Clinical Nutrition ESPEN 32 (2019) 158–164

Contents lists available at ScienceDirect

Clinical Nutrition ESPEN

journal homepage: http://www.clinicalnutritionespen.com

Original article

Validity of basal metabolic rate prediction equations in elderly women living in an urban tropical city of Brazil

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ARTICLE INFO

Article history:
Received 4 November 2018
Accepted 10 March 2019

Keywords:
Brazil
Basal metabolism
Calorimetry, Indirect
Validation studies

SUMMARY

Objectives: To measure basal metabolic rate (BMR) and to compare it with the values obtained from predictive equations in a sample of elderly (≥60 y) women.
Design: Cross-sectional study.
Participants and setting: Seventy-nine women living in Niterói, Rio de Janeiro, Brazil enrolled in physical activity programs open to the community.
Measurements: Anthropometric measures were obtained using standard procedures. Percent body fat (PBF) was assessed by DXA. BMR was measured (BMR_m) by indirect calorimetry under standardized conditions and compared with BMR estimated by 14 predictive equations that included elderly individuals in their development.
Results: Mean (±SD) age, BMI and PBF were 69.7 ± 6.5 y, 27.2 ± 4.6 kg/m^2 and 42.1 ± 5.9%. BMR_m (4188.3 ± 707.2 kJ/day) was significantly lower than estimated BMR by all predictive equations, including the equation developed for the Niteroian adult population (4565.6 ± 607.9 kJ/day). This population-specific equation provided the largest number of results within ±10% of BMR_m and the lowest overestimation (10.6 ± 15.4%), much lower than the results from the internationally recommended Schofield equation (27.2 ± 17.6%). Regression of calf circumference (CC), age and body mass on BMR_m provided similar estimates in comparison to models with fat-free mass (FFM).
Conclusions: All predictive equations provided biased, inaccurate estimates of BMR values in comparison to BMR_m. Anthropometry and body composition explained only approximately 50% of the variability of BMR_m. New equations should account for the variability of organ-metabolic rates and underlying undetected health conditions in older individuals living in tropical regions.

1. Introduction

The major legacy of the XX century for humanity is the increase in life expectancy (longevity revolution) which allows the prediction of more than 2 billion 60 y+ people in the world by 2050 [1]. Aging is a natural biological process and increase in the proportion of this age segment will create higher specialized demand for public health care systems in the present context of promotion of healthy physical, mental and social life environments [2]. Bodily and metabolic changes are striking in aging. In relation to body composition, longitudinal studies [3,4] have documented increases in body fat (BF) and decreases in fat-free mass (FFM), with or without changes in total body mass. However, BF in individuals over 75 years of age tends to stabilize or even decline in both sexes [5]. Changes in body composition may alter total daily energy expenditure and its components such as basal metabolic rate (BMR) [4].

BMR is the amount of energy needed to maintain vital body functions and accounts for 45–70% of total daily energy expenditure in humans which makes it the essential information for estimating energy requirements of populations [6]. BMR measurement requires specific equipment that is not always available in health facilities. In these settings, the viable alternative is the use of predictive equations for its estimation. The current report on human

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https://doi.org/10.1016/j.clnesp.2019.03.003

energy requirements [6] recommends the international use of the BMR predictive equations developed by Schofield [7] for populations of all ages. Validation studies of these equations in some populations have revealed that, in most cases, they tend to overestimate BMR in adults in several parts of the world [8–11]. Particularly in the elderly, these equations tend to provide estimated BMR (BMR_e) values up to 15% in error [10,12,13]. Considering these errors, some researchers have proposed specific equations for their populations but most of them were done in small samples of elderly individuals [13,14] or in data compilations [8,9,15]. Thus, it is extremely important to assess the accuracy of the BMR equations so that they can be recommended for widespread use. In Brazil, Anjos et al. [16] developed BMR predictive equations from a probability sample of the adult population of Niterói, Rio de Janeiro, Brazil. These equations have already been documented as valid for the adult (20-60 y) Brazilian population [11]. To this end, the purpose of the present study was to measure BMR in elderly women residing in a tropical locality in Brazil and to compare the results with those obtained by several predictive equations developed in different parts of the world that included elderly people in their development.

