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BMR in a Brazilian adult probability sample: the Nutrition, Physical Activity and Health Survey

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Abstract

Objective: To measure BMR in a probability sample of adults from an urban city of Brazil and to compare indirectly measured BMR (BMR_i) with BMR predicted from different equations.
Design: BMR data were obtained by indirect calorimetry and estimated by different predictive equations (Schofield; Harris and Benedict; Henry and Rees). Anthropometric and body composition measures were also obtained.
Setting: The Nutrition, Physical Activity and Health Survey (PNAFS), a household survey conducted in Niterói, Rio de Janeiro state, Brazil.
Subjects: Representative sample of 529 adults (aged ≥20 years; 339 females) living in Niterói, Rio de Janeiro state, Brazil.
Results: Mean BMR_i values were 5839·7 (SE 73·9) kJ/d and 4758·1 (SE 39·5) kJ/d for men and women, respectively. Predicted BMR by all equations was significantly higher (difference between means and 95 % CI did not include zero) than BMR_i in both men and women of all ages. Overall bias in BMR (predicted BMR minus BMR_i) using the Schofield equations (overestimation of about 20 %) was higher than when using the Henry and Rees equations (13 % and 16 % overestimation for males and females, respectively). The percentage of individuals whose BMR predicted by the Schofield equations fell within 10 % of BMR_i was very low (7·8 % and 14·1 % of males and females, respectively).
Conclusions: Current available predictive equations of BMR are not adequate to estimate BMR in Brazilians living in Niterói, Rio de Janeiro, Brazil.

Keywords
Basal metabolism
Calorimetry
Indirect
Validation studies
Brazil

In 1985 the FAO/WHO/United Nations University Report on Human Energy Requirements established that the energy requirement of populations should be based on total daily energy expenditure instead of energy intake, as was suggested in previous reports(1). The report recommended the use of the simplified factorial method based on BMR in combination with the physical activity level (PAL) to estimate total daily energy expenditure of the population. Recognizing that measures of BMR would not be easily available worldwide, the report provided a set of age- and gender-specific predictive equations to estimate BMR based on body mass. The report also provided a range of PAL values for different standardized occupational levels of physical activity.

Following the 1985 report the interest in measuring and predicting BMR in different ethnic groups was revived, and many studies showed that the equations from the report did not accurately estimate BMR in different populations around the world(2–5). In fact, the data set used to derive the equations was based on compiled BMR measurements available in the literature mainly in the first part of the last century and included a large number of Europeans and North Americans. Therefore, these equations were based on BMR information that was not representative worldwide(6) and might not represent BMR in contemporary societies(7).

As has been documented in many countries in the world, Brazil faces a nutrition transition period characterized by declining rates of underweight/malnutrition and increasing rates of overweight/obesity(8). Determination of energy requirement under these circumstances is a challenge for all health professionals since it relies on accurate estimation of BMR. The observed increase in the values of body mass of the population will represent greater estimated BMR and consequently higher energy requirement which will not be derived from actual higher energy expenditure. Before revisions in PAL values are implemented it is important to improve the prediction of BMR(9) because, even though the magnitude of these improvements may be small, it is well recognized that

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small positive energy balance over time may affect overweight and obesity[10]. Thus, more information on BMR in segments of the population from different regions of the world is necessary to better estimate the energy requirement in population-level nutritional studies. Aware of the criticism about the BMR predictive equations, the joint FAO/WHO/United Nations University Expert Consultation on Human Energy Requirements reviewed the available information and endorsed the use of the Schofield equations[11] in the most recent report on Human Energy Requirements[12] but emphasized the need to re-evaluate the equations in the following years when more contemporary data on BMR around the world become available.

We have previously reported the inadequacy of different predictive equations in estimating BMR in small groups of Brazilians living in tropical and temperate regions of the country[3,13] and abroad[14]. Thus, the objective of the present study was to measure BMR in a probability sample of adults living in Niterói, Rio de Janeiro state, Brazil and to compare the results with BMR predicted by various equations.

