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

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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.

Key words: Basal metabolism. Predictive value. Calorimetry. Energy expenditure.

INTRODUCTION

The daily energy expenditure involves basal expense, thermic effect of food and physical activity expense[1]. 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 level[2].

The indirect calorimetry (IC) is a method that determines the nutritional requirements based on the oxygen intake and on the production of carbonic gas obtained from the air inhaled and exhaled by lungs[3,4]. 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 respiration[5]. It deals about a practical method to identify the nature and amount of the energetic substrates being metabolized by the organism[5].

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 temperature in order to avoid alterations caused by cold or anxiety. For the resting metabolic rate, the individual should be in rest for at least 30 minutes and in fast for 2-3 hours[6,7]. The basal metabolism requires higher attention, with fasting of 12 hours and be measured after wakening up, in the morning.

Studies show duration of inhaled and exhaled gases collection of about 20 minutes, with an average performed in the interval of the most constant 10 minutes[8,9]. The energy expenditure measured in this interval is extrapolated to 24 hours and is considered as representative of the daily basal energy expenditure[6,10,11].

The energy expenditure may be measured by IC or simply estimated through predictive equations. In 1985, the World Health Organization started recommending that the energy requirements were based on the energy expenditure measurements[12]. Considering that most of the times the basal metabolic rate (BMR) is not possible to be measured, it has been recommended the international use of prediction equations to estimate BMR, modified from a compilation of data performed by Schofield[13] (1985). Some studies have been conducted with different groups[14-17] and have demonstrated that these equations provide high BMR estimations, especially for those who live in the tropics. These differences may be due to the fact that these equations are mostly originated from samples of North American and European populations that may present different body composition characteristics and live in distinct environments.

The equation of Harris and Benedict[18] (1919), which is one of the most used and known equations, estimates the resting energy expenditure with accuracy of about 10% in 80 to 90% of the healthy individuals[7]. When a predictive equation is employed, it is important knowing the population from whom it was obtained and the factors that affect and modify the predictive capacity[19].

Henry and Rees[17] (1991) gathered all BMR data from tropic populations and created specific equations for these populations. Although these equations provide lower estimations when compared to those obtained through FAO/WHO/UNU[12] equations (1985), the values obtained by the latter equations seem to overestimate the BMR in tropical regions[14,20].

A study involving female university students in Rio de Janeiro[14] demonstrated that the prediction equations overestimated BMR between 7 and 19%, and another study with non-obese children demonstrated that none of the five prediction equations was capable to estimate the energy expenditure[21].

More studies on the several segments of the Brazilian population are required in order to validate or to propose suitable equations to predict BMR. Since IC is an expensive and complex test, the accurate estimation of the energy expenditure and caloric ingestion for the alimentary planning would be facilitated by means of prediction equations, also being very important for this particular group that has the objective of loosing weight[21].

Researches comparing measured BMR with BMR predicted by means of prediction equations in obese adolescent boys are

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scarce[22]. 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[12] (1985), Harris and Benedict[18] (1919), Henry and Rees[17] (1991), and Schofield[13] (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[23] (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 (HCPA) under number 03-497.

The body fat percentile was measured by means of the Dual Energy X-Ray Absortiometry (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 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 ($\dot{V}O_2$) and the carbonic gas production ($\dot{V}CO_2$) 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[18] (1919) (15 to 74 years of age, male): 66.4730 + (13.7516 x BM) + (5.0033 x STA) – (6.7550 x AG)

2 – Schofield[13] (1985) (10 to 18 years of age): (0.074 x BM) + 2.754

3 – FAO/WHO/UNU[12] (1985) (10 to 18 years of age): (0.0732 x BM) + 2.72

4 – Henry and Rees[17] (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: [(estimated BMR – measured BMR)/measured BMR] x 100.

The statistic 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.

TABLE 1
Physical characteristics and measured and predicted BMR results (av. ± sd)

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

* > measured BMR ($p < 0.05$); [a] 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, once 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[26] 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.

