Are basal metabolic rate prediction equations appropriate for overweight and obese adolescents?

Patrícia Schneider¹ and Flávia Meyer²

ABSTRACT

The known predictive equations can present different values for basal metabolic rate (BMR) compared to those measured through indirect calorimetry. The objective of this study was to describe BMR through indirect calorimetry of overweight and obese boys (with ages between 12 and 17 years old) living in Porto Alegre, Brazil, and to compare the measured value with values estimated by predictive equations. Thirty-five volunteers had their BMR measured through indirect calorimetry in the morning, under standard conditions of fasting, rest and environment. The average (± standard deviation) of measured BMR was of 1,900.5 ± 248.8 kcal/24 hours. Estimated BMR were significantly greater, in three of four equations (6.5 to 9.5%), than measured BMR (p < 0.05). These results show that predictive equations are not suitable to estimate BMR in these groups of overweight and obese boys. The use of estimated BMR can lead, in most cases, to an overestimation of energy requirements for boys with similar characteristics.

INTRODUCTION

The daily energy expenditure involves basal expense, thermic effect of food and physical activity expense²⁻⁴. The basal expense represents 60 to 75% of the daily energy expenditure and includes the energy spent with the maintenance of the organism’s vital functions. The energy spent with physical activities represents 15 to 30% of the daily energy expenditure and changes according to the individual’s physical activity level²².

The indirect calorimetry (IC) is a method that determines the energetic requirements based on the oxygen intake and on the production of carbonic gas obtained from the air inhaled and exhaled by lungs³⁻⁴. The denomination indirect indicates that the energy production, unlike the direct calorimetry, which measures the heat transfer from the organism into the environment, is calculated based on the caloric equivalents of the oxygen consumed and carbonic gas produced. Thus, the total amount of energy produced is calculated using the oxygen consumed in the use of the energetic substrates oxidation and the carbonic gas eliminated through respiration⁵. It deals about a practical method to identify the nature and amount of the energetic substrates being metabolized by the organism⁶.

The IC requires some cautions in relation to the environment, individual and to the technical aspects. The environment should be noiseless and not much illuminated and at comfortable tempera-

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Therefore, the objective of the present study was to describe BMR by means of IC in a group of obese and overweight boys and to compare measured BMR with BMR estimated through FAO/WHO/UNU (1985), Harris and Benedict (1919), Henry and Rees (1991), and Schofield (1995) equations.

**METHODS**

The sample included 35 obese and overweight student boys who live in Porto Alegre, Rio Grande do Sul, Brazil, with ages ranging from 12 to 17 years. Among them, 24 were pubescent and 11 were postpubescent, according to Tanner (1962). The participation of the volunteers only occurred when they and one of their parents or responsible signed the consent term. The project was approved by the Ethics Committee in Researches of the General Hospital of Porto Alegre (HCFA) under number 03-497.

The body fat percentile was measured by means of the Dual Energy X-Ray Absorbiometry (DEXA), label Lunar; model DPX-L with the use of the pediatric program SmartScan version 4.7c as software. The body fat was used to verify whether volunteers presented overweight or obesity and for correlations with BMR. The BMR collection was performed by means of indirect calorimetry. Thus, a gas analyzer label MedGraphics Cardiorespiratory Diagnostic Systems, model CPX/D of Medical Graphics Corporation was used. This device collects gas samples through face mask, mouthpiece, and ventilated canopy. The collections were performed between 7:00 and 9:00 am during the second fortnight of February and the first fortnight of March 2004. The participants attended the place in day and time scheduled, being verified the adhesion to the place in day and time scheduled, being verified the adhesion to the protocol for the BMR measurement that included fasting of at least 12 hours, eight hours of sleep in the night before and the maintenance of the daily activities, avoiding intense physical activities in the eve. For the measurement of the body mass, a scale label Filizola with resolution of 0.1 kg was used. Boys were weighted barefoot, wearing t-shirts and trunks. For stature, a stadiometer provided with metric scale was used, which resolution of 1 mm and the individuals were measured barefoot and on their feet.

The BMR was collected in a calm room with adequate conditions; controlled room temperature, low luminosity and noiseless. Initially, the test was explained to volunteer, who remained 20 minutes lying in rest. Later, a mask was fixed to his face and connected to the calorimeter. The oxygen intake (V\textsubscript{O\textsubscript{2}}) and the carbonic gas production (V\textsubscript{CO\textsubscript{2}}) were measured during 15-25 minutes with volunteer lying still. This time interval was selected according to the data standard presented at the moment of the test; in other words, if data had little variation, the measurement time was shorter and, if a higher variation occurred, the measurement time increased.