Methods

A household survey – the Nutrition, Physical Activity and Health Survey (PNAFS) – was conducted in 2003 to assess the nutritional and health status and the physical activity patterns of the adult population of Niterói, Rio de Janeiro state. Niterói is located in the tropics, in the south-east region of Brazil at 22°53′00″S, 43°06′13″W, with an area of 131 km^2.

Details of the sampling procedures have been published elsewhere[9,15,16]. In short, a sample was designed in three stages to identify: (i) census enumeration areas (CEA), (ii) households within CEA and (iii) an adult within a household. In the first stage, 110 CEA were selected with a probability proportional to the number of household dwellings from a list ordered according to average household income, which allowed an implicit income stratification of the CEA[17]. In the second stage, sixteen households were selected with equal probability using an inverse sampling technique[18] similar to that of the World Health Survey in Brazil[19]. The households were visited after the selection order until sixteen interviews were completed. In the third stage, for each interviewed household an adult was selected to participate in the study with equal probability among all adults in the household. To be eligible the adult had to be free of any cardiac or metabolic condition, and under no medication that could alter heart rate or metabolism. A sub-sample of five selected participants per CEA (*n* 550) was invited to come to the laboratory for a series of physiological measurements including basal metabolism.

During the household interview, all procedures related to the measurement of BMR by indirect calorimetry (BMR_i) were explained and participants were acquainted with the facemask to be used in the measurements before scheduling the laboratory visit. All participants were advised to drive his/her own car or use public transportation to come to the laboratory immediately after waking early in the morning. Each participant had to have fasted for 12 h, slept for 6–8 h, and neither engaged in vigorous exercise nor consumed alcohol during the preceding 24 h.

Upon arrival at the laboratory, the participants read and signed an informed consent form. Prior to BMR_i measurement the participant's adherence to the protocol was verified and a heart-rate monitor (POLAR S-610; Polar Oy, Kempele, Finland) was placed on the participant's chest after which the participant rested for 15 min in the supine position in a dark, isolated, temperature-controlled (22–25°C) room. This duration was chosen to keep the participants awake and has been proven to allow accurate BMR measures given that the test environment is physically comfortable[20]. After the rest, a facemask was adjusted to the participant and gas exchange was measured for 25 min using a validated[21] calorimeter (VO2000 Portable Metabolic Testing System; MedGraphics, St. Paul, MN, USA) which was calibrated according to the manufacturer's instructions. Minute heart-rate data were obtained simultaneously to minute $\dot{V}O_2$ and $\dot{V}CO_2$. These data were converted to energy expenditure using the Weir equation[22] and expressed in kJ/d. BMR_i was calculated as the average of the last 20 min of gas-exchange data collection. One researcher monitored the participant to check for activity, hyperventilation or nap. The criterion for a valid BMR_i was a $<10\,\%$ variation of $\dot{V}O_2$ as recommended in the literature[20,23,24]. A total of 120 participants were rescheduled due to instability of $\dot{V}O_2$, napping or restlessness.

Forty-two participants (twenty-five women) repeated the BMR_i measures on two different days. Mean BMR values between days were not significantly different (mean difference $= -12{\cdot}8$ (se 26·1) kJ/d; $P = 0{\cdot}63$) and the two measures were highly correlated ($r = 0{\cdot}98$). The mean intra-individual CV of BMR_i was 4·72 %. The inter-individual CV was calculated for the pooled data and age groups by gender.

Anthropometric and body composition information measurements were done following the BMR_i measurement with the participant barefoot and wearing standardized light clothes and no shoes. Stature (S) was measured in duplicate on a wooden stadiometer to the nearest 0·1 cm. The average of the two measures was used in the analysis. Body mass (BM) was obtained with an electronic scale (Tanita TBF-305; Tanita Corporation, Tokyo, Japan) to the nearest 0·2 kg. BMI was calculated as the ratio between BM (in kilograms) and the square of S (in metres). Percentage of body fat was measured using a validated leg-to-leg bioimpedance scale (Tanita TBT-305) using the equations described in Wahrlich *et al.*[25]. The study was conducted according to the guidelines laid down in the Declaration of Helsinki and all procedures involving human subjects were approved by the Ethics Committee of the Oswaldo Cruz Foundation.

