxation. After awakening, subjects had to leave their chamber and walk ~10 m to the ventilated hood system. This was on the same floor as their place to sleep. After 15-min resting, the REE measurement was started. To eliminate effects of subject habituation to the testing procedure, the respiratory measurements during the first 10 min were discarded, and the following 20 min were used to calculate REE (18).

Body composition

Anthropometric measurements. The body height without shoes was measured using a wall-mounted stadiometer to the nearest 0.1 cm (Mod.220; SECA, Hamburg, Germany). The BM was measured to the nearest 0.1 kg with a digital scale (KCC 300; Mettler, Greifensee, Switzerland) with subjects wearing a swimsuit only. The BMI (kg/m2) was calculated as weight divided by height squared.

Densitometry. Whole-body density (Db) was determined by underwater weighing in the fasted state. BM in air and underwater was determined on a digital balance, accurate to 0.01 kg (KCC 300; Mettler, Greifensee, Switzerland). Lung volume was measured simultaneously with the helium dilution technique using a spirometer (Volugraph 2000; Mijnhardt, the Netherlands). Body density was used to calculate body fat according to the two- and more-compartment models (see below).

Deuterium dilution. Total body water (TBW) was measured with deuterium dilution according to the Maastricht protocol (19). In the evening before the measurements, subjects drank a weighed dose of a deuterium dilution, 70 g water with an enrichment of 5 atom% excess ^{2}H, after voiding (background sample). Deuterium enrichment was measured in urine from the second voiding of the following morning.

DXA. Bone mass content and regional lean BM was determined by a whole DXA (Hologic, QDR4500; Hologic, Waltham, MA). Calculations were performed by QDR Windows software.

Body composition models. The two- and more-compartment models are based on the principle that body volume is the sum of separate compartment volumes. The equations for the calculation of percentage body fat were:

Two - compartment model (2C) (19),

$$\%BF = (4.95 \times Db^{-1} - 4.5) \times 100;$$

Three - compartment model incorporating TBW (3C) (20),

$$\%BF = \left(\frac{2.118}{Db} - 0.78 \times \frac{TBW}{BM} - 1.354\right) - 100;$$

Four - compartment model (4C) (21),

$$\%BF = \left(\frac{2.747}{Db} - 0.714 \times \frac{TBW}{BM} + 1.235 \times \frac{TBMC}{BM} - 2.0503\right) \times 100.$$

Where Db is whole-body density, TBW is total body water, BM is body mass, and TBMC is total body mineral content.

Statistics

Data are presented as mean and standard deviations. Adjusted metabolic rates were calculated as the group mean metabolic rate plus measured metabolic rate minus the predicted metabolic rate, where the group mean metabolic rate is the mean absolute rate, the measured metabolic rate is the rate measured in each subject, and the predicted metabolic rate is the calculated rate obtained by using the individual fat-free mass as independent and REE as dependent variable in a linear regression. To assess the contribution of independent variables to the intra and interracial variability of REE measurements, multiple and simple linear regression analyses were used. Data were analyzed by independent *t*-tests. The SPSS program, version 11 (SPSS, Chicago, IL), was used for the statistical analysis.

RESULTS

Subjects

The subject characteristics are summarized in **Table 1**. The differences between Asians and whites were not systematically related to gender; therefore men and women are combined in the analysis. White subjects were significantly taller than Asian subjects. They had a significant higher body weight and fat-free mass, and significantly lower fat percentage. White subjects were significantly younger compared with the Asian subjects. On average, whites had a lower fat mass and a lower BMI, but these differences were not significant.