Data of Spur *et al.*[27] (1992) also overestimated BMR through Schofield equation in non-obese half-breed boys, 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 overestimates 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 values 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[12], 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

1. Houssay BA. El intercambio material y energético del organismo. In: Fisiología humana. Buenos Aires: Librería El Ateneo Editorial, 1969;487-502.
2. Astrand PO, Rodahl K. Textbook of work physiology. New York: McGraw-Hill Book, 1970.
3. Ferrannini E. The theoretical bases of indirect calorimetry: a review. Metabolism 1988;37:287-301.
4. Branson RD. The measurement of energy expenditure: instrumentation, practical considerations, and clinical application. Respir Care 1990;35:640-59.
5. Diener JRC. Calorimetria indireta. Rev Assoc Med Brasil 1997;43:245-53.
6. Mullen JL. Indirect calorimetry in critical care. Proc Nutr Soc 1991;50:239-44.
7. Dickerson RN, Vehe KL, Mullen JL, Feurer ID. Resting energy expenditure in patients with pancreatitis. Crit Care Med 1991;19:484-90.
8. Isbell TR, Klesges RC, Meyers AW, Klesges LM. Measurement reliability and reactivity using repeated measurements of resting energy expenditure with a face mask, mouthpiece, and ventilated canopy. JPEN J Parenter Enteral Nutr 1991; 15:165-8.
9. Stokes MA, Hill GL. A single, accurate measurement of resting metabolic expenditure. JPEN J Parenter Enteral Nutr 1991;15:281-7.
10. Van Lanschot JJ, Feenstra BW, Vermeij CG, Bruining HA. Calculation versus measurement of total energy expenditure. Crit Care Med 1986;13:981-5.
11. McClave SA. Effective utilization of indirect calorimetry during critical care. Intensive Care World 1992;9:194-200.
12. FAO/WHO/UNU. Energy and protein requirements. Geneva: World Health Organization, 1985. [WHO Technical Report Series, 724].
13. Schofield WN. Predicting basal metabolic rate, new standards and review of previous work. Hum Nutr Clin Nutr 1995;39C:5-41.
14. Cruz CM, Silva AF, Anjos LA. A taxa metabólica basal é superestimada pelas equações preditivas em universitárias do Rio de Janeiro, Brasil. Arch Latinoam Nutr 1999;49:232-7.
15. Piers LS, Diffey B, Soares MJ, Frandsen SL, McCormack LM, Lutschini MJ, et al. The validity of predicting the basal metabolic rate of young Australian men and women. Eur J Clin Nutr 1997;51:333-7.
16. Wahrlich V, Anjos LA. Validação de equações de predição da taxa metabólica basal em mulheres residentes em Porto Alegre, RS, Brasil. Rev Saúde Pública 2001;35:39-45.

17. Henry CJK, Rees DG. New predictive equations for the estimation of basal metabolic rate in tropical peoples. Eur J Clin Nutr 1991;45:177-85.
18. Harris JA, Benedict FG. A biometric study of basal metabolism in man. Boston: Carnegie Institution of Washington, 1919.
19. Weissman C, Kemper M. Metabolic measurements in the critically ill. Crit Care Clin 1995;11:169-97.
20. Piers LS, Shetty PS. Basal metabolic rates of Indian women. Eur J Clin Nutr 1993;47:586-91.
21. McDuffie JR, Adler-Wailes DC, Elberg J, Steinberg EN, Fallon EM, Tershakovec AM, et al. Prediction equations for resting energy expenditure in overweight and normal-weight black and white children. Am J Clin Nutr 2004;80:365-73.
22. Van Mil EGAH, Westertep KR, Kester ADM, Saris WHM. Energy metabolism in relation to body composition and gender in adolescents. Arch Dis Child 2001; 85:73-8.
23. Tanner JM. Growth and adolescence. Oxford: Blackwell Scientific Publications, 1962.
24. Molnár D, Schutz Y. The effect of obesity, age, puberty, and gender on resting metabolic rate in children and adolescents. Eur J Pediatr 1997;156:378-81.
25. Wahrlich V. Taxa metabólica basal em mulheres residentes em Porto Alegre, Rio Grande do Sul [Dissertação]. Rio de Janeiro: Universidade Federal do Rio de Janeiro, 2000.
26. Wong WW, Butte NF, Hergenroeder AC, Hill RB, Stuff JE, Smith EO. Are basal metabolic rate prediction equations appropriate for female children and adolescents? J Appl Physiol 1996;81:2407-14.
27. Spurr GB, Reina JC, Hoffmann RG. Basal metabolic rate of Colombian children 2-16yr of age: ethnicity and nutritional status. Am J Clin Nutr 1992;56:623-9.
28. Dietz WH, Bandini LG, Schoeller DA. Estimates of metabolic rate in obese and nonobese adolescents. J Pediatr 1991;118:146-9.
29. Maffeis C, Schutz Y, Micciolo R, Zoccante L, Pinelli L. Resting metabolic rate in six-to ten-year-old obese and nonobese children. J Pediatr 1993;122:556-62.
30. Stensel DJ, Lin FP, Nevill AM. Resting metabolic rate in obese and nonobese Chinese Singaporean boys aged 13-15y. Am J Clin Nutr 2001;74:369-73.