Data analysis

Means and their standard errors, minimum and maximum values are presented for all continuous variables. Nutritional status was evaluated for gender and age groups according to BMI cut-off points proposed by WHO[26]: underweight (BMI < 18·5 kg/m^2); normal (18·5 ≤ BMI < 25·0 kg/m^2); overweight (25·0 ≤ BMI < 30·0 kg/m^2); and obesity (BMI ≥ 30·0 kg/m^2). Measured BMR_i was compared with estimated BMR from various predictive equations: those of Schofield[11], Henry and Rees[2], and Harris and Benedict[27]. The equations are based on BM, S, age (A) and gender (Table 1). The Harris and Benedict[27] equations are given in kcal/d and include age. Henry and Rees[2] do not provide equations for the age group ≥60 years.

Bias (predicted BMR minus BMR_i) was calculated for each equation along with the percentage of participants whose predicted BMR fell within ±10 % of measured BMR_i[28]. Bland–Altman[29] analysis was performed for the comparison between BMR predicted with the Schofield equations and measured BMR_i.

Sample weights were calculated as the inverse of the product of the inclusion probabilities in each selection stage. The Integrated Household Weighting System was used to calibrate the sample weights in order to adjust the estimates to known population totals by gender and age groups. Of the recruited 550 participants, BMR_i measurement was not performed in twenty-one participants due to instrument malfunction, non-adaptation to the facemask or refusal. The final sample of 529 participants (190 men and 339 women) represents the estimated total of 324 671 adults (145 886 men and 178 785 women) living in Niterói at the time of the study. The data were divided into age groups (20–30 years; 30–60 years; ≥60 years) merely for comparison with the results of the current recommended predictive equations of BMR[11,12]. All analyses were performed using the SAS statistical software package release 9·2. Mean values, standard errors and 95 % confidence intervals were obtained using the procedure SURVEYMEANS. The procedure SURVEYREG was used to generate gender-specific BMR prediction from equations based on BM, S and A. Significance of the difference between measured BMR_i and predicted BMR for the pooled data and within each age category was identified when the 95 % confidence interval of the bias did not include zero.

Results

Age ranged from 20·0 to 80·3 years and the mean value was 42·6 (se 1·4) years for men and 44·9 (se 1·0) years for women (Table 2). The participants presented a large range of BMI (15·5–45·3 kg/m^2). Based on mean BMI, both men and women were, on average, overweight (BMI ≥ 25·0 kg/m^2). Only approximately 1 % (2·0 % and 0·9 % of females and males, respectively) of participants were underweight. Obesity was higher in women than men (16·3 % and 12·4 %, respectively). Percentage body fat increased with increasing age for both men and women and was always higher in women than in men.

The inter-individual CV of BMR_i was 12·8 % in women and 13·8 % in men. In women, the CV was 11·6 %, 12·8 % and 12·6 % for the 20–30-, 30–60- and ≥60-year-old groups, respectively. The same values for men were 11·0 %, 12·3 % and 15·8 %, respectively. Average measured BMR_i values were 5839·7 (se 73·9) kJ/d and 4758·1 (se 39·5) kJ/d for men and women, respectively (Tables 3 and 4). BMR values decreased with increasing age. Estimated BMR by all predictive equations was significantly higher than measured BMR_i in both men and women in each age group. Larger BMR overestimation occurred for young men when using the Schofield equations (26·0 %) followed by the Harris and Benedict (24·0 %) equation. For older women (≥60 years), the Schofield and Harris and Benedict equations yielded lower overestimations compared with both groups of younger women (Table 4). When using the Henry and Rees equations, the lowest overestimation within women was observed in the group aged 20–30 years (13·8 %; Table 4), whereas in men the lowest overestimation occurred for the age group of 30–60 years (11·8 %; Table 3). Overall, the percentage of participants whose BMR predicted by the Schofield equations fell within 10 % of measured BMR_i was very low (7·8 % and 14·1 % of Niterói men and women, respectively).