REE

Absolute REE was lower in Asian subjects (5.87 ± 0.91 MJ/day) than in white subjects (7.00 ± 1.11 MJ/day). Values as predicted from age, weight, and gender with the Schofield equations (3)

Table 1 Subject characteristics

	Asians (11 women, 10 men)	Whites (10 women, 10 men)
Height (m)	1.64 ± 0.74***	1.78 ± 0.90
Age (years)	30 ± 6**	25 ± 5
Weight (kg)	63.1 ± 11.4*	70.8 ± 11.5
BMI (kg/m²)	23.4 ± 3.3	22.4 ± 2.7
FFM-4C (kg)	46.1 ± 9.3**	56.6 ± 10.8
FM-4C (kg)	17.1 ± 5.9	14.2 ± 5.8
Fat-4C (%)	26.9 ± 7.1**	20.1 ± 7.4
REE predicted (MJ/day)	6.38 ± 0.97	6.90 ± 1.02
REE measured (MJ/day)	5.87 ± 0.91**,†	7.00 ± 1.11††

FFM-4C, fat-free mass four-compartment model; FM-4C, fat mass four-compartment model; REE predicted, resting energy expenditure predicted with the Schofield equations (3).
*P < 0.05; **P < 0.01; ***P < 0.001 for differences between Asian and white subjects. †P < 0.001; ††ns for differences between predicted and measured values of the same group.

Table 2 Resting energy expenditure (REE) data for Asian and white subjects without and with correction for body composition

	Asians (11 women, 10 men)	Whites (10 women, 10 men)
REE (MJ/day)	5.87 ± 0.91**	7.00 ± 1.11
REE (MJ/day) adjusted for body mass	6.19 ± 0.48**	6.66 ± 0.46
REE (MJ/day) adjusted for FFM-2C	6.33 ± 0.48	6.48 ± 0.39
REE (MJ/day) adjusted for FFM-3C	6.35 ± 0.45	6.46 ± 0.33
REE (MJ/day) adjusted for FFM-4C	6.34 ± 0.45	6.47 ± 0.32
REE (MJ/day) adjusted for LBM-DXA in the trunk	6.30 ± 0.46	6.51 ± 0.30
REE (MJ/day) adjusted for LBM-DXA in the extremities	6.24 ± 0.43**	6.61 ± 0.27

DXA, dual-energy X-ray absorptiometry; FFM-2C, -3C, -4C fat-free mass two-, three-, and four-compartment model, respectively; LBM, lean body mass.
**P < 0.01 for differences between Asian and white subjects.

were significantly higher than measured values for Asians, while predicted values were not different from measured values for whites (**Table 1**). When REE was adjusted for BM there was still a significant difference between Asians and whites. After controlling for fat-free mass as estimated with DXA and two- or more-compartment models, REE did not differ significantly between Asians and whites (**Table 2**, **Figure 1**). The difference in REE was still present after correction for lean BM in the extremities, but disappeared when REE was corrected for lean BM in the trunk.

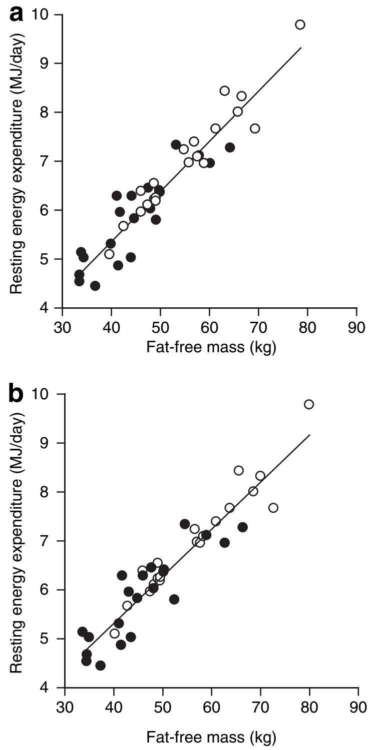

Figure 1 Resting energy expenditure (**a**) plotted as a function of fat-free mass as measured with deuterium dilution, and (**b**) plotted as a function of fat-free mass as measured with a four-compartment model, in Asians (n = 21, closed circles) and whites (n = 20, open circles) with the linear regression lines.