2. Methods

2.1. Subjects

The study was conducted in elderly women (≥60 y) living in the city of Niterói, Rio de Janeiro, located in the tropics in the southeast region of Brazil at 22°53′ South and 43°06′ West. The research procedures were presented to the participants of municipal projects aimed to encourage the participation in physical activity programs. Demographic and contact data were obtained in site and the individuals who met the inclusion criteria were later contacted by telephone, when the objectives and procedures of the study were explained again. Upon agreement to participate, a visit to the laboratory was scheduled.

Inclusion criteria were women aged 60 y+ and those with diabetes, hyper or hypothyroidism, and users of beta-blocker antihypertensive drugs were excluded due to its potential role in metabolism [17]. A total of 92 individuals were recruited of whom, 11 hypertensive women with beta-blocker and two diabetic taking antihypertensive drugs were excluded, resulting in a sample of 79 women. The study procedures were approved by the Research Ethics Committee of the Antônio Pedro University Hospital, addressing the ethical aspects of human research.

2.2. Measured BMR

For the BMR measurement, all the elderly women were instructed to come to the research laboratory early in the morning after sleeping for 6–8 h, having fasted for 12 h and avoided vigorous physical activity for the previous 24 h. Upon arrival, an interview was conducted to confirm adherence to the protocol and to obtain their agreement to participate in the study by signing the Informed Consent Form.

BMR was measured between 7 and 9 am in a temperature controlled room with low light and noise. Before starting the measurement, the women rested in a reclining chair for 15 min. After this period, a canopy was placed over the individual's head and gas exchange was measured for 25 min with an indirect open circuit calorimeter (Vmax Encore 29, Sensormedics, Palm Springs, CA). The calorimeter was calibrated prior to each measurement following the manufacturer's manual. The Weir [18] equation was used to convert the $\dot{V}O_2$ and $\dot{V}CO_2$ values in kcal/min and the 24 h measured BMR (BMR_m) was obtained by multiplying the mean value of the last 20 min of gas exchange by 1440. Valid BMR_m data were considered when the coefficients of variation of both $\dot{V}O_2$ and $\dot{V}CO_2$ were less than 10% [19].

Box
Basal metabolic rate (BMR) predictive equations developed from elderly and adult women worldwide.

Author (year)	Country	n	Age (y)	Equations	
				Adults and elderly	R^2
Harris & Benedict (1919)[a] [20]	USA	103*	15–74	655.0955 +(9.5634 x BM) +(1.8496 x S) -(4.6756 x A)	0.53
Mifflin et al. (1990)[b] [21]	USA	244	19–78	(9.99 x BM) +(6.25 x S) -(4.92 x A) - 161	0.71
Liu et al. (1995)[a] [22]	China	121	20–78	(13.88 x BM) +(4.16 x S) -(3.43 x A) -(112.40) + 54.34	0.81
Müller et al. (2004)[c] [9]	Germany	1046	18–91	(0.047 x BM) - (0.01452 x A) + 3.21	0.73
Livingston & Kohlstadt (2005)[a] [23]	USA	356**	18–77	(248 x $BM^{0.4356}$) -(5.09 x A)	0.71
Korth et al. (2007)[b] [24]	Germany	54	20–66	(41.5 x BM) -(19.1 x A) +(35.0 x S) - 1731.2	0.71
Anjos et al. (2014)[b] [16]	Brazil	339***	20–80	(37.46 x BM) +(37.13 x S) -(2.92 x A) - 3407.09	0.83
				Only elderly	
Schofield (1985)[c] [7]	Various	38	>60	(0.038 x BM) + 2.755	0.46
Luhrmann et al. (2002)[a] [25]	Germany	179	>60	3169 +(50 x BM) - (15.3 x A)	0.74
Henry (2005)[c] [8]	Various	334	>60	(0.0424 x BM) + 2.38	0.62
Alemán-Mateo et al. (2006)[a] [14]	Chile	8	>60	1.6447 + (0.05714 x BM)	0.75
	Cuba	5			
	Mexico	8			
Hedayati & Dittmar (2011)[d] [26]	Germany	49	60–83	Model 1: 46.155 - (0.273 x HC)	0.70
				Model 2: 69.865 - (0.229 x HC) - (0.173 x S)	0.83
				Model 3: 68.143 - (0.025 x HC) - (0.210 x S) - (0.519 x BMI)	0.91