When results were compared according to BMI classification, predicted BMR was higher than measured

Table 1 Equations used in the present study to predict BMR

Sex/age (years)	Schofield[11] (MJ/d)	Henry and Rees[2] (MJ/d)	Harris and Benedict[27] (all ages) (kcal/d)
Women			
18–30	0·062 × BM + 2·036	0·048 × BM + 2·562	655·0955 + (9·5634 × BM)
30–60	0·034 × BM + 3·538	0·048 × BM + 2·448	+(1·8496 × S) − (4·6756 × A)
≥60	0·038 × BM + 2·755	–	
Men			
18–30	0·063 × BM + 2·896	0·056 × BM + 2·800	66·4730 + (13·7516 × BM)
30–60	0·048 × BM + 3·653	0·046 × BM + 3·160	+(5·0033 × S) − (6·7550 × A)
≥60	0·049 × BM + 2·459	–	

BM, body mass in kilograms; S, stature in metres; A, age in years.
1 kcal = 4·184 kJ.

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Table 2 Age, anthropometric and body composition data according to age group: men (*n* 190) and women (*n* 339) from Niterói, Rio de Janeiro state, Brazil

	Age group (years)							
	20–30		30–60		≥60		Pooled	
Variable	Mean	SE	Mean	SE	Mean	SE	Mean	SE
Men								
n	44		127		19		190	
Age (years)	25·3	0·5	43·3	0·9	65·9	1·2	42·6	1·4
Body mass (kg)	74·0	1·5	76·2	1·5	66·4	3·0	74·0	1·1
Stature (cm)	173·3	1·4	172·5	0·8	167·2	1·3	171·8	0·7
BMI (kg/m^2)	24·6	0·5	25·6	0·5	23·7	1·0	25·0	0·3
Body fat (%)	21·0	1·4	22·2	0·8	22·9	2·0	22·0	0·6
Fat mass (kg)	16·6	1·3	18·0	1·0	15·8	2·0	17·3	0·7
Fat-free mass (kg)	57·8	1·0	57·9	0·7	50·4	1·3	56·6	0·6
Women								
n	85		214		40		339	
Age (years)	24·8	0·3	44·3	0·6	67·0	0·9	44·9	1·0
Body mass (kg)	60·9	1·2	65·8	1·0	62·3	1·7	64·0	0·8
Stature (cm)	162·6	0·7	159·0	0·4	154·7	0·9	158·9	0·4
BMI (kg/m^2)	23·0	0·4	26·0	0·4	26·1	0·8	25·4	0·3
Body fat (%)	34·0	0·7	38·9	0·5	40·3	1·1	39·0	0·3
Fat mass (kg)	21·3	0·9	26·2	0·7	25·6	1·3	25·0	0·5
Fat-free mass (kg)	39·6	0·5	39·6	0·4	36·7	0·6	39·0	0·3

Table 3 Indirectly measured and predicted BMR according to age group: men (*n* 190) from Niterói, Rio de Janeiro state, Brazil

