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Original article

Q6 Validity of a population-specific BMR predictive equation for adults from an urban tropical setting

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SUMMARY

Background & aims: Basal metabolic rate (BMR) is an important physiologic measure in nutrition research. In many instances it is not measured but estimated by predictive equations. The purpose of this study was to compare measured BMR (BMRm) with estimated BMR (BMRe) obtained by different equations.

Methods: A convenient sample of 148 (89 women) 20–60 year-old subjects from the metropolitan area of Rio de Janeiro, Brazil participated in the study. BMRm values were measured by an indirect calorimeter and predicted by different equations (Schofield, Henry and Rees, Mifflin-St. Jeor and Anjos. All subjects had their body composition and anthropometric variables also measured. Accuracy of the estimations was established by the percentage of BMRe falling within ±10% of BMRm and bias when the 95% CI of the difference of BMRe and BMRm means did not include zero.

Results: Mean BMRm values were 4833.5 (SD 583.3) and 6278.8 (SD 724.0) kJ*day^{-1} for women and men, respectively. BMRe values were both biased and inaccurate except for values predicted by the Anjos equation. BMR overestimation was approximately 20% for the Schofield equation which was higher comparatively to the Henry and Rees (14.5% and 9.6% for women and men, respectively) and the Mifflin-St. Jeor (approximately 14.0%) equations. BMR estimated by the Anjos equation was unbiased (95% CI = −78.1; 96.3 kJ day^{-1} for women and −282.6; 30.7 kJ*day^{-1} for men).

Q2 *Conclusions:* Population-specific BMR predictive equations yield unbiased and accurate BMR values in adults from an urban tropical setting.

1. Introduction

Basal metabolic rate (BMR) was recognized as the basis for the establishment of energy requirements of populations three decades ago [1]. For this purpose, different BMR predictive equations have emerged in the literature. Most of these equations are based on studies with convenient samples in clinical or research settings [2–6] or compilations of data derived from studies available in the literature [7–9]. After reviewing the available data on BMR, the most recent Joint FAO/WHO/UNU Expert Consultation on Human Energy Requirements [10] decided on recommending the use of the BMR equations published by Schofield [7] until more comprehensive analysis of existing updated information become available. To this end, the Expert Consultation encouraged the development of studies with broader geographic and ethnic representation because studies of the validity have demonstrated that the proposed equations could overestimate BMR when applied to different populations [6,9,11]. It has been speculated that the problems related to the original data set and the calorimeter used for data collection may have led to higher BMR values which could explain part of the inadequacy of the equations [9,12]. A reanalysis of Schofield's original data set of BMR measurements obtained in the tropics conducted by Henry & Rees [8] indicated that the Schofield equations overestimated BMR by approximately 8% in all age groups and higher in adults. This finding led the authors to develop new specific equations for peoples living in the tropics. In Brazilian adults, the Schofield [7] equations have provided overestimation of BMR in subjects living in different parts of the country and abroad [11,13–15].

In order to overcome these limitations, Anjos et al. [11] developed predictive equations for BMR based on data from a probability sample of adults in a household survey in Niterói, Rio de Janeiro,

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Brazil. Apparently, this was the first attempt to derive predictive equations to estimate BMR in a representative sample of adults in a tropical setting but they should be validated before they can be broadly recommended. Thus, the present study was carried out to verify the adequacy of these equations in adults living in the same tropical town. The working hypothesis was that the new set of equations would adequately estimate BMR in the present sample of adults.

2. Subjects and methods

2.1. Subjects

Fifty-nine men and 89 women were enrolled in the study. They were recruited from posters displayed at the University *Campus* and from personal contacts. Volunteers were apparently healthy, between 20 and 60 years of age. Women were not pregnant or lactating. All procedures were approved by the Ethics Committee of the University which is responsible to review the Ethical Principles for Medical Research Involving Human Subjects established by the Declaration of Helsinki. Prior to participation, the subjects signed an informed consent form.

2.2. BMR measurement

All subjects reported to the laboratory after having fasted for 12 h, slept for 6–8 h, and done no vigorous exercise in the 24 h prior to the measurements. As soon as the subject arrived at the laboratory, an interview was conducted to confirm adherence to the protocol and a heart rate (HR) monitor was affixed on their thorax. BMR was measured (BMR_m) by indirect calorimetry (Vmax Encore 29, Sensormedics, Palm Springs, CA) using a canopy in a quiet, dark room with controlled temperature after calibrating the calorimeter according to the manufacturer's recommendation. Prior to the measurement, the subject laid down and rested for 15 min as recommended [16]. After this period, $\dot{V}$ O_2 and $\dot{V}$ CO_2 were measured for 25 min and the data from the first five minutes were discarded.