BM = Body mass (kg); S = Stature (cm); A = age (y); HC = Hip circumference (cm), BMI = Body mass index.
Unities: [a]kcal/day; [b]kJ/day; [c]MJ/day; [d]kcal/kg/day.
*Only 6 subjects ≥60 y of whom 2 > 70 y. R^2 calculated by the authors using the original published data.
**Include own measurements and data from Harris & Benedict [20] and Owen et al. [27].
***Probability sample.
Unities: [a]kcal/day; [b]kJ/day; [c]MJ/day; [d]kcal/kg/day.

2.3. Estimated BMR

BMR_e was derived from the equations described in the Box. These equations were selected because they included samples of elderly individuals in their development, they used anthropometric measures as independent variables and had R^2 greater than 0.60. The classic equation of Harris & Benedict [20] and the one recommended for international use by FAO/WHO [6], developed by Schofield [7], were also included. All BMR values were expressed in kJ/day using 4.1868 to convert kcal to kJ. Bias was estimated as the difference between BMR_e and BMR_m. Percent bias was calculated as [(bias/BMR_m) X 100].

2.4. Anthropometry

Anthropometry was obtained after the BMR measurement in barefooted women who wore standardized light clothing. Stature was obtained in duplicate in a wooden stadiometer. The readings were made in apnea after a normal inspiration and recorded with an accuracy of 0.1 cm. Body mass (BM) was measured with an accuracy of 0.1 kg on an electronic scale (Filizola model PL-200, São Paulo, Brazil). Body mass index (BMI) was calculated as the ratio of BM (kg) and squared stature (m^2). Nutritional status was classified according to the criteria established by WHO [28] based on BMI: adequate (<25), overweight (25–30) and obesity (≥30 kg/m^2). There was only one underweight subject (BMI < 18.5 kg/m^2) and she was assigned to the adequate group. Calf (CC) and hip circumferences were measured to the nearest 0.1 cm with an inelastic tape at the point of greatest perimeter and horizontally at the largest perimeter of the buttocks, respectively. The mean of the two measures of stature and circumferences was used in the analysis.

2.5. Body composition

Body composition was assessed by dual energy X-ray absorptiometry (DXA, GE Health Care, Lunar iDXA model, Milwaukee, Winsconsin, USA) using software encore 2010 version 13.40, with the elderly women wearing standardized clothes without any metal. Data acquisition was performed by a radiology technician who calibrated the instrument before each measurement as directed by the manufacturer. Fat-free mass (FFM), fat mass (FM) and body fat percentage (%BF) were obtained.

2.6. Statistical analyses

Descriptive analyses (mean, standard deviation, minimum and maximum, and 95% confidence intervals - CI) were calculated for all continuous variables. The significance of the differences between BMR_m and BMR_e was determined by paired t-tests. The main effect of nutritional status (BMI) categories on age, anthropometry, body composition and metabolic variables mean values was assessed by One-way ANOVA. Tukey's post hoc tests were used to identify the significance of the difference among BMI categories. Pearson correlation coefficients were calculated between BMR_m and anthropometry and body composition. Regression analysis was used to develop BMR predictive equations using anthropometric and body composition variables and age as independent variables.

The accuracy of the BMR_e values derived from the various prediction equations was assessed by the percentage of subject's values which fell within ±10% of BMR_m [19,29]. The agreement between BMR_m and BMR_e was assessed by the Bland & Altman [30] graphic method.

3. Results

Approximately 43% of the women were 70 y+ of age and mean age (±SD) was 69.7 ± 6.5 y ranging from 60.1 to 97.0 y. Mean BMI was 27.2 ± 4.6 kg/m^2 (Table 1), 39.2% of the women were overweight, 27.8% were obese and only two of the women had %BF < 30%.