	Age group (years)							
	20–30		30–60		≥60		Pooled	
Variable	Mean	SE	Mean	SE	Mean	SE	Mean	SE
BMR_i (kJ/d)	6025·3	116·8	5987·1	79·3	5056·4	191·1	5839·7	73·9
Predicted BMR (kJ/d)								
Schofield (1985)[11]	7559·9	96·1	7310·0	71·7	5713·1	147·2	7103·3	81·8
Bias (kJ/d)*	1534·6	58·2	1322·8	41·0	656·8	74·0	1263·6	39·2
95 % CI of bias (kJ/d)	1416·2, 1653·0		1240·9, 1404·8		500·3, 813·2		1185·5, 1341·7	
% difference†	26·0	1·34	22·7	0·9	13·9	1·7	22·0	0·7
% within ±10 % of BMR_i‡	0		6·5		23·9		7·8	
Henry & Rees (1991)[2]	6945·7	85·5	6664·6	68·7	–	–	6749·4	56·3
Bias (kJ/d)*	920·4	60·1	677·4	40·9	–	–	750·8	33·2
95 % CI of bias (kJ/d)	798·1, 1042·7		595·8, 759·1		–		684·7, 816·9	
% difference†	15·8	1·2	11·8	0·8	–	–	13·0	0·6
% within ±10 % of BMR_i‡	21·2		35·5		–		31·2	
Harris & Benedict (1919)[27]	7449·9	112·3	7049·5	102·7	5735·7	202·1	6928·3	93·3
Bias (kJ/d)*	1424·6	52·9	1062·3	421·9	679·3	60·8	1088·6	35·5
95 % CI of bias (kJ/d)	1317·0, 1532·2		978·6, 1146·0		550·3, 808·3		1017·9, 1159·3	
% difference†	24·0	1·1	17·7	0·7	13·8	1·2	18·6	0·6
% within ±10 % of BMR_i‡	0		8·9		16·5		8·0	

BMR_i, BMR measured by indirect calorimetry.
*Predicted BMR – BMR_i.
†(Bias/BMR_i) × 100.
‡Percentage of participants whose predicted BMR fell within 10 % of BMR_i.

BMR_i in all categories (Table 5). Both overweight and obese men and women had higher BMR compared with underweight and normal-weight participants. The lowest overestimation (13·2 %) was seen in underweight women and the highest in underweight men (28·3 %). Overall, the Schofield equations overestimated BMR by about 20 % (19·3 (SE 0·6) % in women and 22·0 (SE 0·7) % in men).

The relationship between bias and average of predicted and measured BMR_i (Bland–Altman analysis) is presented in Fig. 1 and indicates that the bias does not vary in any systematic way (R^2 = 0·118, 0·067 and 0·025 for pooled, men and women, respectively). Average biases were 1055·2 (95 % CI 1006·5, 1104·1) kJ/d for the pooled data, 1263·6 (95 % CI 1185·5, 1341·7) kJ/d for men and 885·2 (95 % CI 839·3, 931·2) kJ/d for women. The generated equations are:

$$\text{Males, BMR (kJ/d)} = (9{\cdot}99 \times \text{BM}) + (7{\cdot}14 \times \text{S}) - (2{\cdot}79 \times \text{A}) - 450{\cdot}5$$

$$(R^2 = 0{\cdot}87;\ \text{SEE} = 290{\cdot}0\,\text{kJ/d})$$

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Table 4 Indirectly measured and predicted BMR according to age group: women (*n* 339) from Niterói, Rio de Janeiro state, Brazil

	Age group (years)							
	20–30		30–60		≥60		Pooled	
Variable	Mean	SE	Mean	SE	Mean	SE	Mean	SE
BMR_i (kJ/d)	4845·3	71·9	4829·8	45·3	4480·7	93·9	4758·1	39·5
Predicted BMR (kJ/d)								
Schofield (1985)[11]	5813·8	77·8	5775·1	34·3	5122·8	65·0	5643·3	36·7
Bias (kJ/d)*	968·6	48·5	945·4	22·7	642·1	64·2	885·2	23·2
95 % CI of bias (kJ/d)	871·6, 1065·6		900·4, 990·4		511·6, 772·6		839·3, 931·2	
% difference†	20·4	1·2	20·5	0·6	15·3	1·7	19·4	0·6
% within ±10 % of BMR_i‡	10·2		8·7		32·2		14·1	
Henry & Rees (1991)[2]	5486·8	60·2	5606·3	48·4	–	–	5572·5	39·9
Bias (kJ/d)*	641·5	44·0	776·5	23·8	–	–	738·5	21·6
95 % CI of bias (kJ/d)	553·6, 729·4		729·3, 823·8		–		695·6, 781·3	
% difference†	13·8	1·1	16·5	0·5	–	–	15·8	0·5
% within ±10 % of BMR_i‡	34·6		22·4		–		25·9	
Harris & Benedict (1919)[27]	5952·3	54·1	5737·7	42·2	5119·6	79·0	5652·1	39·2
Bias (kJ/d)*	1107·0	39·6	907·9	21·2	638·9	57·4	894·1	21·1
95 % CI of bias (kJ/d)	1027·9, 1186·1		865·9, 950·0		522·3, 755·5		852·2, 936·0	
% difference†	23·6	1·2	19·4	0·5	15·0	1·5	19·4	0·5
% within ±10 % of BMR_i‡	1·7		7·8		29·4		11·1	