The BMR measured by means of IC was used in the comparison with values obtained through the most used BMR prediction equations (daily kilocalories = kcal in 24 hours) in which BM = body mass, STA = stature and AG = age:

1. - Harris and Benedict (1919) (15 to 74 years of age, male): 66.4730 + (13.7516 x BM) + (5.0033 x STA) - (6.7550 x AG)
2. - Schofield (1985) (10 to 18 years of age): (0.074 x BM) + 2.754
3. - FAO/WHO/UNU (1985) (10 to 18 years of age): (0.0732 x BM) + 2.72
4. - Henry and Rees (1991) (10 to 18 years of age): (0.084 x BM) + 2.122

The last three equations presented results in millijoules per day (mJ/day), where the result is multiplied by 239 for the attainment of values in kilocalories (kcal). The difference percentiles between values of BMR estimated through each equation rolled above and the values measured were thus calculated: \[\text{[(estimated BMR – measured BMR)/measured BMR] x 100}}\]

The statistical analysis included the paired t-test for comparison of differences between measured BMR and values obtained through the prediction equations. The Pearson correlation coefficient was used to describe the correlation between BMR, anthropometrical measures and body composition. The partial correlation coefficient between these variables after control through body mass was also calculated. The significance level adopted was of p < 0.05.

**RESULTS**

The average (± SD) of physical characteristics and measured and estimated BMR are presented in table 1.

| Physical characteristics and measured and predicted BMR results (av. ± sd) |
|-----------------------------|-----------------------------|-----------------------------|
| N                          | 35                          | 35                          |
| Age (years)                | 13.7 ± 11                   | 13.7 ± 11                   |
| Body mass (kg)             | 77.2 ± 9.8                  | 77.2 ± 9.8                  |
| Stature (cm)               | 166.7 ± 8.5                 | 166.7 ± 8.5                 |
| BMI                        | 27.7 ± 2.0                  | 27.7 ± 2.0                  |
| Body fat (%)               | 36.6 ± 8.8                  | 36.6 ± 8.8                  |
| *BMR – Indirect calorimetry (kcal/day) | 1,900.5 ± 249.8 | 1,900.5 ± 249.8 |
| Harris and Benedict equation (kcal/day) | 1,870.2 ± 169.2 | 1,870.2 ± 169.2 |
| Schofield equation (kcal/day) | 2,024.2 ± 173.7* | 2,024.2 ± 173.7* |
| FAO/WHO/UNU equation (kcal/day) | 2,001.3 ± 171.8* | 2,001.3 ± 171.8* |
| Henry and Rees equation (kcal/day) | 2,057.7 ± 197.2* | 2,057.7 ± 197.2* |

* > measured BMR (p < 0.05); * BMR = Basal Metabolic Rate.

The Harris and Benedict equation was the only one showing no differences between measured and predicted BMR (p < 0.05). The other equations overestimated BMR (p < 0.05), where the Henry and Rees equation was the one that most overestimated BMR (9.5%) followed by BMR estimated by the Schofield (7.7%) and FAO/WHO/UNU equations (6.5%). Although three out of the four equations employed overestimated BMR, underestimations of BMR with the same equations were observed in some cases: 28.6% of the volunteers presented BMR values estimated through Schofield equation lower than measured values; 31.4% with FAO/WHO/UNU equation and 25.7% with Henry and Rees equation.

The measured BMR presented significant correlation with the following anthropometrical and body composition measures: age (r = 0.55), body mass (r = 0.49), stature (r = 0.60) and body fat (r = -0.52). The second order correlations, controlled by body mass with statistical significance between BMR and the anthropometrical and body composition measures tended to decrease: age (r = 0.45), stature (r = 0.40), BMI (r = -0.41), body fat (r = -0.48).

**DISCUSSION**

The average of BMR measured from obese adolescents in this study was of 1,900 kcal/day. This value was compared with four prediction equations and only one of them, the Harris and Benedict equation was not significantly different from the measured BMR (p > 0.05). This result was expected, since the prediction equations were not originated from obese adolescent groups but rather from physically active young individuals (45%) and adults (12,13). Thus, one needs caution when BMR prediction equations are extrapolated to adolescents.

One also needs caution when BMR between obese and non-obese children and adolescents are compared, once these values do not seem to differ only when adjusted by the lean body mass (LBM), which is it best predictor and responds for up to 80% of its variance (22,24,25). Only one study (22) found higher BMR values in obese in relation to non-obese individuals, even when adjusted by the LBM.