Overall mean BMR_m was 4188.3 ± 707.2 kJ/day which was significantly lower than BMR_e by all predictive equations. Mean BMR_e varied from 4565.6 ± 607.9 kJ/day for the Anjos et al. [16] equation to 5361.0 ± 701.3 kJ/day for the Alemán-Mateo et al. equation [14] which meant overestimation of 10.6 and 29.9%, respectively (Table 2).

The Anjos et al. [16] predictive equation provided the highest percentage (44.3%) of subjects with values within ±10% of BMR_m followed by the Mifflin et al. [21] equation (40.5%). The Harris & Benedict [20] and Schofield [7] equations provided only 11.4 and 12.7% within the range, respectively (Table 2).

Table 3 presents the anthropometric and body composition profiles and the BMR_m and BMR_e of the least biased [16,21] and the Schofield [7] equations as a function of BMI. Only age, stature and the percentage bias of BMR_m and BMR_e were not significantly different among BMI categories. Higher BMR_m values progressively followed the increase in BMI. The % of values within ±10% of BMR_m was higher in the two BMI extremes for the Mifflin et al. [21] and Anjos et al. [16] equations.

Only four women had bias <0 kJ/day when the Schofield [7] equation was used (Fig. 1A). There was a tendency for lower bias as BMR increased using the Schofield [7] equation but no tendency when the Mifflin et al. [21] (Fig. 1B) and the Anjos et al. [16] (Fig. 1C) equations were used.

BMR_m was correlated with BM (r = 0.64), FFM (r = 0.66) and CC (0.54) but the regressions of BM and FFM on BMR_m showed a lot of variability (Fig. 2) and a large standard error of the estimate (SEE). Including CC in the regression model improved slightly the prediction of BMR when FFM and age were in the model. A model with BM, age and CC was as good as the model with FFM and age. The developed BMR predictive equations are presented in Table 4.

4. Discussion

BMR serves as the basis for energy requirements of populations [6] and in most clinical settings it is estimated by predictive equations [31]. The present study measured BMR in elderly women living in a tropical environment and compared the results with different equations available in the literature that were developed with data from studies that included 60 y+ women. Despite its origin and the characteristics of the predictive equations tested, all of them provided biased, inaccurate and overestimated BMR values in the elderly women as observed in other studies [32,33]. It is interesting to note that three of the equations specifically

Table 1
Descriptive statistics of age, anthropometric and body composition data of the 79 elderly women.

Variables	Mean	SD	Min	Max
Age (years)	69.7	6.5	60.1	97.0
Body mass (kg)	65.0	12.3	40.6	93.7
Stature (cm)	154.6	6.3	139.9	172.8
Body mass index (kg/m^2)	27.2	4.6	17.3	39.9
Body fat percentage	42.1	5.9	21.2	53.5
Fat mass (kg)	27.8	8.1	8.9	46.6
Fat free mass (kg)	37.2	5.5	25.2	53.5
Calf circumference (cm)	35.7	3.6	29.1	46.2
Hip circumference (cm)	103.2	9.7	83.0	125.6

Table 2
Descriptive statistics of measured and estimated basal metabolic rate (BMR) of the 79 elderly women.