BMR_i, BMR measured by indirect calorimetry.
*Predicted BMR – BMR_i.
†(Bias/BMR_i) × 100.
‡Percentage of participants whose predicted BMR fell within 10 % of BMR_i.

and

$$\text{Females, BMR (kJ/d)} = (8{\cdot}95 \times \text{BM}) + (8{\cdot}87 \times \text{S}) - (0{\cdot}70 \times \text{A}) - 814{\cdot}3$$

$$(R^2 = 0{\cdot}83;\ \text{SEE} = 254{\cdot}5\ \text{kJ/d})$$

where SEE is the standard error of the estimate.

Discussion

The present study measured BMR_i in participants from a household survey in Niterói, Rio de Janeiro state, Brazil and compared the results with BMR predicted by different equations. Based on a literature review performed by the authors, the present study is apparently the largest data set of BMR obtained in a developing country and the first attempt to obtain BMR information in a probability sample of a specific population. The majority of the studies with large samples used to generate BMR predictive equations were based mainly on compiled data available in the literature[1,2,7,11].

As for many developing countries, there are very few data on BMR in Brazilian samples. Absolute BMR values for men and women of Niterói were similar to the values of seventy male garbage collectors of mean age ~37 years (5888·2 (SE 106·2) kJ/d)[30] and eighty-one college-aged women (4819·1 (SE 74·3) kJ/d) living in Rio de Janeiro, but lower than the values of forty-eight students of college age (twenty-three women) from southern Brazil[31]. Rodrigues *et al.*[32] retrospectively analysed resting energy expenditure data of 760 Brazilian female participants in a hospital setting and the results were higher than the values found for women from Niterói. This discrepancy may be due to the characteristics of Rodrigues *et al.*'s sample that included in-patients and comprised a large number of obese females.

All predictive equations examined in the present analysis significantly overestimated mean BMR in both men and women. The greatest overestimation, in general, was observed with the equations presently recommended for international use[12] and the lowest with the equations suggested to be used in populations living in the tropics[2]. The FAO/WHO recommended equations to be used internationally (Schofield)[11] have been reported to overestimate BMR, particularly in people living in tropical regions of the world[2,33,34]. For many years it was thought that people living in the tropics had lower BMR values comparatively to Europeans and North Americans[2,11]. In fact, this idea gained strength in the early years of the 20th century when Almeida[35,36] found that the BMR values of twenty Brazilian men living in Rio de Janeiro (tropics) were 20 % lower than the published values for North American men. Later, Almeida[37] concluded that BMR was lower in the populations living in the tropics based on measured BMR_i values of eight individuals in comparison to the values obtained from the equations of Harris and Benedict[27]. During the last century these premises have been weakened by growing evidence that BMR values of people living in the tropics are similar to those of people living elsewhere when body composition is considered[4,38]. Comparison of results from studies in young Brazilian women using the same protocol and calorimeter showed that BMR was not significantly different between women who lived in the tropics (Niterói, Rio de Janeiro state)[3] and women who lived below the Tropic of Capricorn in the temperate

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Table 5 Physical characteristics and indirectly measured and predicted BMR according to nutritional status: men (*n* 190) and women (*n* 339) from Niterói, Rio de Janeiro, Brazil