DISCUSSION

This study showed that there were no significant differences in REE between Asians and whites after adjustment for differences in body composition at the whole-body level. Several studies showed that existing predictive equations to calculate REE are not suitable for Asians (4–7,22). Therefore, authors concluded that REE of Asians is lower compared with their white counterparts. However, those predictive equations are based on height, weight, age, and gender. A literature overview of Deurenberg *et al.* (23) showed that Asian populations studied had a higher fat percentage at a similar BMI compared with whites. Generally, for the same BMI, their fat percentage was 3–5% points higher compared with whites (23). In this study, Asian subjects had an average BMI of 23.4 kg/m² and a fat percentage of 26.9%. White subjects had an average BMI of 22.4 and fat percentage of 20.1%. Thus, the difference in body composition between Asians and whites explains the overestimation of predictive equations in Asian subjects. A global prediction equation, which is suitable for all populations in the world, should therefore be based on fat-free mass. When information about fat-free mass is not available it is necessary to calculate REE with a predictive equation specific to the racial group of the subjects.

Deurenberg and Deurenberg-Yap described differences in body composition among different Asian groups (17). The Asian subjects in this study were all from Eastern Asia, where 18 of the

21 were from Indonesian origin. Thus, the results are characterized as being predominantly reflective of Asian Indonesians.

Theoretically, changing lifestyle could lead to a change in body composition and therefore the commonly used formulas might no longer be suitable for the white populations in the future. There is a growing body of evidence to show that the equations of Harris and Benedict consistently overestimate the REE of present-day Americans (24–26). Furthermore, Soares *et al.* and Piers and Shetty showed that an equation specific for the Indian population predicts the REE of Americans closely but underestimates the REE of Europeans (22,27). This suggests that present-day North Americans and Asians have similar body compositions when matched for height, weight, age, and gender.

Significant overall weight gains have been reported in recent years in North American and European groups (28). Kyle *et al.* (29) compared North American with European body composition parameters in large populations. They found that American subjects did have a higher body weight which resulted in higher values of fat-free mass, body fat, and fat percentage in American than in European men and women (29). However, from this data it is still unclear whether present-day Americans have the same high body fat percent/low BMI relationship as Asians. Further research is needed to answer this question.

The data of our study confirmed the study of Soares *et al.* (15) who found that differences in REE between the two race groups could contribute to differences in body composition. Hunter *et al.* studied REE in whites and African Americans and found diminished racial differences in REE after adjustment for trunk lean tissue (30). This suggests that low REE in African-American women is mediated by a lower volume fraction of metabolically active organ mass. In this study, we adjusted REE for total fat-free mass with different compartment models and for lean BM in the trunk. The racial differences in REE after adjusting for fat-free mass in the trunk were not significantly different than after adjusting for total fat-free mass. This suggests that lower REE in Asians is not mediated by low volumes of metabolically active organs but by lower total fat-free mass.

Adjusting REE with fat-free mass measured with a 2-compartment model leads to the same result as adjusting fat-free mass measured with a 4-compartment model, suggesting that hydrodensitometry alone is sufficiently accurate to estimate fat-free mass for this purpose. Adjusting REE for fat-free mass in the extremities did not explain the differences in REE between Asians and whites. Because the metabolic rate of muscles is lower than of visceral organs, this came up to our expectations.

The limitation of most studies measuring REE in different races is that differences in methodology or conditions under which REE was measured were not standardized. In our study, all measurements were performed with the same ventilated hood system, according to the same protocol. Furthermore, the within-machine variability was checked every week with methanol burning and the variation was always within the narrow limits of 5% (18). During the REE measurement, all subjects were continuously observed, and we made sure that subjects were lying motionless, while did not fall asleep. Furthermore, the subjects were instructed to refrain from intensive exercise the day before the measurements. Therefore, we believe that the differences in races are especially related to physiological and not to methodological differences.

In the past, a possible effect of a tropical climate, food intake, and other environmental factors on REE has been suggested, but reports are inconclusive (31,32). In this study, Asian subjects were measured within 3 months after their arrival in the Netherlands and no effect of climate or food intake on REE was found.

It may be wondered whether differences in fat-free mass are influenced by climate, food intake, or other environmental factors. Krishnaveni *et al.* showed that the muscle-thin but adipose body composition of south Asian adults is already present at birth and this phenotype persists in childhood (33). This suggests that the racial difference in body composition reflects the action of genes and/or the maternal environment and not of other environmental factors.

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DISCLOSURE

The authors declared no conflict of interest.

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