	Basal metabolic rate (kJ/day)			Bias[a]		% Bias[b]		% of BMR_e within
	Mean	SD	95% CI	Mean	SD	Mean	SD	±10% of BMR_m
Measured[c]	4188.3	707.2	4029.9; 4346.7	–	–	–	–	–
Estimated by predictive equations developed from adult and elderly samples								
Harris & Benedict (1919) [20]	5179.7	550.8	5056.4; 5303.1	991.5	519.9	25.7	16.3	11.4
Mifflin et al. (1990) [21]	4655.8	644.7	4511.4; 4800.2	467.5	546.9	12.6	15.0	40.5
Liu et al. (1995) [22]	5228.1	790.8	5051.0; 5405.3	1039.9	611.9	26.3	17.4	16.5
Müller et al. (2004) [9]	5254.9	598.5	5120.9; 5389.0	1066.6	536.7	27.5	16.7	12.7
Livingston & Kohlstadt (2005) [23]	4886.5	564.9	4760.0; 5013.0	698.2	521.2	18.5	15.3	25.3
Korth et al. (2006) [24]	5047.3	675.5	4896.0; 5198.6	859.0	564.9	22.2	16.3	24.0
Anjos et al. (2014) [16]	4565.6	607.9	4429.4; 4701.7	377.3	565.9	10.6	15.4	44.3
Estimated by predictive equations developed from elderly samples								
Schofield (1985) [7]	5226.5	466.4	5122.0; 5330.9	1038.2	541.0	27.2	17.6	12.7
Luhrmann et al. (2002) [25]	5354.7	636.4	5212.1; 5497.2	1166.4	546.7	29.8	17.1	12.7
Henry (2005) [8]	5137.7	520.4	5021.1; 5254.2	949.4	544.7	24.9	17.1	15.2
Alemán-Mateo et al. (2006) [14]	5361.0	701.3	5204.0; 5518.1	1172.8	594.0	29.9	18.0	12.7
Hedayati & Dittmar (2011) [26]								
Model 1	4769.3	389.6	4681.4; 4857.1	580.4	613.8	16.4	17.6	31.6
Model 2	5172.5	421.3	5077.5; 5267.5	983.6	623.1	26.3	19.3	12.7
Model 3	5020.2	209.8	4972.9; 5067.5	831.3	647.1	23.0	19.8	25.3

[a] Bias = Estimated BMR − measured BMR.
[b] % Bias = (Bias/measured BMR) x 100.
[c] Measured BMR is statistically lower than estimated BMR for all equations ($p < 0.0001$).

Table 3
Descriptive statistics of age, anthropometric, body composition, and measured and estimated basal metabolic rate (BMR) data by body mass index of the 79 elderly women.

	Body mass index (kg/m^2)					
	<25 (n = 26)		25-30 (n = 31)		≥30 (n = 22)	
	Mean	SD	Mean	SD	Mean	SD
Age (years)[a]	70.5	6.1	69.5	5.7	69.1	8.0
Body mass (kg)	53.0	6.2	65.0	7.1	79.4	6.9
Stature (cm)[a]	154.1	5.2	154.5	7.5	155.3	5.8
Body fat percentage	36.9	5.4	43.1	3.9	46.9	4.0
Fat mass (kg)	19.7	4.3	27.9	3.3	37.3	5.3
Fat free mass (kg)	33.3	3.3	37.1	5.3	42.0	4.0
Calf circumference (cm)	33.0	2.0	35.5	2.5	39.3	3.6
Hip circumference (cm)	93.3	5.5	103.6	4.2	114.6	5.6
Basal metabolic rate (kJ/day):						
Measured	3744.4	461.0	4195.2	728.7	4703.1	569.7
Mifflin et al. (1990) [21]	4122.4	387.8	4655.4	524.4	5286.8	450.1
Bias	378.0	364.4	460.2	629.0	583.7	603.0
% Bias[a]	11.0	11.1	13.1	17.0	13.9	16.3
% within ±10% of BMR_m	46.1		35.5		40.9	
Anjos et al. (2014) [16]	4092.3	394.1	4561.4	532.0	5130.6	414.2
Bias	347.9	361.3	366.3	662.9	427.5	634.2
% Bias[a]	10.2	11.1	10.9	17.8	10.7	16.7
% within ±10% of BMR_m	46.1		38.7		50.0	
Schofield (1985) [7]	4768.8	234.3	5224.0	269.1	5770.8	263.2
Bias	1024.4	392.3	1028.9	637.6	1067.7	567.2
% Bias[a]	29.0	15.2	27.6	19.9	24.5	17.1
% within ±10% of BMR_m	3.8		19.3		13.6	

Bias = Estimated BMR − measured BMR.
% Bias = (Bias/measured BMR) x 100.
[a] Main effect (ANOVA) of body mass index categories not significantly different ($p > 0.05$).

developed for the elderly [7,14,25] were among the ones with the highest overestimations including the equation developed by Schofield [7] and recommended for use worldwide.