BMI (kg/m^2)	<18·5				≥18·5 and <25·0				≥25·0 and <30·0				≥30·0			
Gender	F		M		F		M		F		M		F		M	
Percentage	2·0		0·9		50·6		58·7		31·1		28·0		16·3		12·4	
	Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE
Age (years)	38·0	9·2	24·6	2·8	40·8	1·3	44·5	1·8	49·6	1·6	39·1	2·3	49·2	2·6	42·8	2·8
Body mass (kg)	46·5	0·9	55·2	1·6	56·7	0·4	66·3	0·8	67·4	0·7	79·7	1·1	82·0	2·1	98·6	2·2
Stature (cm)	162·0	1·2	175·9	0·3	160·4	0·4	171·5	0·8	157·4	0·6	172·4	31·0	156·4	1·1	171·6	1·7
BMI (kg/m^2)	17·7	0·3	17·8	0·6	22·0	0·1	22·5	0·2	27·2	0·1	26·7	0·2	33·4	0·6	33·6	0·9
Body fat (%)	21·1	1·0	6·1	1·3	33·7	0·3	17·1	0·6	41·8	0·2	26·8	0·6	46·7	0·5	35·6	1·0
Fat mass (kg)	9·9	0·6	3·3	0·7	19·3	0·3	11·7	0·5	28·2	0·4	21·7	0·6	38·4	1·1	35·2	1·5
Fat-free mass (kg)	36·6	0·3	51·9	0·9	37·4	0·2	54·6	0·7	39·2	0·4	58·0	0·9	43·6	1·2	63·4	1·3
BMR_i (kJ/d)	4309·3	52·7	4975·9	120·7	4561·3	36·4	5469·4	77·7	4804·9	59·3	6222·2	98·6	5332·5	120·7	6786·1	135·4
Predicted BMR (kJ/d)*	4868·1	47·6	6377·1	34·9	5410·4	17·1	6661·3	49·7	5754·3	28·3	7499·2	49·5	6247·7	61·4	8348·3	66·3
Bias (kJ/d)†	558·7	127·0	1401·2	221·3	849·0	30·3	1191·9	50·4	949·3	41·6	1276·9	75·2	915·1	86·3	1562·1	137·9
95 % CI of bias (kJ/d)	258·4, 859·1		1411·3, 4213·7		788·7, 909·3		1091·1, 1292·6		866·4, 1032·3		1125·1, 1248·8		740·4, 1089·9		1274·4, 1849·8	
% difference‡	13·2	2·7	28·3	3·3	19·4	0·8	22·1	1·0	20·4	0·9	20·9	1·2	18·0	1·7	23·6	2·2
% within ±10 % of BMR_i§	36·3		0		11·4		6·1		13·2		10·9		21·5		9·2	

F, females; M, males; BMR_i, BMR measured by indirect calorimetry.
*BMR predicted by the Schofield equations[11].
†Predicted BMR – BMR_i.
‡(Bias/BMR_i) × 100.
§Percentage of participants whose predicted BMR fell within 10 % of BMR_i.

region of the country (Porto Alegre, Rio Grande do Sul state, at 30°01′59″S, 51°13′48″W)[13].

The Schofield equations have also been shown to be inadequate to estimate BMR in clinical settings of people living in Europe and North America[5,7,39–43]. It has been suggested that the equations have unsolved problems in origin because they were based on a non-representative sample of the population[6], limiting their use for prediction of BMR in different populations. The equations were derived from compiled data available in the literature mainly in the first part of the last century and the final data set included 7173 participants (4809 men and 2364 women) who were mainly from Europe and North America[2]. Approximately 50 % of the sample were Italians who had higher BMR compared with participants of other nationalities represented in the data set, which may have introduced some bias in the final equations[44].

Aware of these problems, Henry and Rees[2] revised the available information on BMR of people living in the tropical region and ended up with data on 2822 subjects (3–60 years of age), of whom 1896 were between 18 and 60 years of age. The authors derived different equations for men and women of four age groups (3–10 years; 10–18 years; 18–30 years; 30–60 years). These equations yield lower BMR values than the ones predicted by the Schofield[11] equations, but the values were still significantly greater than BMR_i in the adult population of Niterói. This has also been reported in other samples of adult women from tropical regions[3,31].