The coefficient of variation (CV) of the $\dot{V}$ O_2 and $\dot{V}$ CO_2 values was calculated for each subject. The criterion for valid BMR_m was a steady-state measure with CVs of both $\dot{V}$ O_2 and $\dot{V}$ CO_2 < 10% [16]. The mean intra-individual CV of BMR_m in previous studies in our laboratory was 4.72% [11]. Weir [17] equation was used to convert gas exchange data in energy expenditure, expressed in kJ day^{-1}.

2.3. BMR predictive equations

BMR values were also estimated for men and women using four sets of predictive equations based on body mass (BM) in kg, stature (S) in cm, and age (A) in years: the Schofield [7], the Henry & Rees [8], the ones developed in a probability sample of men and women aged 20+ years from a household survey conducted in Niterói, a metropolitan city of Rio de Janeiro (Anjos et al. [11]), and the Mifflin-St. Jeor [18] equations. The Schofield [7] equations (MJ day^{-1}) are: for women, 18–30 y, $(0.062 \times BM) + 2.036$ and $(0.034 \times BM) + 3.538$, for the 30–60 y and for men: $(0.063 \times BM) + 2.896$ and $(0.048 \times BM) + 3.653$, respectively. The Henry & Rees [8] equations (MJ day^{-1}) are: for women, 18–30 y, $(0.048 \times BM) + 2.562$ and $(0.048 \times BM) + 2.448$, for the 30–60 y and for men: $(0.056 \times BM) + 2.8$ and $(0.046 \times BM) + 3.16$, respectively. The Anjos et al. [11] equations (kJ day^{-1}) are: for women, $(37.46 \times BM) + (37.13 \times S) - (2.92 \times A) - 3407.09$ and for men, $(41.79 \times BM) + (29.86 \times S) - (11.69 \times A) - 1884.93$. The Mifflin-St. Jeor equation [18] [kcal day^{-1} = $(10 \times BM) + (6.25 \times S) - (5 \times A)$ (+5, for males or −161, for females)] has been found to be unbiased and accurate in estimating BMR in obese and non-obese individuals [19].

2.4. Anthropometry and body composition measurements

After the BMR measurements, the subjects were asked to remove all jewelry or any worn plastic or metal piece and their shoes and to wear a light standardized gown. S was measured twice on a stadiometer where the subject stood with the arms relaxed and the head positioned in the Frankfort plane. The reading was taken to the nearest 0.1 cm after an expiration. BM was measured on a Tanita BC-418 scale with 100 g precision. BM (kg) was divided by and S squared to yield the body mass index (BMI). Nutrition status was classified based on BMI according to WHO [20] as Underweight, ≤18.5; 18.5 < Adequate ≤ 25; Overweight, ≥25; and Obesity, ≥30 kg m^{-2}.

Body composition information (percentage body fat – %BF, fat-free mass – FFM, and fat mass – FM) was obtained by a Lunar iDXA system (GE Health Care, Madison, WI) using version 13·40 of the 2010 encore software. DXA data acquisition was performed by a technician and prior to each measurement a calibration was done according to the manufacturer's recommendation.

2.5. Data analysis

For each equation, bias (estimated minus BMR_m) was calculated along with the proportion of subjects whose estimated BMR was within ±10% of BMR_m (accuracy [16]). The significance of bias was assessed when the 95% confidence intervals (CI) of the differences between estimated and BMR_m excluded zero [19]. For comparison purposes, two groups of BMI and age were formed: <25 and ≥25 kg m^{-2} and <30 and 30–60 y. Comparisons between means of gender, age and BMI categories were carried out with independent Student t-tests for the normally distributed variables and Wilcoxon tests for the others. Likewise, the relationship between BMR_m and anthropometric and body composition variables was assessed by correlation coefficients (Pearson or Spearman, accordingly). The significance of the difference of estimated and BMR_m was done with dependent Student t-tests. Bland–Altman [21] plots were drawn to verify the agreement between estimated and BMR_m. An α of 0.05 was used to establish significance in all analyzes using SAS (Statistical Analysis Systems) package for PC, release 9.2.

3. Results

Mean age was not different between women and men. On average, men were taller and heavier and had higher values of BMI than women (Table 1). Mean %BF and FM were significantly higher in women compared to men while mean FFM was lower in women. Mean basal $\dot{V}$ O_2 and estimated and BMR_m were significantly lower in women. BMR estimated by the Anjos et al. [11] equation was not significantly different from BMR_m for both men and women. The Schofield [7] equations yielded biased estimates in women and men (mean measured significantly lower than estimated BMR) and inaccurate (only 20.3% of the subjects had estimated BMR within 10% of BMR_m). The Henry & Rees [8] and Mifflin St. Jeor [18] equations also yielded biased and inaccurate (41.9%) BMR estimates. The population specific equations [11] were both unbiased and accurate (70.3%).

BMR_m was significantly different from the values predicted by the Schofield [7], Mifflin-St. Jeor [18], and Henry & Rees [8] equations in men and women of both age bands (Table 2). The Anjos et al. [11] equations provided adequate estimations of BMR. The percentage of individuals whose predicted BMR fell within 10% was