Most of the available BMR predictive equations for the elderly comes from convenient small samples or they were developed from compilation of data available in the literature. However, it is not the number of subjects that made the equations yield more accurate estimates of BMR in the present sample of elderly women. For instance, Müller et al. [9] used data from 1046 subjects aged 18–91 from various regions of Germany but the equation overestimated BMR_m by 27.5%. On the other hand, the equation developed by Livingston & Kohlstadt [23] provided much lower biased values. This equation was developed using data from 356 women of whom 103 came from data published in Harris & Benedict [20] and 44 from data published in Owen et al. [27]. Harris & Benedict [20] included only 6 subjects aged ≥ 60 y of whom, 2 were 70 y+ olds and Schofield [7] used data from only 38 elderly subjects to develop his equation.

There has been a long concern about the adequacy of using equations derived from samples of subjects from Europe or North America, such as in the Schofield [7] equations, in populations living in the Tropics because of reports of BMR overestimation in peoples from these areas [34]. There are several possible reasons for the inadequacy of the equations. The sample in Schofield's dataset comprised a large number of subjects with BMI <20 kg/m^2 and a proportionally larger number of Italian nationals who presented higher body mass corrected BMR values than other nationalities [9,11]. In addition, the data were collected a century ago using nonstandardized protocols well established presently. Despite the knowledge of the inadequacy of the Schofield [7] equations for some populations, the current energy requirement recommendations [6] are that they be used until more BMR data are gathered worldwide. Specifically for the tropical regions, Henry & Rees [34] compiled, almost 30 years ago, the available data of BMR for populations living in these areas of the world. However, the new equations were developed for subjects aged up to 60 y due to the unavailability of data for older individuals in the tropics. The equation developed by Alemán-Mateo et al. [14] was based on data of 21 and 19 rural women and men from Chile (8 women), Cuba (5 women) e Mexico (8 women). Overall mean measured BMR for the elderly women from these countries was about 5361.0 kJ/day which is approximately 135 kJ/day higher than the value estimated by the Schofield [7] equation and agrees with other reports [32,33]. In the present sample of elderly women, the Alemán-Mateo et al. [14] equation provided the highest overestimation of BMR among all tested equations.

Specific equations developed for the elderly do not necessarily provide better BMR_e in comparison to the values predicted from equations developed from adult and elderly subjects combined.