In clinical settings, the equations of Harris and Benedict[27] are still widely used[45]. These equations were derived from BMR_i measurements of 239 American adults (136 women) almost a century ago with techniques that may have led to some discomfort and therefore higher BMR values[46]. There is some evidence that these equations do not work in the general North American population[28] and other groups worldwide[39,41,47–49], but in some studies they have been shown to be valid[45,50]. As observed in other studies conducted in tropical regions[3,4,6,48], the Harris and Benedict[27] equations significantly overestimated BMR in all age groups of the adult population of Niterói. Regression analyses with BMR data of the adult population of Niterói yielded equations with higher R^2 and lower SEE than the values of the three sets of published equations used in the present study. It is worth noting that only the Harris and Benedict equations included BM, S and A, the same variables included in the developed equations.

Niterói is an urban city located in the most developed area of Brazil, the south-eastern region, with high prevalences of overweight/obesity in adults[15] and adolescents[17]. Indeed, the prevalence of underweight was very low in both adult men and women of Niterói but overweight was observed in >40 % of the adult population. Energy requirement determination in countries undergoing nutrition transition is a challenge, since it relies on accurate estimation of BMR which is multiplied by appropriate

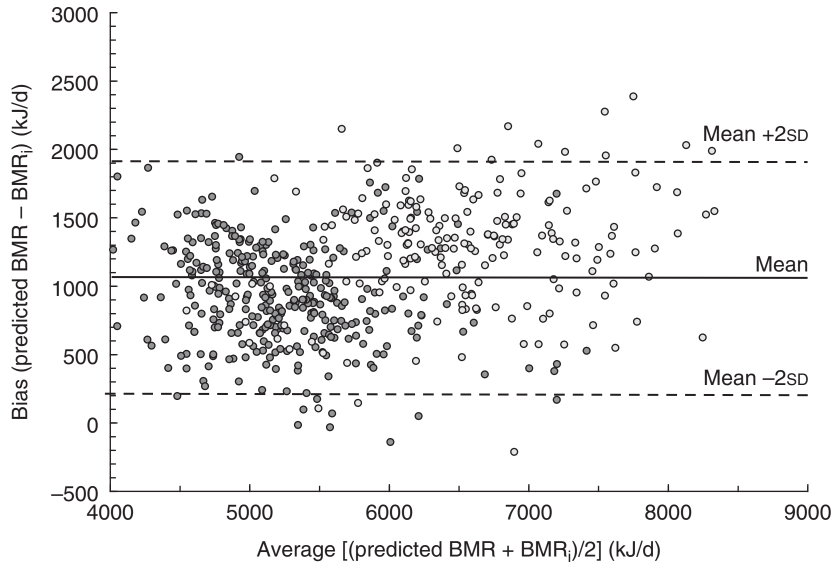

Fig. 1 Bland–Altman plot showing the mean bias (——) and limits of agreement (– – –) between BMR predicted by Schofield's equations[11] and BMR measured indirectly (BMR_i) among adults aged ≥20 years (○, men, *n* 190; ●, women, *n* 339) from Niterói, Rio de Janeiro state, Brazil

values of the PAL depending on the lifestyle of the subjects[12]. The results of the present study indicate that BMR is not adequately estimated across all nutritional status categories. With the current recommended procedures[12], the energy requirement of the adult population of Niterói would be overestimated by ∼20 %, exactly the same value documented by Almeida some 80 years ago and a problem for a population undergoing nutrition transition at present. It is evident that more data on energy expenditure must be generated for establishing the energy requirement of populations in the tropics[51] to ascertain whether it will be necessary to revise the suggested PAL values presently recommended[9].

Conclusion

The present study showed that the currently available predictive equations of BMR[2,11,27] are not adequate to estimate BMR in the adult population living in Niterói, Rio de Janeiro state, Brazil. A new set of equations has been developed and should be validated before its use is recommended.

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