Many studies have demonstrated overestimation of BMR through prediction equations. In the study of McDuffie et al. (21) (2004) with 502 non-obese, white and black boys and girls with...
ages ranging from 6 to 11 years, none of the five prediction equations showed accurate estimation of the energy expenditure measured through indirect calorimetry. Another study showed that the prediction equations are not suitable to estimate BMR in non-obese female children and adolescents with accuracy, once five equations overestimated BMR, among them the Harris and Benedict, FAO/WHO/UNU and Schofield equations. The data of Spur et al. (27) (1992) also overestimated BMR through Schofield equation in non-obese half-breeds, but not in girls. A study of Dietz et al. (28) (1991) performed with adolescents showed similar BMR values measured through IC when compared to values obtained through the FAO/WHO/UNU equation. However, Henry and Rees (17) (1991) demonstrated that this equation over-estimates the BMR of children and adolescents who live in the tropics, corroborating data of the present study. Besides this study, Maffeis et al. (29) (1993), who analyzed prepubescent boys and girls (33 obese and 97 non-obese) demonstrated that the prediction equations overestimated BMR even more among obese than among non-obese individuals, among them the FAO/WHO/UNU equation.

Still comparing the prediction of BMR through the FAO/WHO/UNU equation, the study of Van Mil et al. (22) (2001) with Dutch adolescents demonstrated the overestimation in obese boys and the underestimation in non-obese boys. In this study, the values of the resting metabolic rate of obese individuals were higher than those obtained from non-obese individuals from both genders (1,997 vs. 1,535 kcal/day) and the values of obese boys were also higher when compared to values obtained from obese girls (2,129 vs. 1,839 kcal/day). The prediction equations in adults overestimate the measured BMR in 2.2 to 13.5% (14,15,17,20,25). In the present study, the results of this percentage ranged within 6.5 to 9.5%.

The study of Wahrlich and Anjos (16) (2001), which took place in the same city as the present study with 26-year-old non-obese women, presented higher overestimation percentile values of Schofield and FAO/WHO/UNU equations when compared to values obtained in the present study, of 12.5 and 13.5% vs. 7.7 and 6.5%, respectively. In relation to the underestimations, the FAO/WHO/UNU equation underestimated the BMR values of 20% of the women, compared to 31.4% of the boys in the present study. It was quite surprising the BMR estimation through the Harris and Benedict equation in obese adolescents, once in the other group, composed of American women, Benedict himself verified that the equation systematically provided values below the measured BMR and recommended that the estimations would be reduced in 5% (25). Maybe this equation had been the one showing the best results due to the use of stature and age, unlike the other equations.

The BMR values found in this study are similar to those found in literature with similar protocol. In these studies, Molnar and Schutz (24) (1997) and Stensel et al. (30) (2001) presented 1,727 and 1,702 kcal/day, respectively, in groups of obese male adolescents from the same age range.

The study of Wong et al. (26) (1996) presented BMR of 1.350 kcal/day for non-obese female children and adolescents. This value is below values measured in this study, corroborating data found by Van Mil et al. (22) (2001), who presented lower BMR values for girls compared with boys and for non-obese compared with obese individuals.

In the present study, the anthropometrical measurements were significantly correlated with BMR, with correlation coefficients ranging from 0.49 to 0.60. The partial correlation coefficient values between BMR and the age, stature, BMI and body fat volumes controlled by body mass tended to decrease, what indicates that the correlations between BMR and the other body measurements are only a reflex of the body mass.

The reduced sample and the use of the male gender only was a limitation of this study. For the performance of further studies, we suggest the enlargement of the sample and the inclusion of girls with the objective of creating prediction equations for these groups, once there are differences of gender in the basal metabolism evaluation.

The inadequacy of prediction equations may lead to errors in the energy requirements estimation of populations. For the obese adolescents evaluated in the present study, the energy requirement obtained through the multiplication of the BMR by the activity factor (physical activity level) of 1.56, which is the value recommended for light physical activity (22), would be of 2,965 kcal/day when the measured BMR is used, and of 3,210 kcal/day when the BMR estimated through the Henry and Rees equation is used. The use of this prediction equation would lead to an average overestimation of approximately 250 kcal/day, resulting in a positive energetic balance, what would be unacceptable for this group, with high body fat percentage. The maintenance of a positive energetic balance could worsen this condition, leading to an even higher obesity prevalence. The same behavior could be expected for the other prediction equations, once all of them provided, on average, estimations significantly higher than the measured BMR.

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REFERENCES