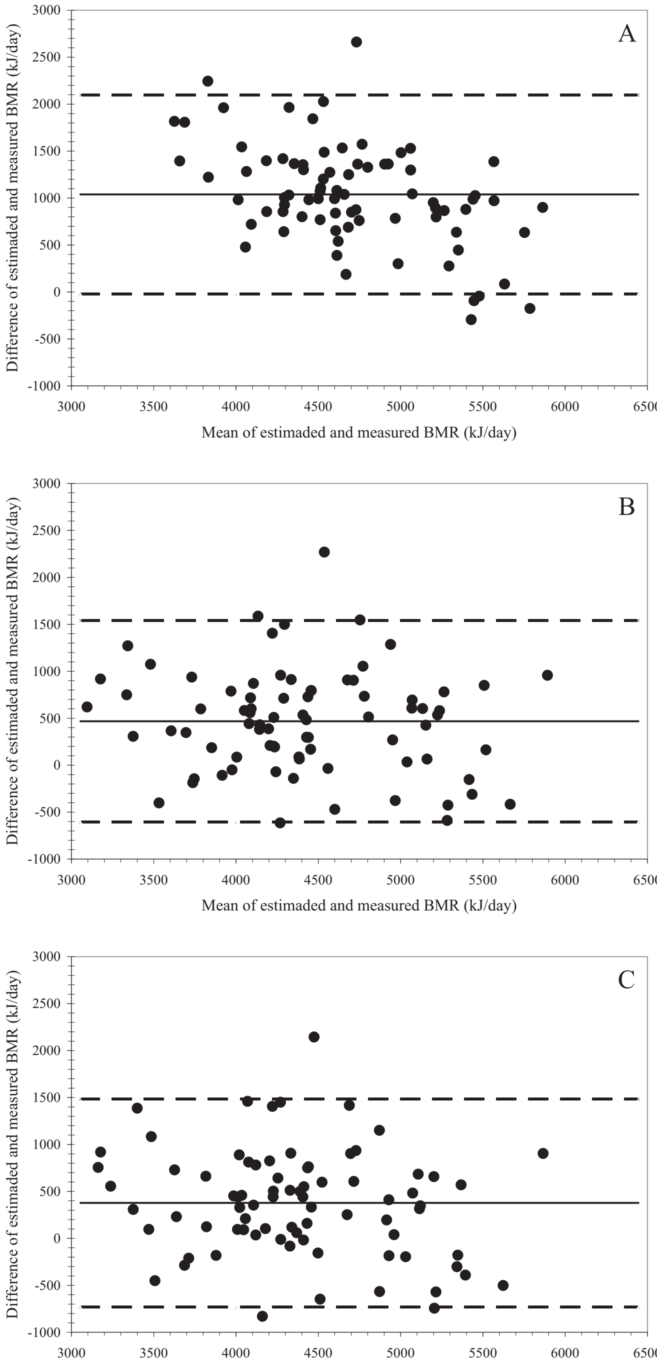

Fig. 1. Bland & Altman [30] graphs for the agreement of measured and estimated basal metabolic rate by the Schofield [7] (A), Mifflin et al. [21] (B) e Anjos et al. [16] (C) equations in the 79 elderly women.

For instance, BMR estimated by the Anjos et al. [16] and Mifflin et al. [21] equations provided the least biased BMR values in the Niteroian elderly women. The agreement analysis between BMR_m and BMR_e using these two equations showed no tendency which occurred for the elderly-specific Schofield [7] equation. The equation that most closely estimated BMR was the one developed by Anjos et al. [16] in a probability sample of adults (20-80 y) from the same city as the present sample of women. The BMR_m value of the 60 y+ women in the survey was higher than the observed in the present sample of elderly women who had higher BMI and %BF [16].

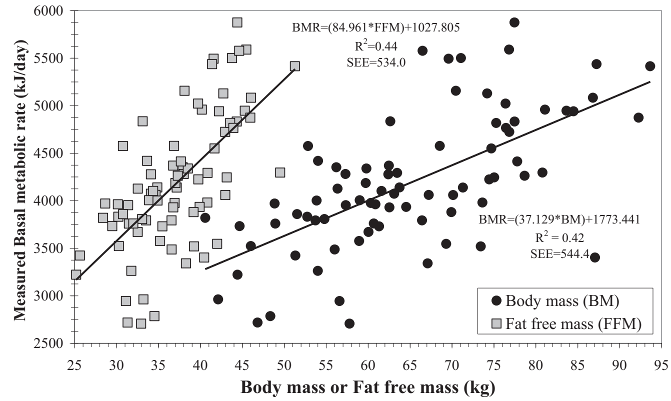

Fig. 2. Scatter plot of measured basal metabolic rate (BMR) and body mass (BM) or fat-free mass (FFM) of the 79 elderly women.

Table 4
Predictive regression equations of basal metabolic rate based on anthropometric and body composition data from the 79 elderly women.

Equation (kJ/day)	SEE (kJ/day)	R^2
2799.590 + 79.482 (FFM) - 22.499 (Age)	517.6	0.48
2471.518 + 60.612 (FFM) - 29.322 (Age) + 41.921 (CC)	504.8	0.52
3747.461 + 35.010 (BM) - 26.347 (Age)	520.5	0.47
3336.337 + 98.070 (CC) - 38.172 (Age)	564.8	0.39
3460.188 + 27.377 (BM) - 31.819 (Age) + 32.415 (CC)	517.3	0.49

SEE = Standard error of the estimate; R2 = coefficient of determination; FFM = fat free mass; CC = calf circumference; BM = body mass.

Predictive equations provide average estimations at the population level and should be used cautiously to estimate BMR and energy requirements in individuals [35]. For this reason, Frankenfield et al. [29] have proposed that BMR_e values within ±10% of BMR_m could be considered adequate assuming that the indirect calorimetry method has an error of around 5% [36]. The Anjos et al. [16] equation provided the highest percentage of BMR_e values in this range. However, as indicated earlier, this equation provided significantly different BMR values in the present sample of elderly women in spite of having been developed in a probability sample of 20 y+ subjects from the same city.

As observed in other age groups, body composition, especially FFM, is correlated with BMR at levels higher than BM. This fact has led investigators to suggest the development of BMR predictive equations using FFM in the model [24]. However, equations based on FFM are not practical because body composition techniques are not universally available for the general health professional. Besides, similarly to what was found in the present study, predictive equations with FFM improve BMR_e only slightly in comparison to BM-derived BMR equations [9,24,37,38]. Specifically in the elderly, Luhrmann et al. [25] proposed equations based on FFM, fat mass and waist-to-hip ratio but these measures did not improve the prediction of BMR comparatively to the equations with BM, age and gender in the calculation. Alternatively, Isobe et al. [39] suggested that CC be used as an easier estimate of muscle mass because they found that CC was positively associated with basal energy expenditure in Japanese diabetic patients. The results of the present study confirm this finding. The inclusion of CC in the prediction models improved the estimation of BMR at the same level of FFM alone if BM and age are in the model which suggests that CC can be used as a surrogate of lean tissue in the prediction BMR equations in the elderly. However, the best model was only able to explain approximately 50% of the variability of BMR in the elderly women. Despite its contribution in explaining the variability of BMR, the use of FFM for this purpose has some limitations. It has been suggested that some of the variation of BMR may be due to the different impacts of the composition of FFM (individual organs) which may present variable specific metabolic rates along the life span [40]. Thus, new studies with better statistical models and body composition methods are needed to take into account the variable organ-metabolic rate associations, particularly in older individuals.

Other factors can influence BMR_m either by altering physiological processes or anthropometry and body composition. Some of these factors are easy to identify and control such as, medications, smoking, weight changes or physical activity but others are more subtle. For instance, Valenti et al. [41] have recently reported an inverse relationship between BMR and sleep quality in a sample of 40 elderlies (mean age of 63 ± 7 y) who spent one night in a respiration chamber. Furthermore, sleep duration has been shown to influence BMR in adults [42]. Specifically in older individuals, morbidity plays an important role in the variability of BMR [43]. Thus, some health conditions may already be present but unnoticed by the subject but its influence in the metabolic status can impact the BMR_m values. This may help explain the large variability of BMR results in the present sample of elderly women and the challenge of accurately measuring and predicting BMR in this population.

5. Conclusion

All available predictive equations to estimate BMR in the elderly population were inadequate in elderly women living in a tropical setting in Brazil. Anthropometry and body composition explained only approximately 50% of the variability of BMR_m. Thus, more data should be gathered to develop accurate, unbiased BMR predictive equations for older individuals living in tropical regions of the world, preferably accounting for the variability of organ-metabolic rates and underlying undetected health conditions.

Statement of authorship

MR Sgambato, V Wahrlich, and LA Anjos planned the research and collected the data. LA Anjos analyzed the data. V Wahrlich and MR Sgambato wrote the first draft of the paper, which was revised and approved by all authors.

Ethical standards disclosure

This study was conducted according to the guidelines laid down in the Declaration of Helsinki and all procedures involving human subjects/patients were approved by the Institutional Review Committee of the Universidade Federal Fluminense (CAAE: 01774512.8.0000.5243). Written informed consent was obtained from all subjects/patients.

Funding sources

The research upon which the manuscript is based was partially funded by the Brazilian National Research Council (CNPq, grant numbers 485168/2011-1 and 310461/2016-2) and the Rio de Janeiro State Research Funding Agency (FAPERJ, grant numbers E-26/110.208/2009, E-26/102.182/2010, E-26/110.614/2014 and E-26/203.068/2017). CNPq and FAPERJ had no role in the design, analysis or writing of this article.

Conflicts of interest

None.

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